ECSE 371 Lab #12

Tracking Servo

Provide a schematic for Saturday.

You are supplied a DC motor with a gearbox. Mounted to the output shaft is a laser diode unit which operates on 5VDC (max). The laser diode includes a cylindrical lens which generates a line in the vertical plane. The gearmotor will rotate the laser in the horizontal plane, so the vertical line sweeps its target. The gearmotor shaft is also connected to a pot which will physically limit rotation to about 300 degrees (to prevent damage, there is a slip clutch in series with the pot). The pot may be used to provide a rough, secondary position signal, if needed. Your goal is to design a position control system such that the laser will always point to the center of a target.

The target is a photovoltaic (solar) cell, about 2-3/8" square. The solar cell is mounted on a wooden block to hold it in the vertical plane. Place the solar cell a few feet from the laser and observe that the line sweeps across the cell. A solar cell has constant sensitivity across its surface, so its output will not change as a function of line's position on the cell surface. Therefore, the cell includes an optical mask with a transmission gradient that is designed so that your circuit can determine when the line is at the approximate center of the cell. In other words, with the addition of this optical gradient, the output voltage of the cell will unambiguously represent the left-right location of line.

Experiment with the solar cell to determine the effect of the optical mask, and to characterize the cell as a voltage or current source; select the appropriate input circuit. Remember to consider 60Hz pickup on the leads, as well as interference from the room lights. To improve the S/N ratio you should consider a simple laser- modulation scheme. **Be very gentle with the wire leads.**

You are to design a control circuit that has 2 buttons. These two "Jog" buttons will manually cause the gearmotor to rotate either CW or CCW. When neither button is pressed, your servo circuit will rotate the gearmotor until the line is located exactly in the center of the solar cell; this is the "null" position.

If the gearmotor is jogged (or if the motor unit is manually rotated, or the solar cell is moved) so that the wind is displaced an inch or so in either direction, but stays on the solar cell, the circuit is to quickly rotate the motor so the beam returns to the null position. If the motor unit or solar cell is moved more than this, or if the beam is interrupted, your circuit will cause the gear motor to rotate appropriately and search for the solar cell again and return to the null position. You must incorporate circuitry to limit rotation to around 200°.

Your power supply will be a single 15V bench supply. Operate the laser diode on **5-6VDC** obtained from your circuit's 15V supply with a series 9V or 10V Zener or other dropping means. Please do not overvoltage and destroy the laser. When the line is well off the solar cell target, and when in the jog mode, the motor must operate on the full 15 volts (less saturation voltages).

See: https://photos.app.goo.gl/HsYwkbRu1Fv8J8Et5

Additional Comments; See Below:

1. You must PWM the motor.

2. The plastic pipe tee that holds the laser diode may be removed and rotated so that its "timing" with respect to the pot may be changed (the pot body is glued to the base). To do so, gently pull on the gray plastic hub until it separates from the pipe tee. The pipe tee is tapered and the hub is slotted, so removing the hub from the tee will also release the hub from the pot shaft. When reassembling, do not press the hub too tightly into the tee.

3. The solar cell is mounted on a wood block, which you may place on a bench or windowsill. Adjust the position of the cell so it intersects the beam, nominally at a right angle.

4. The solar cell will always be placed within an arc of 200°; the system is required to search only within this range of rotation.

5. Your circuit should be considered a "state machine". The states are usually defined by a counter or register that takes a different state as inputs are cycled or other events occur. Each state establishes a distinct set of outputs. There is generally a "reset", or an initial state that is assumed upon power-up.

6. Your goal is to design a reliable circuit that minimizes the search and response time (critically damped). You must incorporate proportional control for positioning; **"bang-bang" control is NOT allowed.** When the line is positioned off the solar cell, your circuit must supply the full supply voltage (close to 15V) to the motor. A well-designed circuit will provide proper operation even when the motor unit and solar cell are positioned very far apart: 10 to 15 feet or more. (Note that a large separation corresponds to high proportional gain).

7. Regarding accuracy or precision, your circuit should have enough gain ("P" and probably "I") to always locate the line to within +/- 0.1" of null -the center of the cell. In other words, approaching the center from either direction, no matter where the starting point was, the line should always go to the same point within +/- 0.1". (Hysteresis is **not** good!).

8. You might consider adding a small cap across the motor to minimize any brush RFI.

9. The "Jog" buttons should move the motor in the appropriate direction as long as the button is held down; these buttons override the position feedback.

10. I assume that you have tested the motor and found that the current drain is quite low. Therefore, to drive the motor you can use a low -power IC motor-driver, or T0-92 small-signal BJTs transistors; power MOSFETs or power transistors are absolutely not necessary. The current is so low that you shouldn't have wiring or layout problems, and the solderless breadboard may be used throughout.

11. To PWM the motor, you can make your own H-bridge or use an integrated circuit. We have L293Ds (and maybe the SN754410) available in the lab. You will use two of the 4 sections to configure an H bridge. The datasheet is not clear, but connect both the logic (Vss, pin 16) and motor supply (Vs, pin 8) to 15. Then, with one logic input HGH and the other logic input LOW, the motor will rotate. Reversing the state of these inputs will cause the motor to rotate in the opposite direction. With both inputs at the same state, the motor will not rotate. Note that these inputs float HIGH if they are not connected to ground. The logic "input" and "enable" voltages on the L293D **must not exceed 7V**. Check that you are using the "D" version of the 293; it contains clamp diodes for the inductive kick. You can find application information here: https://www.instructables.com/Using-Motors-With-L293D-IC/

This is a "state machine". For example, one defined state exists when the dot is positioned somewhere on the solar cell, and during this state, and only this state, the system should be driving the motor forward or backward to search for the center of the cell. The system could enter another defined state after the "jog +" button is pressed. You should first define the states, and then determine the actions that the control box take during each state.

Try to be clever and think about various circuit tricks that can simplify things. This might include using a wired- OR connection at comparators or using diodes for simple gating operations. For another example, the open collector of a comparator, a spst switch, or a diode can be used to force a comparator into one state or the other simply by driving its reference appropriately. Also, the emitter-base junction of a transistor can often be used as a simple comparator for non-critical sensing; using both NPNs and PNPs allow you to sense near ground or near the positive rail. This can work well, even from a relatively high-resistance source, if you keep the transistor collector current very low.

You may be tempted to- coupled the output of the solar cell. This is a great idea, but **only if you modulate** the laser so that you have an AC signal at the cell. The line is not moving all the time so you are not producing a voltage that can be considered AC and can be capacitor- coupled.
Is the solar cell a voltage source or current source?