

2.171 Project: Laser Light Show

Assigned: 11/29/06

Midpoint checkoffs: 12/7 and 12/8/06

Report due: In final checkoffs on 12/12 and 12/13/06

1 Project Definition

The 2.171 final project focuses on the design, construction, and testing of a laser x-y beam scanner. We have acquired M-G350DT scanners from General Scanning, and fixtured these into a base along with appropriately mounted mirrors and a laser pointer used as a light source. Your task is to use these scanners along with appropriate controller and trajectory generation to create an interesting display. You need to experimentally develop a model for the system, design appropriate control algorithms, and program the dSPACE controller to display figures of your design. Each team should decide on something interesting that they will display using their scanner. Each station comes equipped with its own patch of ceiling which is used to display your image.

2 Project Plan

You have two weeks to complete this project. To keep you on track, we ask that you present your work to the staff at a midpoint checkoff to be scheduled on 12/7 or 12/8. In order to facilitate progress during this short time interval, we ask that you work in pairs, sharing a common station to which you will be assigned. (If you have a compelling reason for working alone, you'll need to convince us that you can handle all of the workload, and explain your reasoning.) Please use only your assigned station; do not move to other stations. If a problem develops, please contact Kevin or Prof. Trumper and we will attempt to fix the setup as soon as possible. You will need to wisely partition your efforts between the two group members in order to be effective in addressing all parts of the assignment.

Your two-person group will present their work during a set of final checkoffs on 12/12/06 and 12/13/06. These checkoffs will be in the form of a slide presentation showing the design details and results, as well as a demonstration of your operating scanner system. A printout of the the slideshow and any relevant appendices will constitute your lab report for this project.

In the project, at a minimum you will address the following issues:

- Decide what you plan to display and why it will be interesting. What are the expected typical images?
- Develop the system architecture, i.e., a top-level view of how your display will operate, and how the supporting software and controls will function.

- Work out the geometry of your system, and provide us with sketches of the relevant distances and angles which will allow you to draw figures of a desired shape by controlling the angle of the galvanometers.
- Develop a dynamical model of the system. Provide us with a block diagram showing the dynamics that you expect to be important. Given the short time interval, your model can be based upon the experimentally-measured dynamics of the plant including the power amplifier, galvo, sensor, and interface electronics. Even better is to have a model based upon analytical results. How does the model look reasonable? What strange features does it have? Any explanations?
- Lay out the controller design based on the model developed above, and show us what crossover frequency and phase margin you have achieved in your system. Is this bandwidth adequate to support the displays that you plan to implement?
- How do you generate the trajectories and additional information required to drive the galvo setpoints? Do you use feedforward? Explain the details of your data and software architecture.

Proof of success is in the quality and depth of the presentation and in a successful hardware demonstration.

3 Midpoint checkoff

We will hold 20 minute mini-checkoffs on 12/7 and 12/8 in which you are to demonstrate the functioning of your system to a staff member. At a minimum, at this time you need to have both servo loops closed, the ability to electrically modulate the laser pointer on and off, and be displaying something on the ceiling to demonstrate that your system is operational. While we do not require any written documentation at this time, we expect that you will be able to explain pertinent details of your designs.

4 Project presentation and demonstration

We will schedule 30 minute presentations for each group on Tuesday 12/12 or Wed. 12/13, which includes time for the staff to ask questions about your work. Your presentations must be complete in 20 minutes maximum; we will cut you off at 20 minutes in order to allow time for questions. The presentation should lay out the essential issues faced in the design of your device and software architecture, provide calculations supporting your design choices, documentation of experimental results, and compare experimental results with your predictions. Please tell us what is good about the design and how it worked and document it, but also tell us what is not good about the design, document it, and describe ways to improve these problems. Experimental data is an essential part of the

documentation, as are analyses of key performance issues. Your presentation slides will constitute the lab report for the project.

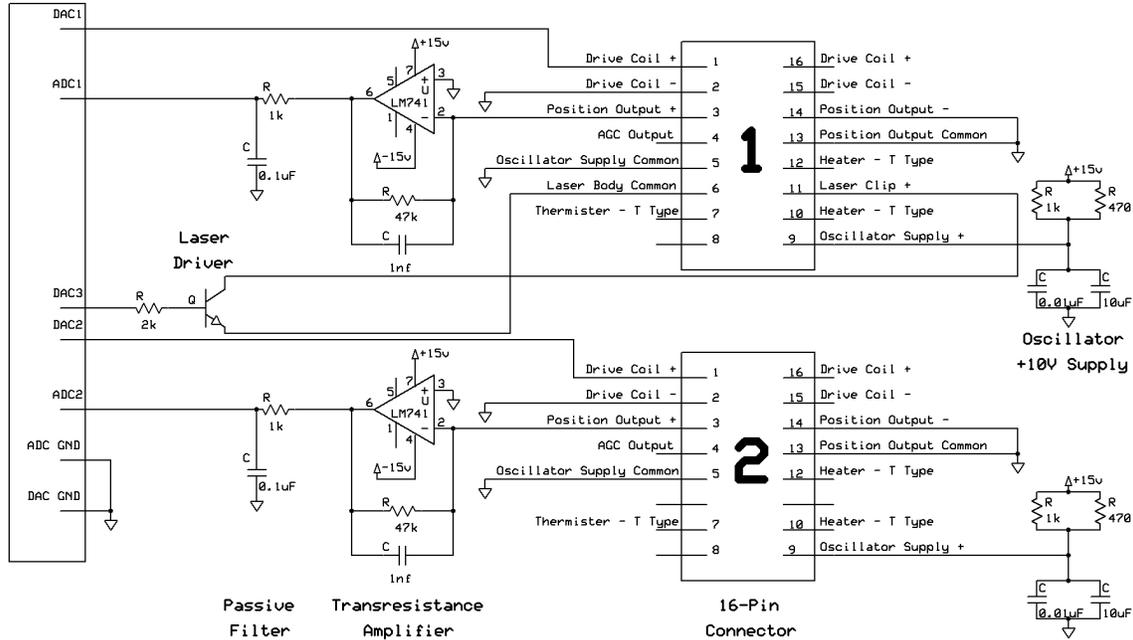
Your presentation will be followed by a 30 minute demonstration of your working system. At this checkoff, you are expected to demo the operation of your system, and explain the details of your design to the staff.

We ask that you document at least the following in your presentation and checkoff:

- What is the crossover frequency and phase margin of each of your scanner servos? You must also include experimentally-measured plant transfer functions for the galvos and use this to document the position loop transmission. Explain to us how you designed your controller to achieve the highest performance possible. What steps did you take in input trajectory generation and in compensation to achieve “good” dynamic response. What is “good”? How is this manifested in the image quality?
- What is the settling time of each axis to 0.1% of a step input? How can you measure this settling time?
- To document the performance of your display system, please draw the following images: 1) diagonal line, 2) circle, 3) square, 4) triangle. Explain any anomalies you see in the image. For best performance, you will need to do some trajectory planning so as not to require excessively high scanner accelerations.
- Demonstrate the scanner displaying images of your own design. Show us what these represent and explain why you chose these images.
- Explain the details of your design, i.e., controllers, interface electronics, data processing, etc.

5 System overview

We have preconfigured the system electronics for you as show in the schematic below.



Please double check the connections before applying power, so that you don't burn out the sensor or scanner coil. As before, do not apply greater than 17 volts to the power amplifier supplies.

We have preconnected the PA-21 amplifiers for you, and have included a 10 ohm power resistor in series with the galvanometer coil to prevent overdriving the galvo. (Note however that in most industrial practice, these resistors would not be included, since they dissipate power and limit the amount of transient torque that can be applied to the actuator.)

The two sensor output pins can be modeled as a current source in parallel with a 4.4 nF capacitor. The sensor pins provide a differential (i.e., opposite polarity in each pin) output current with a sensitivity of $\pm 31 \mu\text{A}$ per degree of rotation at each pin. In order to keep the circuitry simple, we only use one channel of the differential output; the other is connected to common. (In a real system, using both channels would give better signal to noise and interference immunity.) For the single output, we have designed a current to voltage converter circuit (transresistance amplifier) to translate this into a voltage proportional to angle. Use this current sensitivity to calculate the expected sensitivity in volts per radian. Note that the circuit also includes a low-pass filter to remove the 2 MHz sensor bridge drive frequency.

Since the pointer battery life is finite (about 4 hrs per set of batteries), please put a protoboard switch in series with the pointer electrical circuit so that you can turn off the

pointer when you are not actively looking at the display. The staff does not guarantee to supply an infinite set of replacement batteries. You are not allowed to alter the pointer in any way. If the batteries run down, buy a new set and replace them in the laser pointer.

A required 10 volt bias to the sensor oscillator is supplied by the resistors shown. The capacitors act as a low-impedance source for the oscillator supply voltage. In a commercial implementation, where high position accuracy is required, a more stable voltage source would be required, likely configured to use the automatic gain control (AGC) output. For the purposes of this lab, the simple RC circuit is sufficient.

In your model for the galvo, be sure to include the back emf of the actuator, as this provides damping to the system. (Try the torsional impulse response of a representative galvo with coils shorted vs open.)