Solar Panel Positioning system

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Making an analogue P controller system to position solar panels
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Introduction

The aim of this project is to design a solar panel positioning system.They are usually used where less space is provided for the solar panels and no more additional panels can be added to increase the output.

We will use a servo mechanism to adjust the current panels to make sure that they are always facing the Sun. This type of motion can be done in two axes where two motors are used to adjust the East-West direction and North-South direction. We will just be using one motor to adjust the East-West Direction.

It consists of a wooden structure which adjusts its position based on the current light intensity. Light Dependant Resistors i.e LDRs are used as sensors for the project that have a high resistance in darkness and the least resistance in high light intensity.

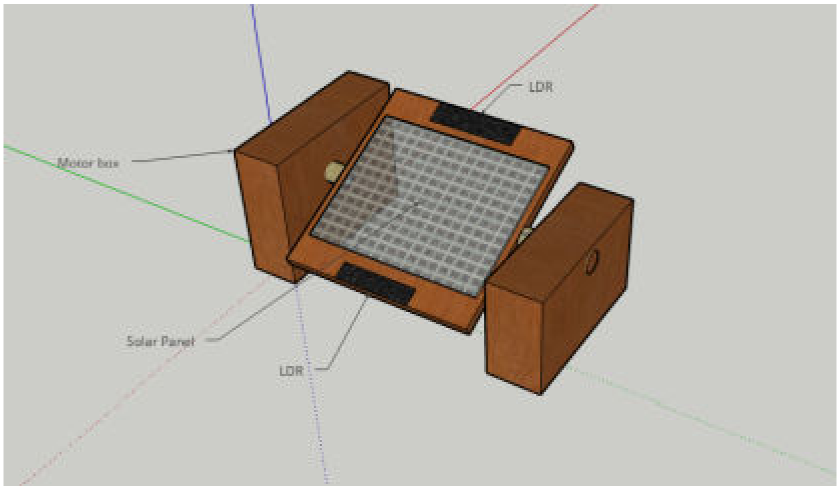
The project serves as a basic framework for large scale applications in the power generation through solar energy where such a mechanism could act as a control system to adjust the position of big solar cells for maximum efficiency.

Methods and Materials

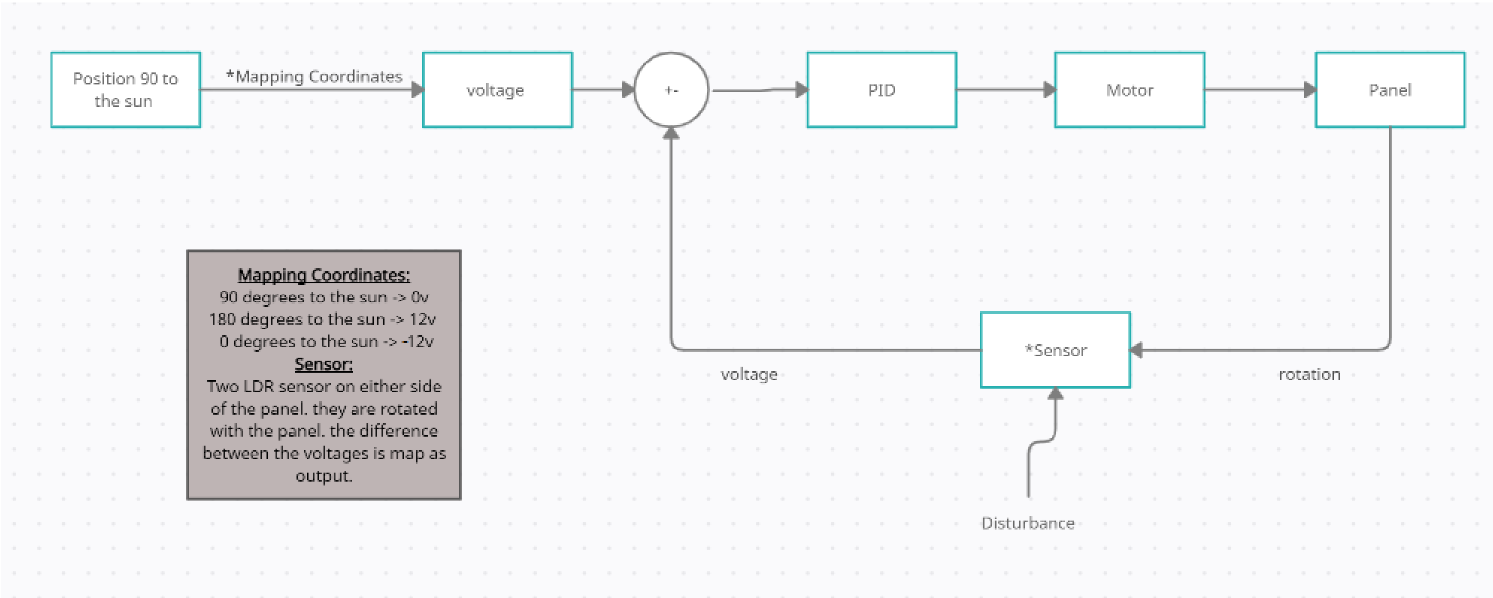
2.1 Design and Fabrication of Plant

The structure is entirely wooden. Two uniform wooden pieces are placed vertically on the base. A PVC pipe is attached to these wooden pieces through holes in the wooden walls and acts as a shaft for rotation.Another wooden frame is mounted on the shaft (PVC pipe) which acts a platform where the solar panel is to be placed. Two LDRs are also placed on this frame equidistant from the center.

2.2 Sketch of the Mechanical Structure



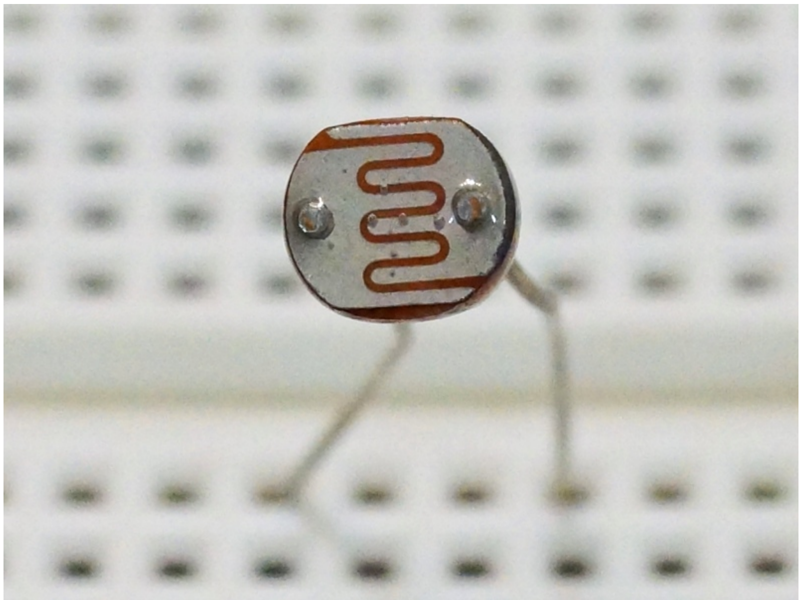
Block diagram



Hardware provided

Motor

LDR



Modeling procedure

Types of modeling

First principles

During the production of a device, the manufacturer has all the details of the model. for example if a motor was to be made. we can use physic to determine the output as we will have information of of the wire diameter, the number of turns, number of poles ETC. Hence the model created from first principle would be very accurate, as it will model resistance and damping as well.

Industries that require precision would need to model all hardware using first principle before they can test out their project. But since our appication does not reqire a very precise model, we can use other procedure for modeling our hardare.

Black box modeling

When we do not posses the knowledge of the inner working of a system, we provide he system with a known input and measure the output. Then we map the iput to the output. This model may not be an accurate representation of the system, but it may work ifwe only have very specific inputs that we want to give.

we will be modeling our sensor model using black box modeling. we do not know how the light intenisty is model inside an LDR. hence we will take measurements of the LDR resisance as we provide it different light intesnsities.

Grey box modeling

Many of the parameter of the motor our known to us. hence we can use grey box modeling to measure the other values that we dont have, such as resistance of the coil, inductance and inertia. hence obtaining a tranfer function.

Motor Modeling

Finding Motor constant

Resistance measured by DMM

```
R_a = 83.2 ; % ohms
```

Inductance measured by inductance meter

```
L = 30 * 10^-3; % H

Va = 12 ; % V operating voltage
Ia= 0.02; % A
```

Speed found by recording the motion of the motor using a video camera and counting revolution in a min

```
W = 57  * (2*pi/60) / 70 % Rad/s
```

```
W = 0.0853
```

using eq Va = Ia * Ra + Kt * W

```
kt = (Va-Ia*R_a)/W
```

```
kt = 121.2124
```

```
km = kt
```

```
km = 121.2124
```

Finding Damping coeffiecent

kt*Ia = B*W

```
B = (kt*Ia)/W % damping coeffiecent
```

```
B = 28.4297
```

Finding Motor Interia

Using motor coupling:

63% of steady state voltage for coupled motor is 21.42V (from oscilloscope)

Time shown at steady state value :

so, Tau = 110ms (from oscilloscope)

Tau = J*R_a/(kt*km)

```
Tau = 110e-3; % seconds
J = (Tau*kt*km)/R_a % motor inertia
```

```
J = 19.4251
```

Finding moment of inertia of plank

```
b = 0.38*10^(-2); % m breath
h= 0.48*10^(-2); % m lenghto

j= 1/12 * 0.009 * (b^2 + h^2)
```

```
j = 2.8110e-08
```

Compound Inertia

```
jc= j +J % compund inertia
```

```
jc = 19.4251
```

Finding the rtransfer function:

T(s) = (Kt/J*Ra/ (s+(BRa +(Kt^2/J*Ra)))

```
Num = kt/(jc*R_a); % numerator of the transfer function
a = (B*R_a + kt^2)/jc*R_a;
Den = [1,a]; % denominator of transfer function
trans_func = tf(Num,Den) % transfer function of the motor
```

```
trans_func =

     0.075
  ------------
  s + 7.306e04

Continuous-time transfer function.
```

```
% W = output(Va)
```

$$P(s) = \frac{\dot{\Theta}(s)}{V(s)} = \frac{K}{(Js+b)(Ls+R)+K^2} \qquad [\frac{rad/sec}{V}]$$

```
M = tf(kt , [jc*L L*B+jc*R_a+R_a*B kt^2])
```

```
M =

              121.2
  ------------------------------
  0.5828 s^2 + 3982 s + 1.469e04

Continuous-time transfer function.
```

Sensor Modeling

LDR modling

```
t= 1.5425:0.1:4.7
```

```
t = 1×32
    1.5425    1.6425    1.7425    1.8425    1.9425    2.0425    2.1425    2.2425 ⋯
```

```
light_intensity= sin(t)
```

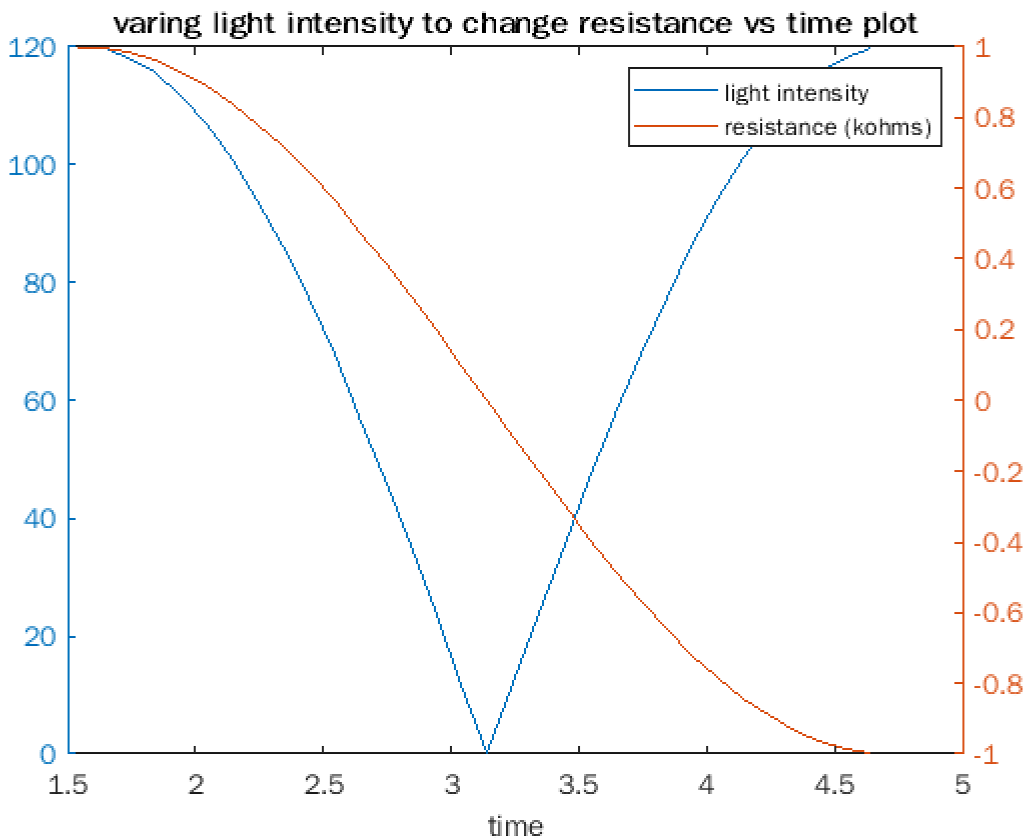
```
light_intensity = 1×32
    0.9996    0.9974    0.9853    0.9633    0.9317    0.8908    0.8410    0.7828 ⋯
```

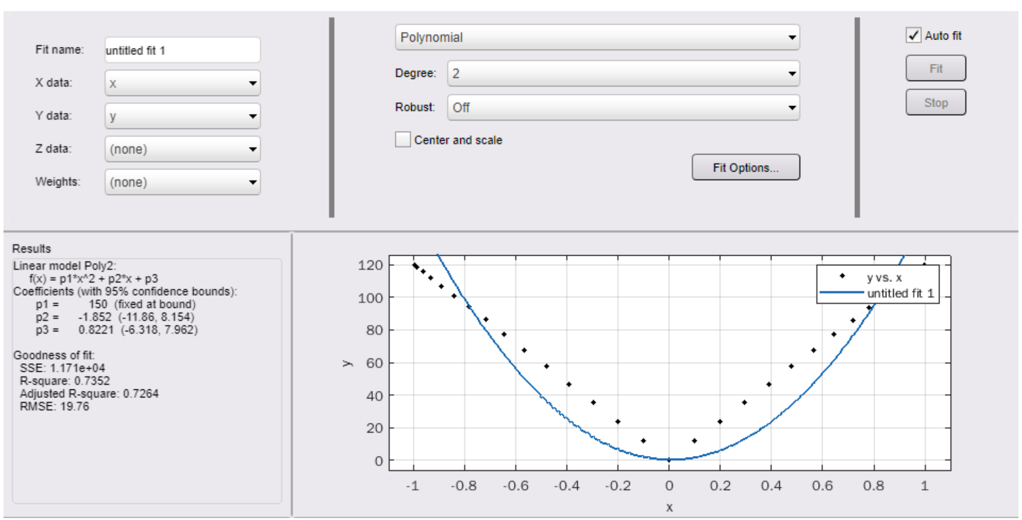
```
Resistance= abs(120*sin(t))
```

```
Resistance = 1×32
  119.9520  119.6916  118.2354  115.5978  111.8052  106.8955  100.9176   93.9315 ⋯
```

```
yyaxis right
plot(t,light_intensity)

yyaxis left
plot(t,Resistance)
```

```
title("varing light intensity to change resistance vs time plot")
xlabel ("time")
legend ("light intensity" , "resistance (kohms)")
```





We are using polynomial for curve fitting and we have added limits in order for it to start from zero resistance and scale upwards. Since the measurments can never be fully accurate the resut we get which is exponentially increasing resistance when light comes near the sensor. hence we can conclude this to be an approximation.

```
p1 =        150
```

p1 = 150

```
p2 =      -1.852
```

p2 = -1.8520

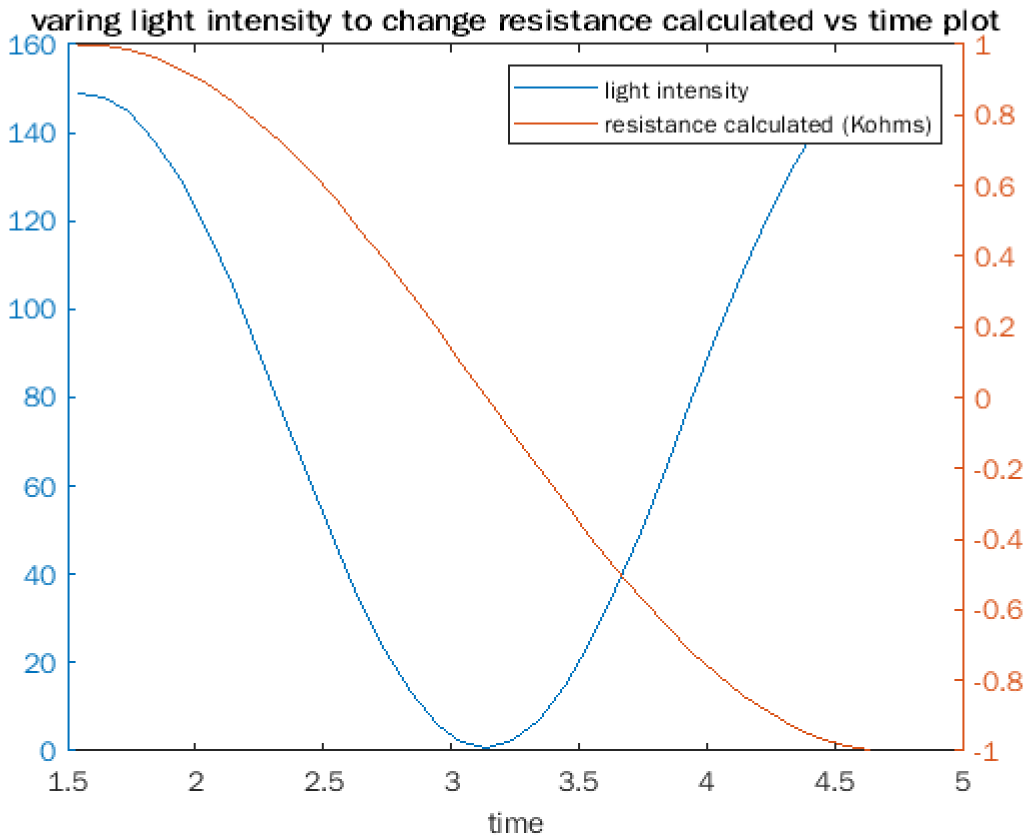
```
p3 =      0.8221
```

p3 = 0.8221

```
Resistance1 = p1*light_intensity.^2 + p2*light_intensity + p3
```

Resistance1 = 1×32
148.8508   148.2050   144.6183   138.2344   129.3091   118.1998   105.3518   91.2800 ···

```
figure
yyaxis right
plot(t,light_intensity)

yyaxis left
plot(t,Resistance1)

title("varing light intensity to change resistance calculated vs time plot")
xlabel ("time")
legend ("light intensity" , "resistance calculated (Kohms)")
```



Voltage divider Modeling

Getting values from experimetation. we will take measurements with different light contidion to vary the resistance hence changing the voltage for one ldr.

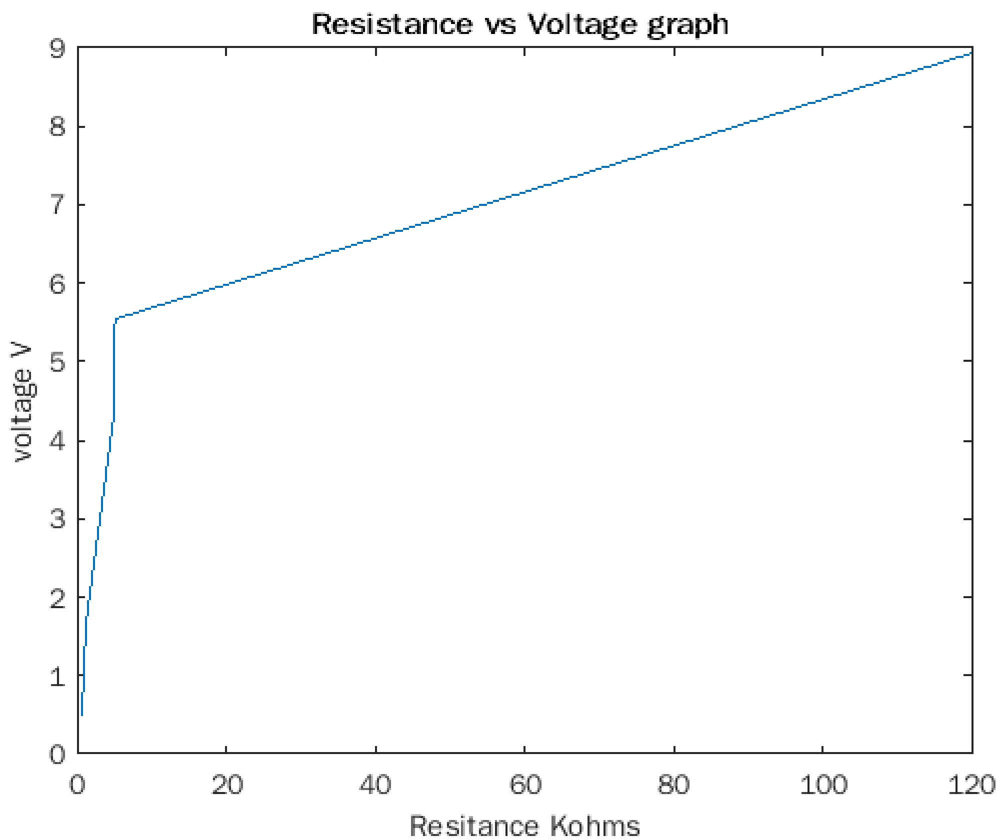
```
v= [0.505    1.68    4.14   4.35 5.418    5.54    8.927]
```

```
v = 1×7
    0.5050    1.6800    4.1400    4.3500    5.4180    5.5400    8.9270
```

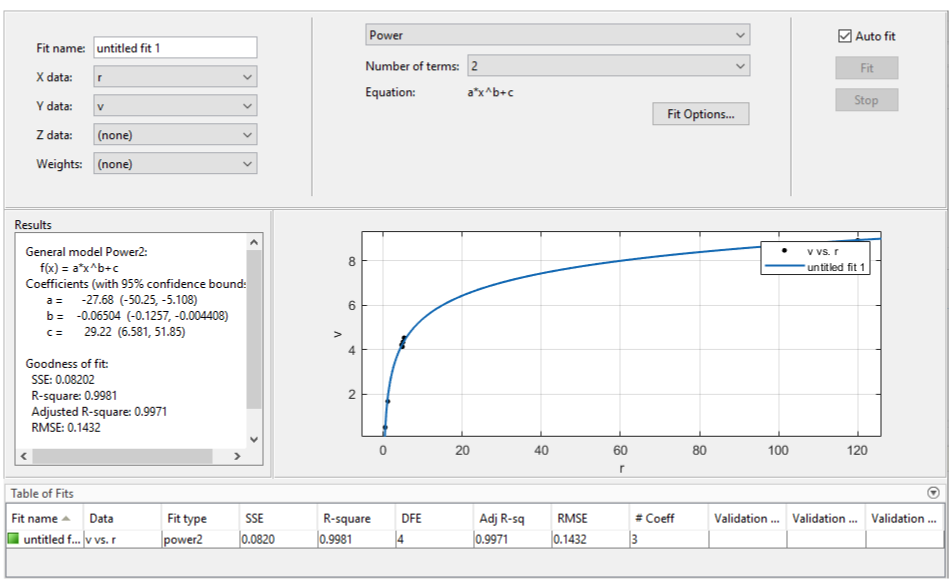
```
r=[0.54    1.2    4.7   4.91    5.053    5.34    120]
```

```
r = 1×7
    0.5400    1.2000    4.7000    4.9100    5.0530    5.3400  120.0000
```

```
figure
plot(r,v)
title("Resistance vs Voltage graph ")
xlabel("Resitance Kohms")
ylabel ("voltage V")
```



Curve Fitting



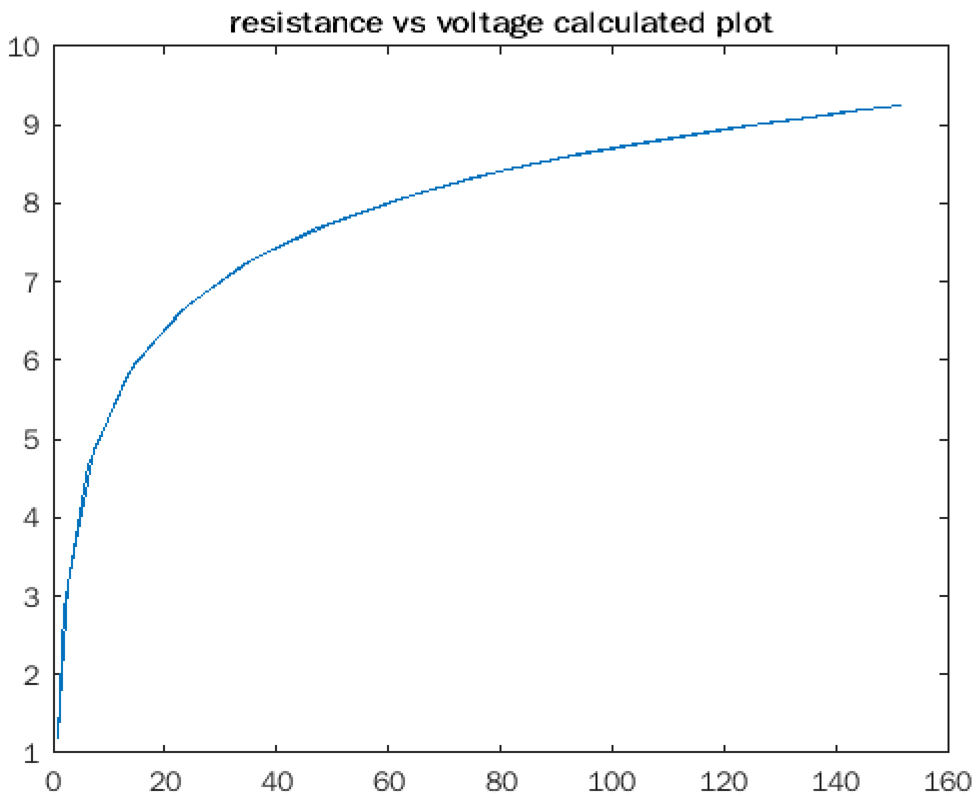

```
a =      -27.68;
b =    -0.06504;
c =       29.22;


v3=a*Resistance1.^b+c % the resistance calsulated in LDR modeling
```

```
v3 = 1×32
    9.2283     9.2226     9.1907     9.1318     9.0444     8.9262     8.7738     8.5822 ···
```

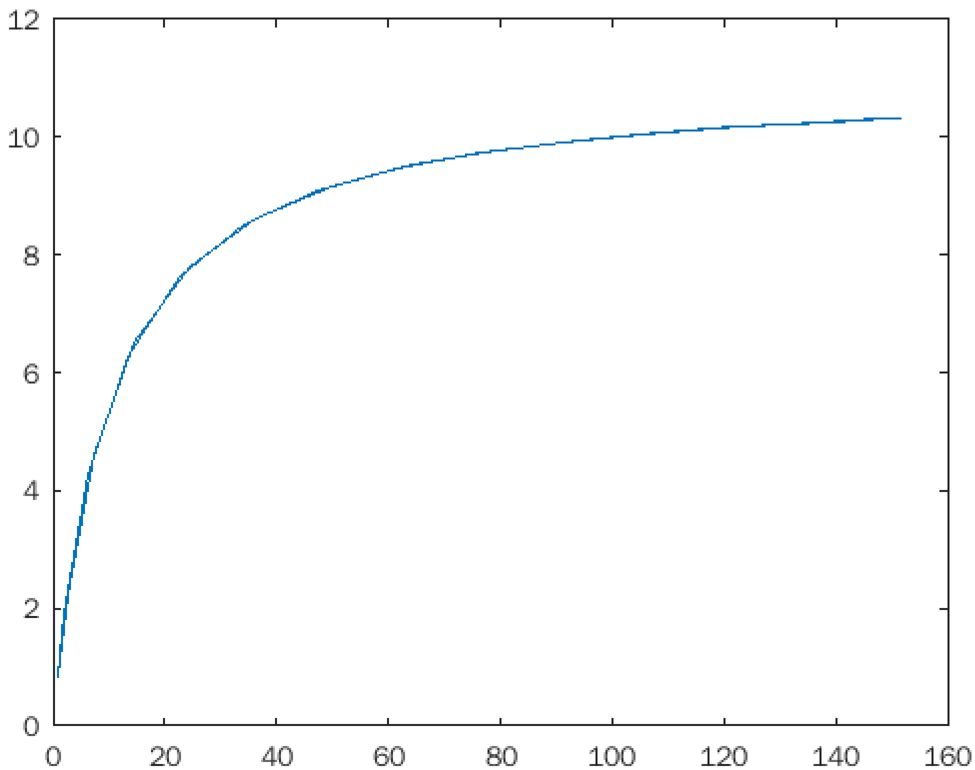
```
v0 = 11;
v1= (Resistance1.*v0)./(Resistance1+10) % if we use the voltage divider formula
```

```
v1 = 1×32
   10.3075    10.3047    10.2886    10.2579    10.2104    10.1420    10.0464     9.9139 ···
```

```
figure
plot(Resistance1,v3)
title("resistance vs voltage calculated plot")
```

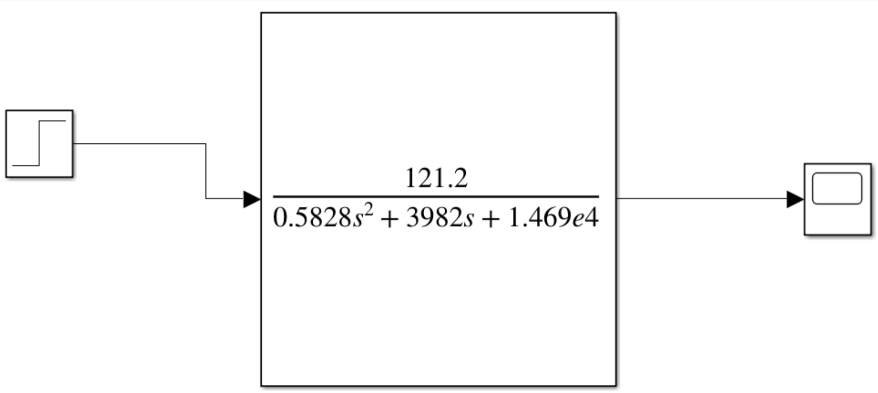



```
figure
title("plot taken out using voltage divider")
plot(Resistance1,v1)
```

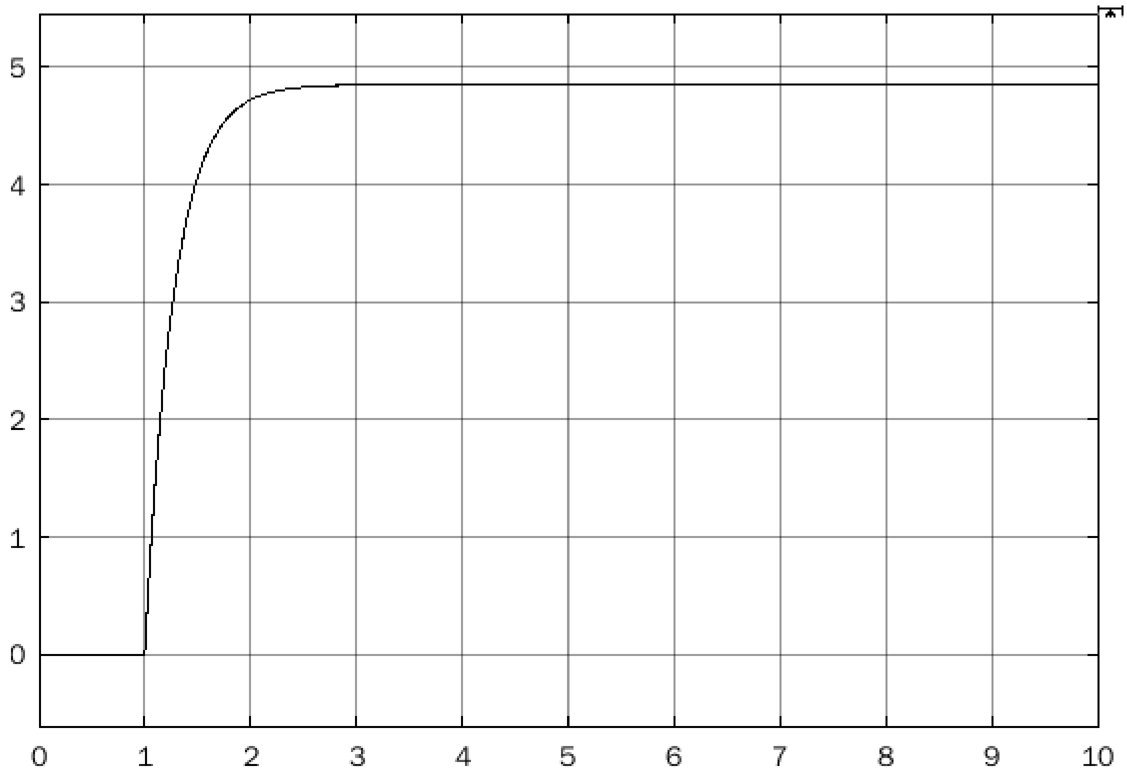


Now we will use two LDR with seperate voltage dividers, which will be connected in series. Since they will be in opposit polarity it will subtract hence we will get max negative voltage or max possitive voltage when one side is in the dark

Block diagrams



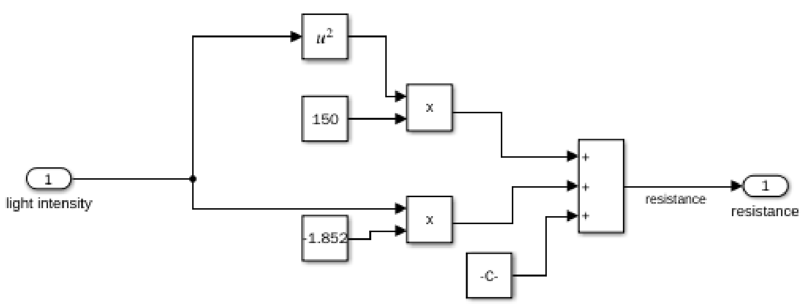
Motor transfer function



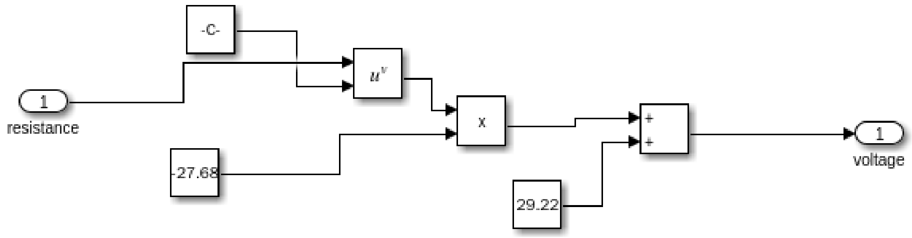
Analysis of open loop response

```
steady_state =  4.9 % rad/s
steady_state =  4.9 * (60  / 2*pi ) %rpm
```

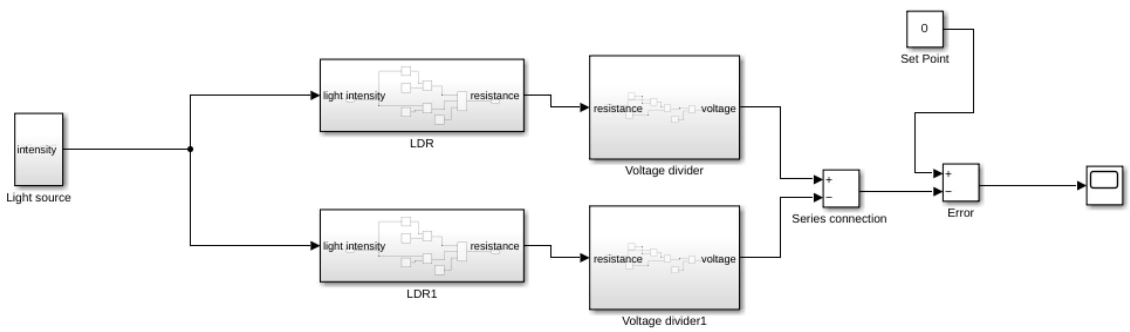
hence the open loop response is similar to the physical repsonse gained by the oscilloscope.



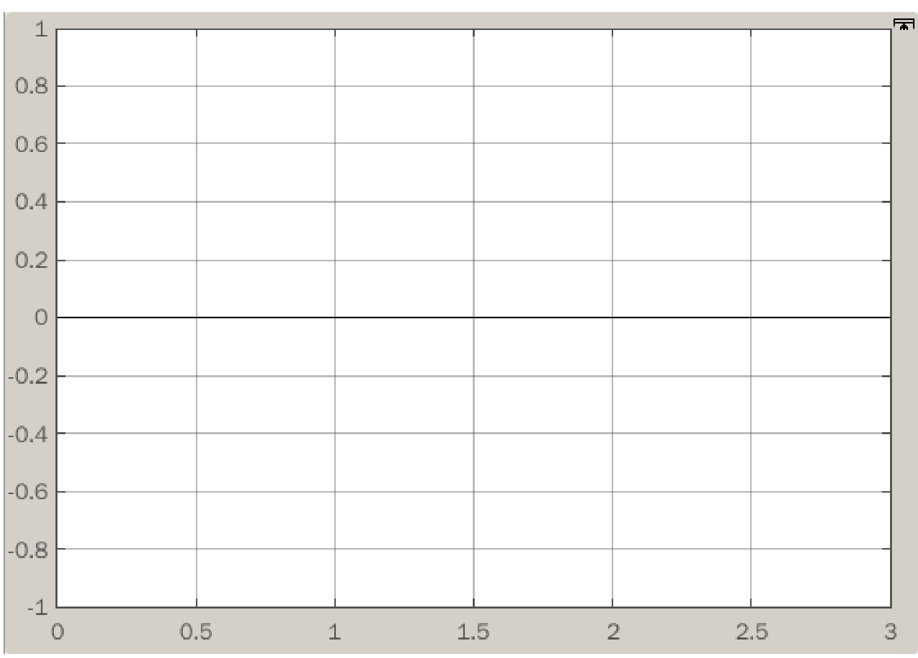
LDR Model in block diagram



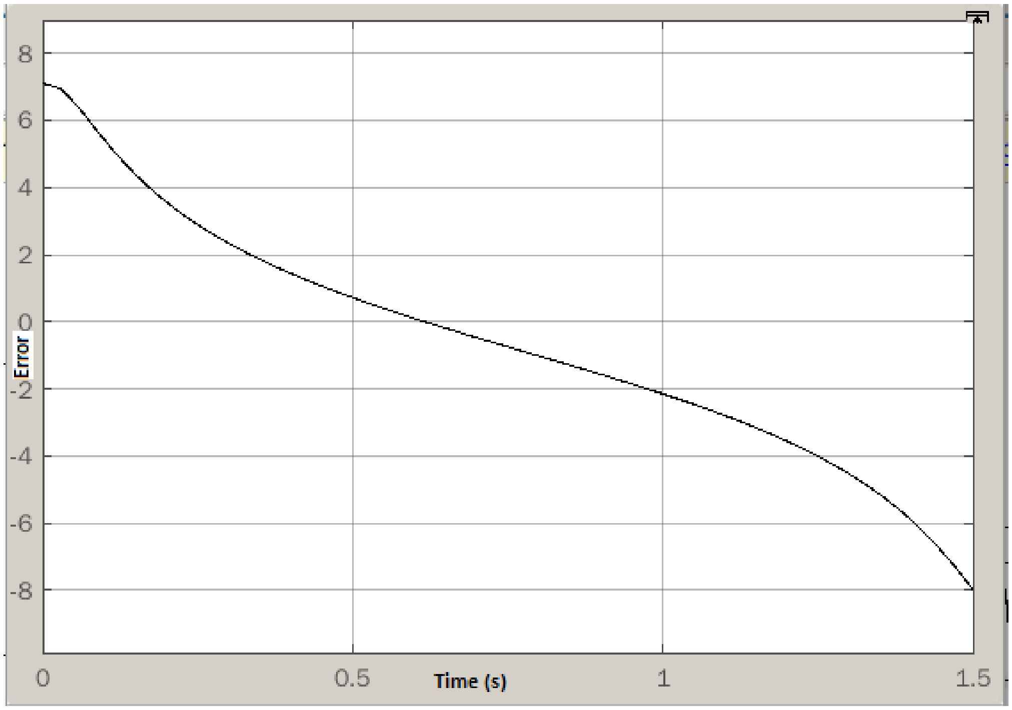
Voltage Model in block diagram



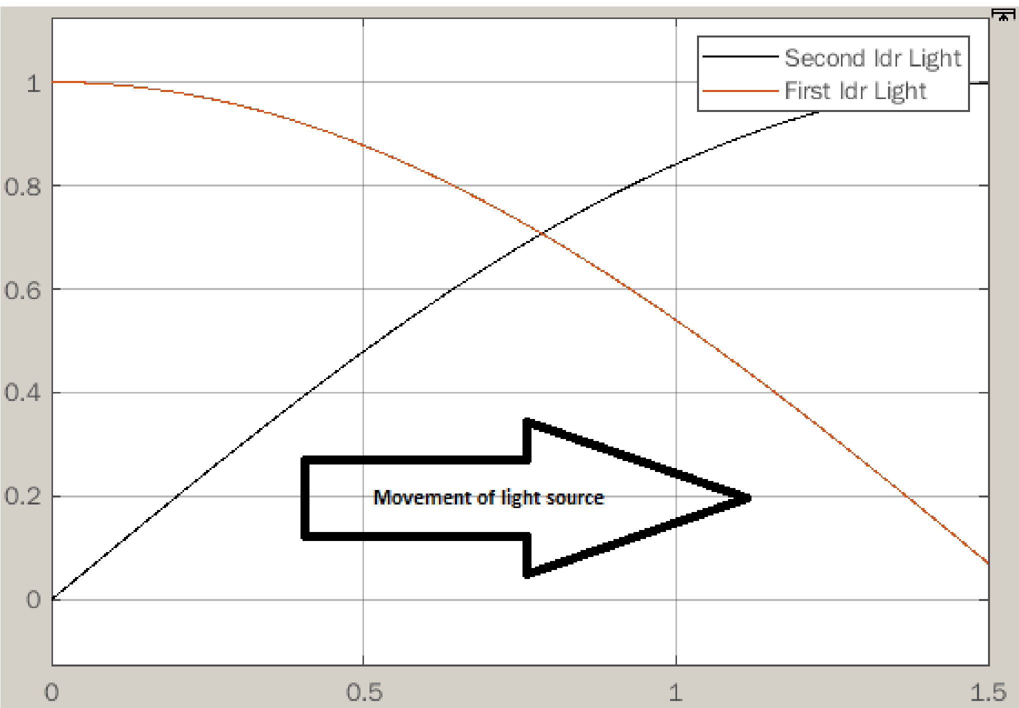
sensor in block diagram



error(volts) generated when both sensors are at the same place and the light moves from left to right. there is zero error as they both have same voltage levels when the light is moving so even tho there resistances are changing they are chnaging for both ldr hence the voltage level after subtraction is zero.



this is obtained when the LDR are placed at different ends and the light is brought closer from one end to the other. Hence we have zero error(volts) at the center where the light source is perpendicular.



this graph shows the light intensity at the sensors at a particular time. we see tha the light source moves from LDR1 to LDR2. in the middle the light intensity is equal for both ldr as it is equvidistant from them.

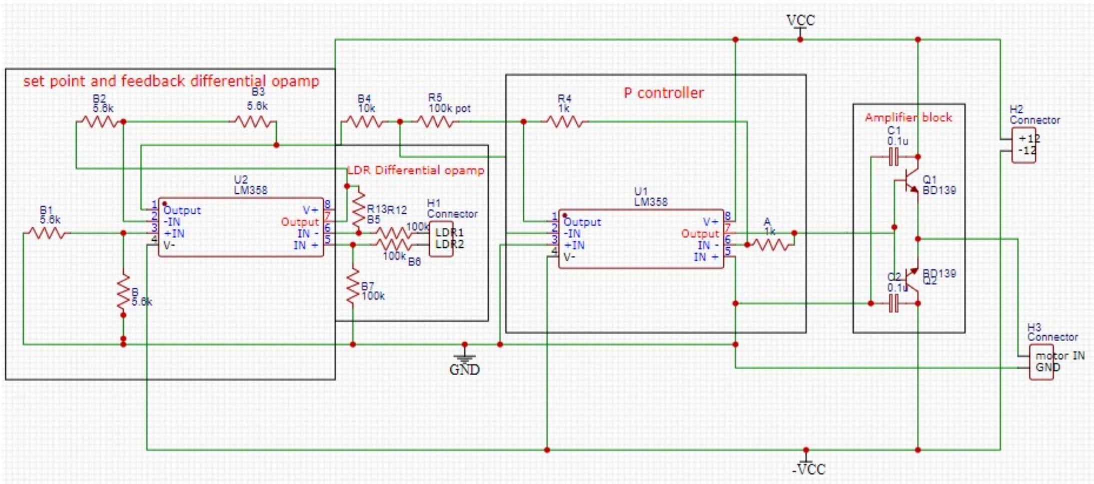
Building our project

Phyical design

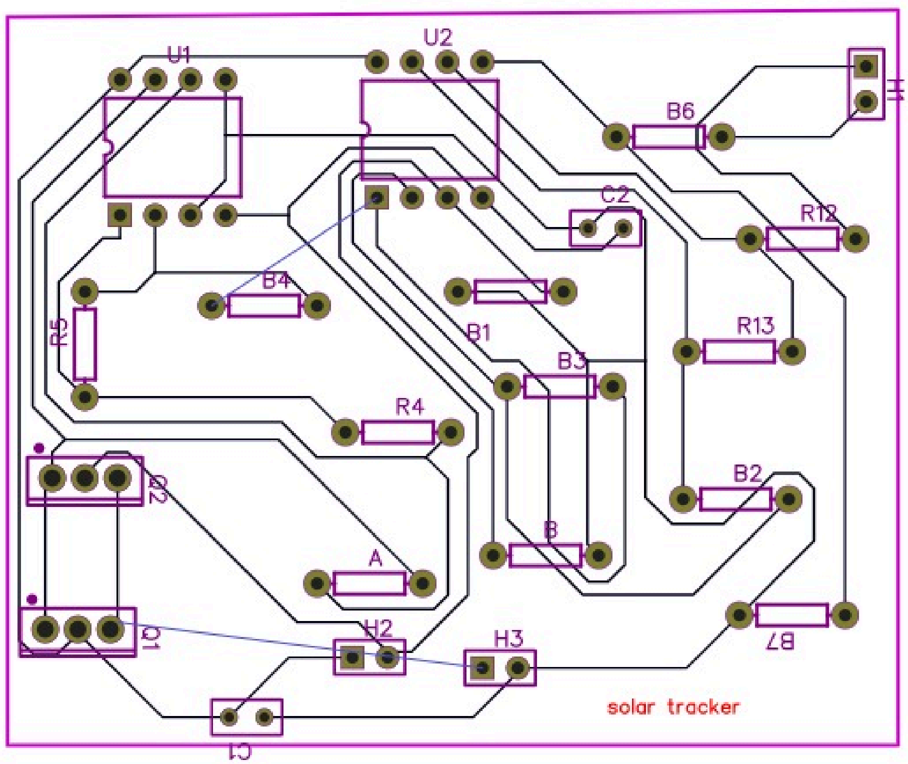
Designing the controller

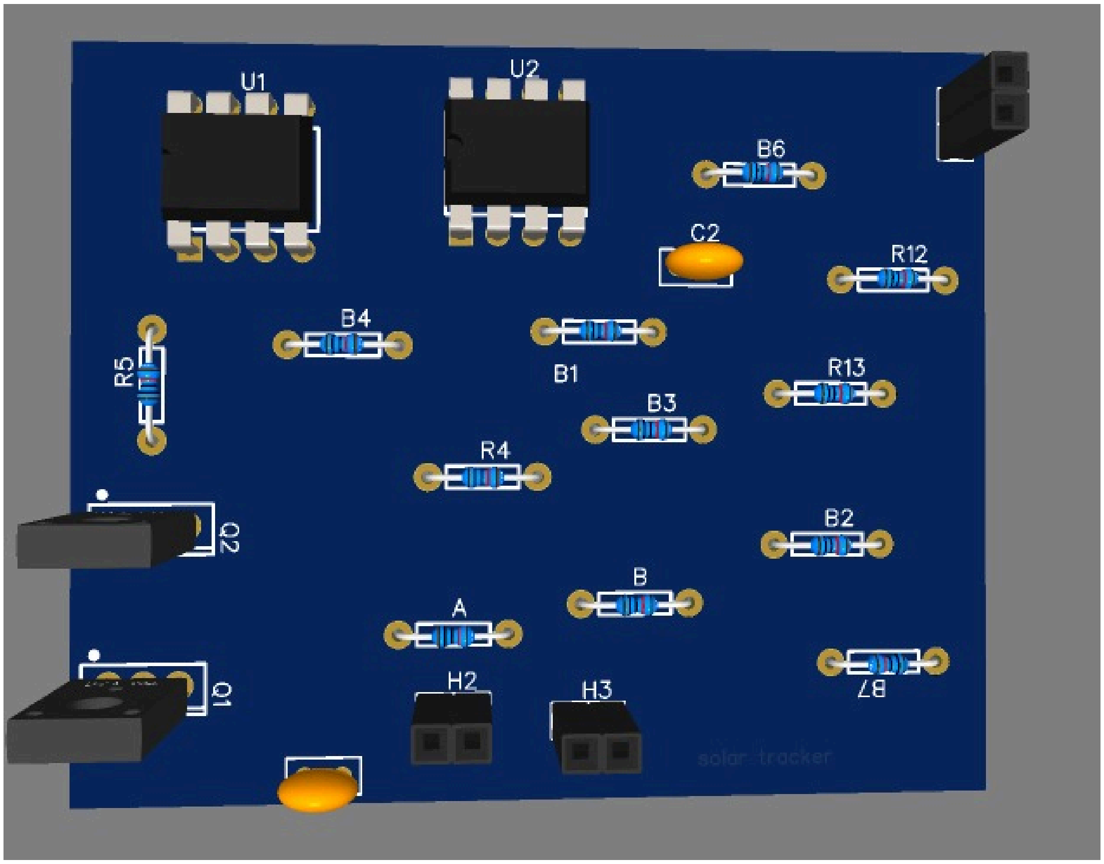
We are first designing a P controller. we will be using opamps to deign an analoge Propotional controller. the gain will be set using a variable resistor. Hence we can ajust the gain once we operate the system in close loop with the controller. The scehmatic of the controller the generic design.

Circuit schematic

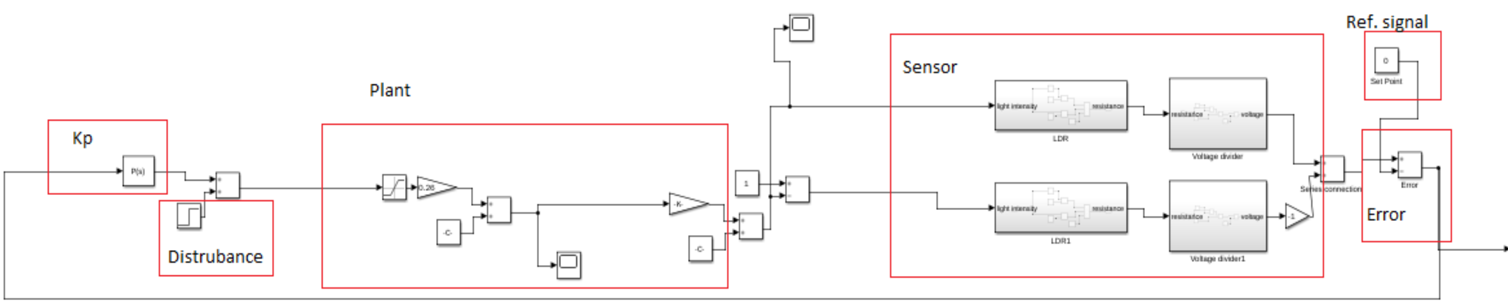


PCB design



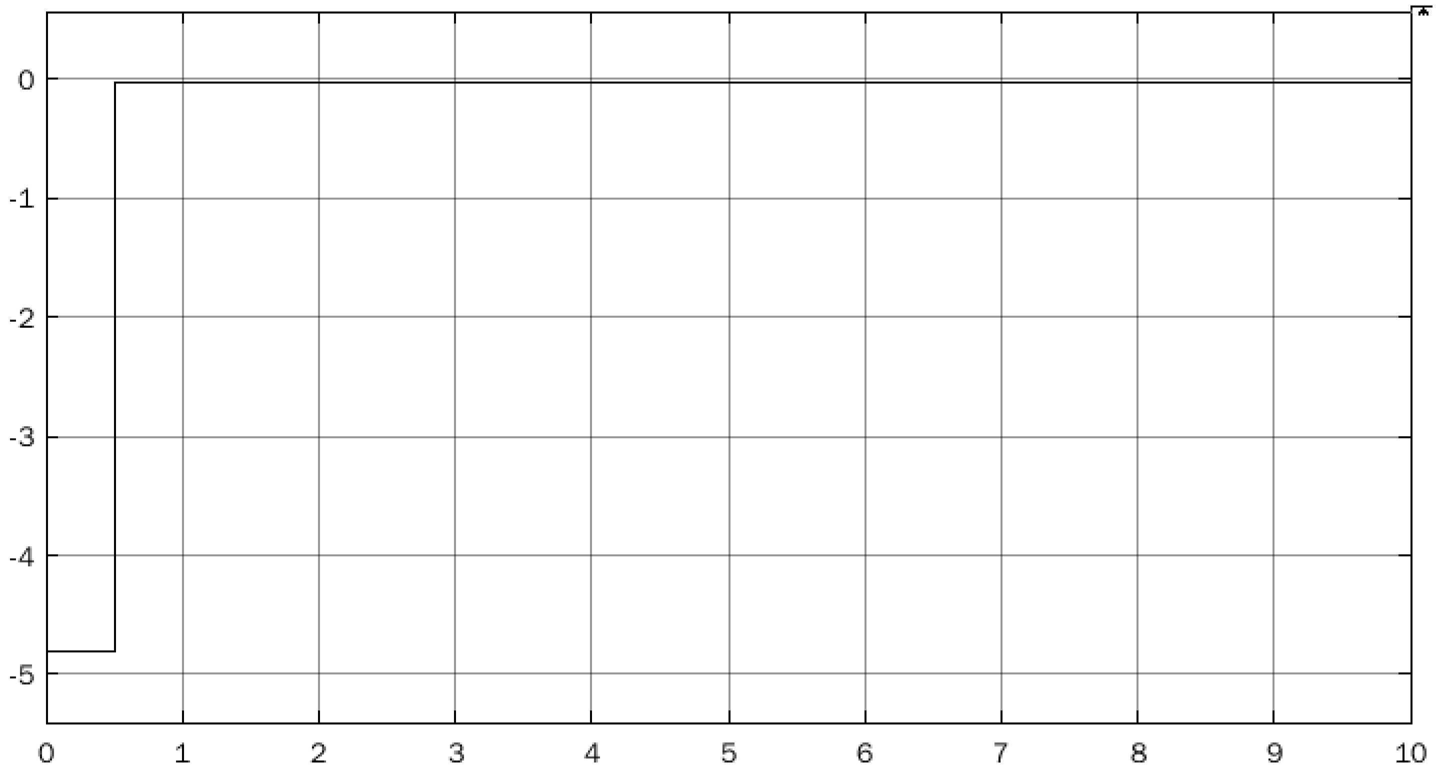


Close loop simulation



Step disturbance response of close loop system

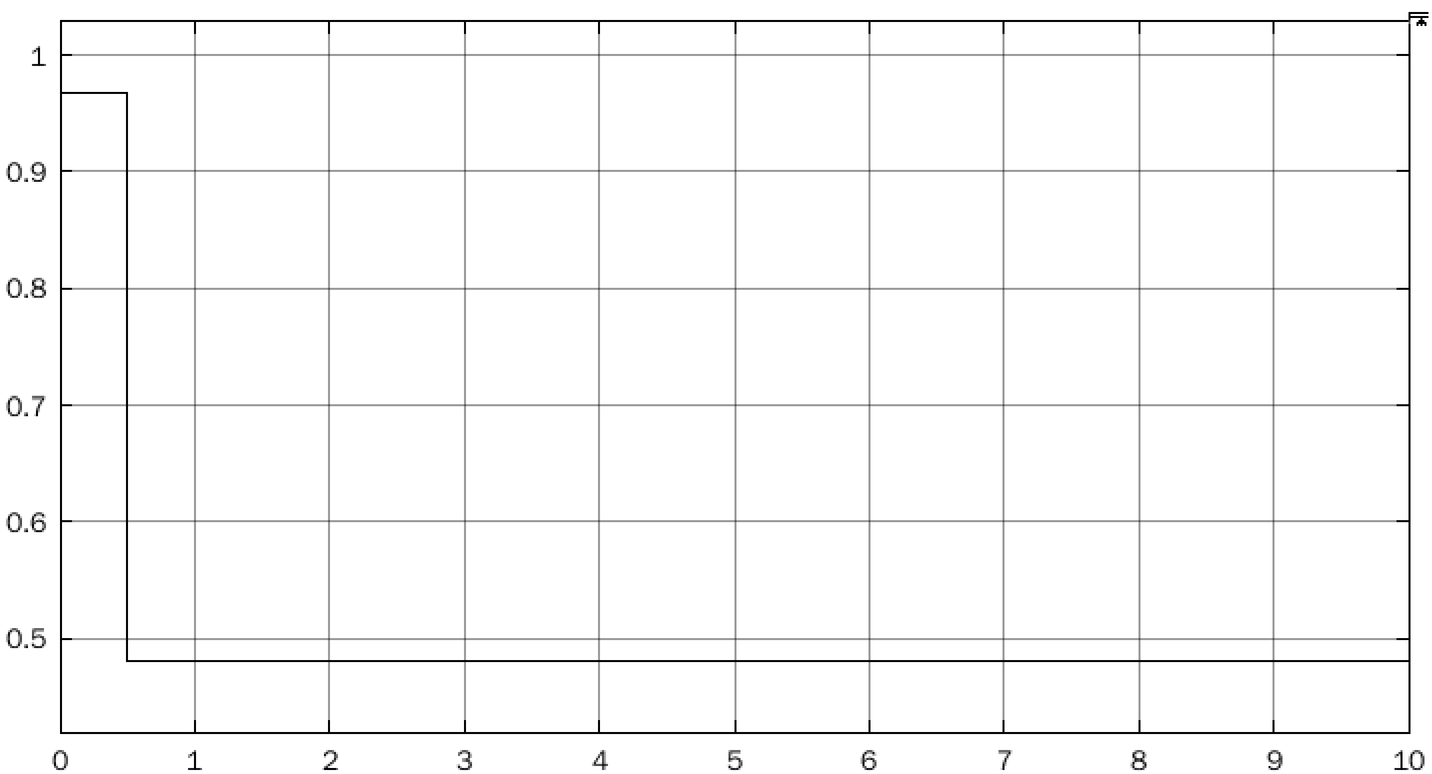
(Error / y axis)



Time / x axis

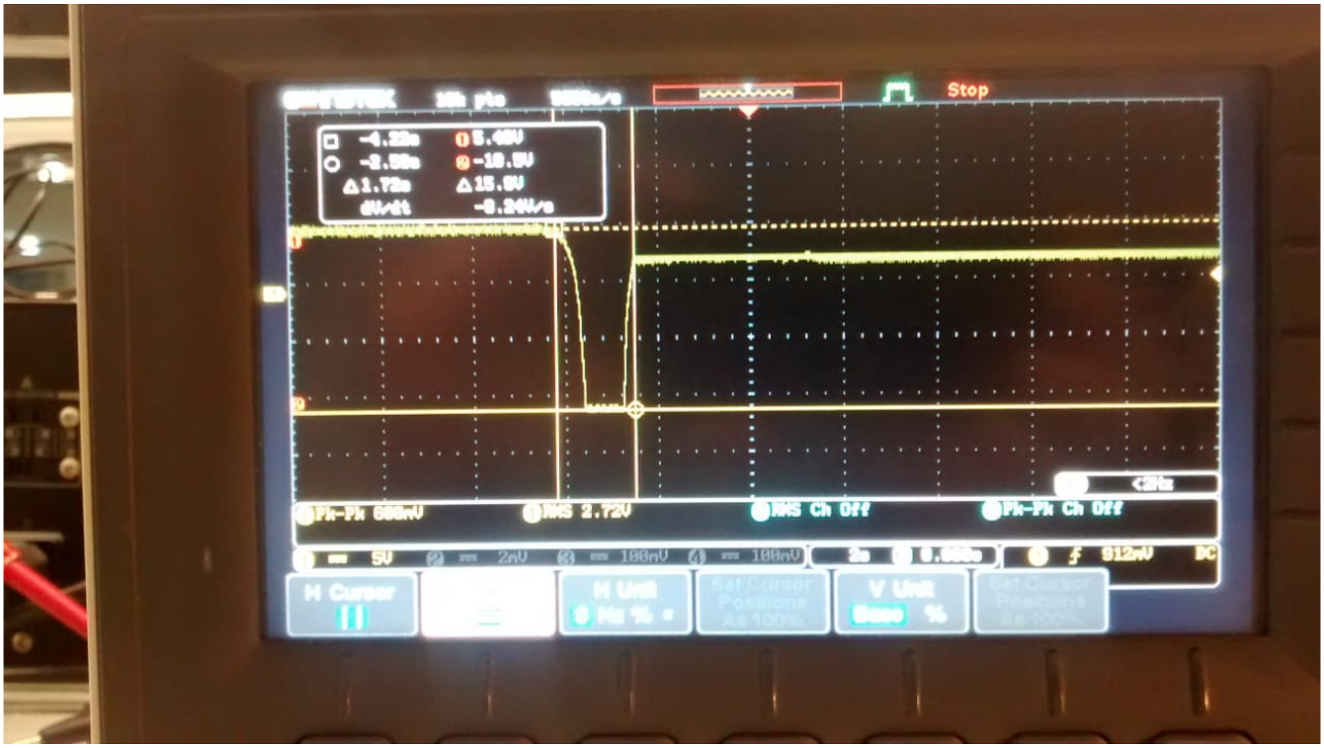
Close loop response of plant with unity gain

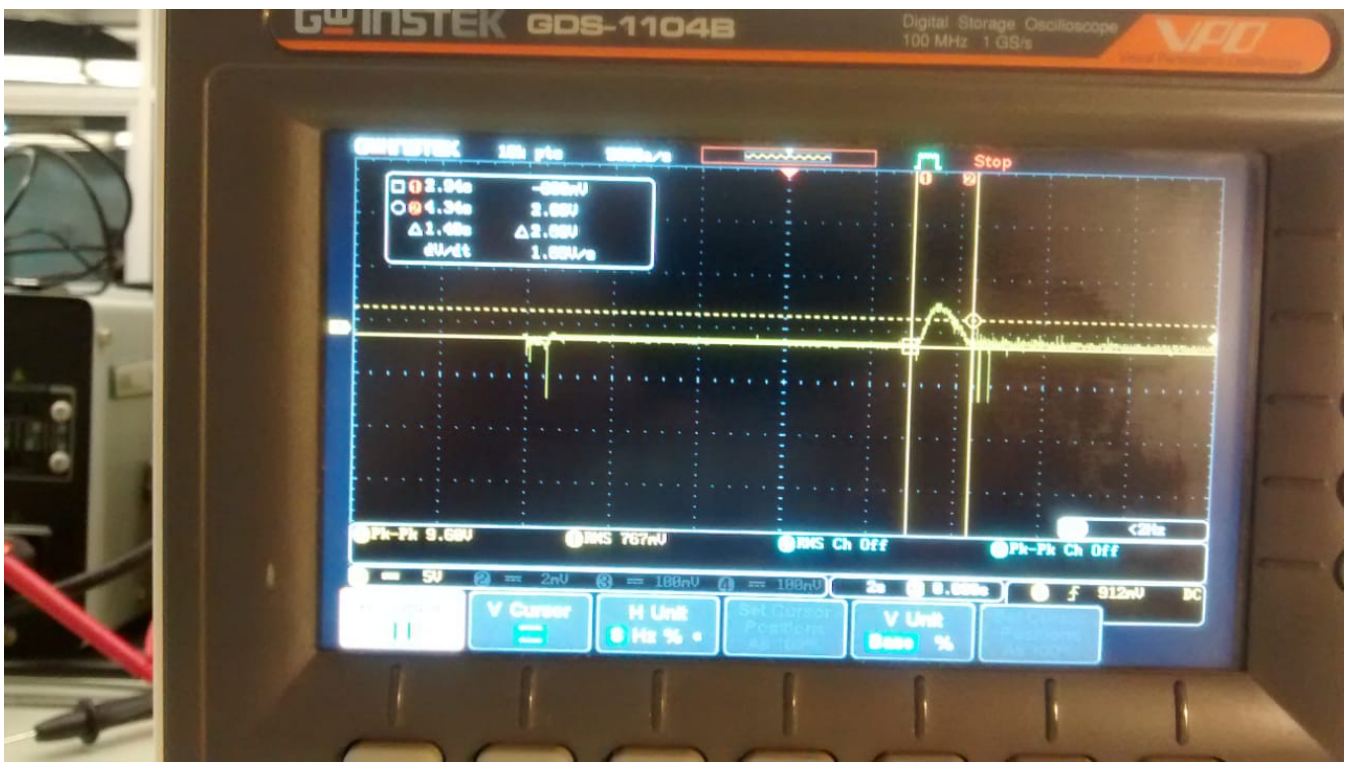
(Error / y axis)



Time / x axis

Physical Response





Comparision between simulated and physical response

The response show that a P controller is enough to get the desired condition. the desired condition being, the tracking of light to optimize the position of light to be perpendicular to the plane at all times.

the physical response and the aimulated reponse show that the error does not go to zero but reaches a steady state value that is close to zero. hence for oour application we can assume it to be acceptable. however if we require better tracking we can increase the gain of the controller from **10** to 20. we may be able to use Pi or PID as well.

we cannot accurately measure the rise time and steady state time of the physical system. this is because the impulse that we give is variable due to it being given by a human. if we need to measure these, we can use a force gauge to accurately measure the impulse and simulate the same force on matlab.

Video links

Disturbance rejection by displacing the plane: https://youtu.be/bfKsQWnzJwM

Disturbance rejection by displacing the light: https://youtu.be/3KM_Id89vXQ

Conclusion

The primary test showed that the implemetation that we took, was adequate. We were able to get the desired result, which was to maximize light on the top sureface of the plane. This project was designed to get a better undersatnding of control systems and to uderstand PID controller. Through out the project there were many meaning full experience that we gained. One of the major abilities that we gained which is inline with the CLOs of the course we gained better insite in the feedback control. Which helped us to view day to day objects that may use similar feedback mechanism. We have a greater apprieceiation for modeling systems, as now we have detailed knowledge of using different modeling methods to simulate systems.