**ECE Project 3A, Sensor Design:**
**Selecting and Designing a Sensor Subsystem**

Group 3 "No Induction Needed"
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**Executive Summary**

Selecting and designing a sensor subsystem is an important component to the overall design of the system. Considering what high level, abstract constraints the sensor must meet and then use those constraints to create engineering requirements for the system play factors in design. It was also necessary to propose tests to ensure that the sensor met all engineering requirements. Through this process promotes a better customer understanding, specifically how to design and test a sensor subsystem that these required parameters.

**Engineering Requirements**

Table 1 shows how customer requirements influenced engineering requirements, and the tests used to determine if the sensor met the customer and engineering requirements.

| Customer Requirements | Engineering Requirements | Tests |
|---|---|---|
| Low Cost | ≤$15.00 | Compare Pricing |
| Distinguishes light colors | Light /Spectrum Detection and Measurement Capabilities | Check sensitivity to ambient light and direct light |
| Lightweight | ≤ 10g | Measure with scale |
| Low power | ≤ 5.00 V and ≤ 25 mA | Connect to circuit and check values with multimeter |
| Able to be mounted to moving arm | ≥1 $cm^2$ of surface area | Measure |

Table 1: Engineering Requirements

**Electrical Design**

Calculations

While the actuator is rated at 4.5 $V_{DC}$, through testing we found the solenoid used about 0.5 A and 3.4 V.

$$P = 3.4\ V \times 0.5\ A = 1.7\ W$$

When the Photo Resistor held light a voltage reading of about 3.5 V. When the Photo Resistor was not holding light, the reading was approximately 0.1 V, which gives a resistance of about 20,000 on the photo resistor.

$$3.5\ V = \frac{470\ \Omega}{470\ \Omega + R_{ph-res1}} \cdot 5V \therefore R_{ph-res1} = \frac{470\ \Omega}{3.5\ V/_{5\ V}} - 470\ \Omega \cong 200\ \Omega$$

$$0.1\ \mathrm{V} = \frac{470\ \Omega}{470\ \Omega + \mathrm{R_{ph-res2}}} \cdot 5\mathrm{V} \therefore \mathrm{R_{ph-res2}} = \frac{470\ \Omega}{0.1\ \mathrm{V}/_{5\ \mathrm{V}}} - 470\ \Omega \cong 20{,}000\ \Omega \cong 20\ \mathrm{k}\Omega$$

Testing and demonstrating the Photo Resistor during demonstration provided graphical reference.

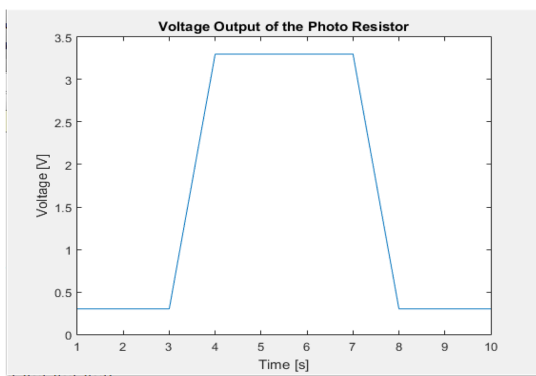


Figure 1: MATlab graph illustrating the voltage output of the Photo Resistor

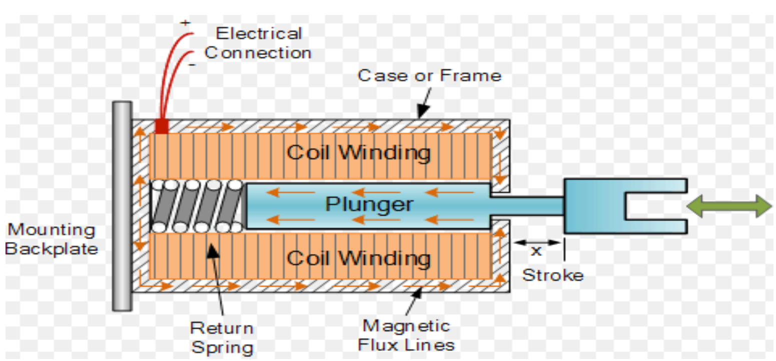


Figure 2: Diagram showing the mechanics of a linear solenoid. (Electronics-tutorials.ws) {http://www.google.com/url?sa=i&source=imgres&cd=&cad=rja&uact=8

### Circuit Schematics

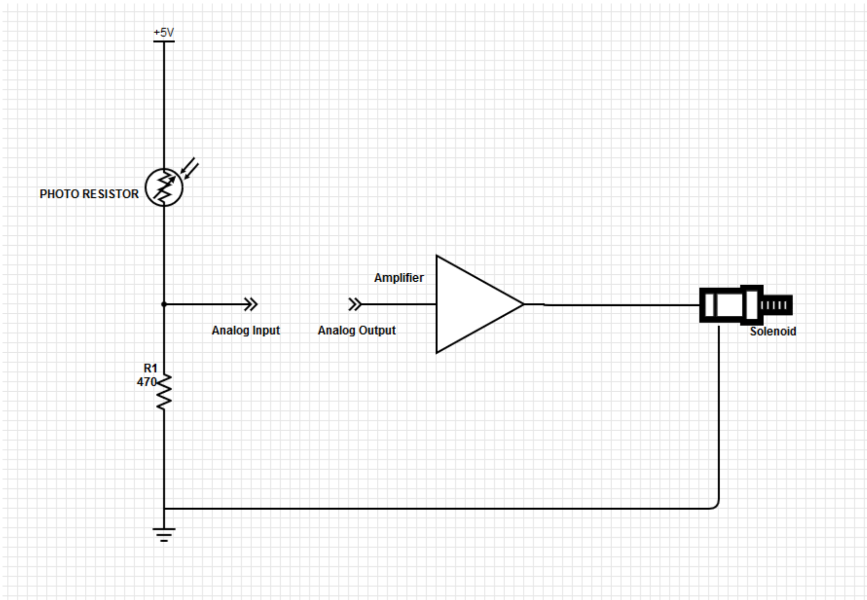


Figure 3: Circuit Diagram depicting the solenoid and Photo Resistor in use

Testing was implemented at the Group W3 workstation with the Quanser Q4 H.I.L control board, the Quanser Q4 Interface board by means of MATLAB R2014b with Simulink Realtime and Microsoft Visual Basic C++.

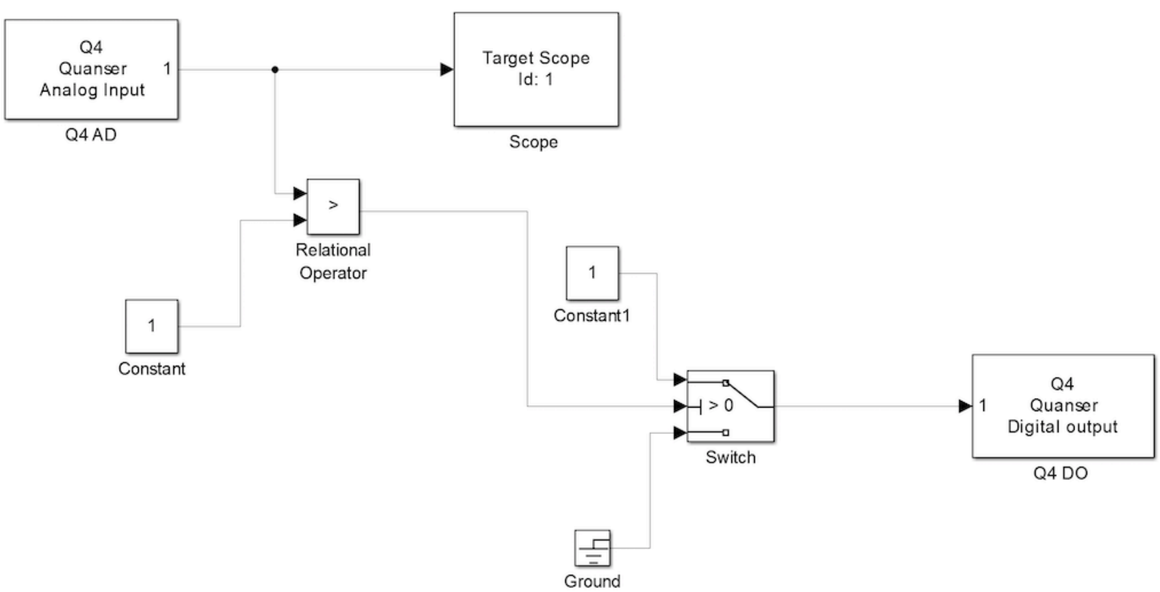


Figure 4: Simulink Diagram depicting the method of operating the circuit through the workstation during the demonstration

**Prototype Demonstration and Testing**

The prototypical design implements a solenoid with push/pull capabilities. The unit is capable of linear motion by sliding along a metal rail. The sliding motion works by using a long linear actuator that turns on for a certain length of time until it moves the proper distance then turns off. The actuator moves forward and backward by changing the polarity on the actuator. The assembly at the end of the actuator is attached to a sliding rail that is mounted in place so that the mechanism is always aligned with the push buttons. There is also another actuator mounted on the arm of the moving assembly that is fixed just above the push buttons. This actuator is a solenoid that will activate once it is above the proper button. The solenoid will shoot out the piston pushing the button then retract when turned off.

The design achieves success by meeting its customer-established requirements. The prototype maintains fluid and precise movements because our linear actuator moves at a constant rate. Also being on the track system allows the design to stay precise at all times. With very few moving parts and only two elements that create motion, the construction is not very complicated. Because of its simplicity, the unit may be assembled and disassembled easily. The only parts that will have a little weight on them are the linear actuator and track system since they have to extend the length of the 18 inch board. Other than these two all the other parts will be lightweight and can be moved easily. Climate will not affect our design unless the assembly gets wet causing the metal actuator or slides to rust ruining our fluid motion. The circuitry is simple and low voltage so from a safety standpoint our design does very well.

Maintenance is fairly easy on the design because there are so few parts. As long as the linear actuator and slide stay in good condition our design should run for a long time. Areas where our design could improve include: Fast movement, Economical, and wiring. Our linear actuator is long but small as possible which means it won't move fast because it has a small motor and has to travel a long distance. The linear actuator is expensive as well so it makes our design not very economical so we need to look for a way to bring this price down. The wiring is complicated because our system is moving so we need to find a way to secure our cables on the system so that they won't get damage or caught on anything.

We will continue to refine our design by trying to discover cheaper solutions for our linear motion. We also will look for better method to get power to the solenoid mounted on the moving object so that the cables are not in the way or don't get damaged. We look for solutions to make this move faster. Coding can help the object work faster by starting the actuator in the middle of the system so it only has to travel half the distance unlike we have it currently. Our design will continue to evolve and modifications will arise before the end result is completed in order to meet all of the customer's design requirements.

**Conclusion**

The customer's request has been completed on schedule and to their desired specifications. The photo resistor sensor has been implemented into the circuit, along with the LED, current amplifier and electromagnetic actuator (solenoid). The photo resistor waits for the LED to emit light, a voltage in the range of 4.8 – 5.0 V. The sensor's resistance drops dramatically to 200 Ω and allows for current to flow through the circuit towards the amplifier. Once arrived at the current amplifier, the current increases to ±5% of 600mA, and "pops" the solenoid out. When the LED returns to the off state the photo resistor regains its resistance of 20,000 Ω and doesn't allow for current to flow, and the solenoid returns to the off position. The tolerances of each part of the circuit operate ideally at ideal conditions, relative to room temperature. Each component of the device function properly and allow for the intended operations to occur. The compact photo-controlled solenoid is a cost effective item, as requested by the customer, and will be easy to manufacture for future use.