ME5643 Mechatronics

Final Term Project

Automated Cantilever Strain Measurement

Group 8
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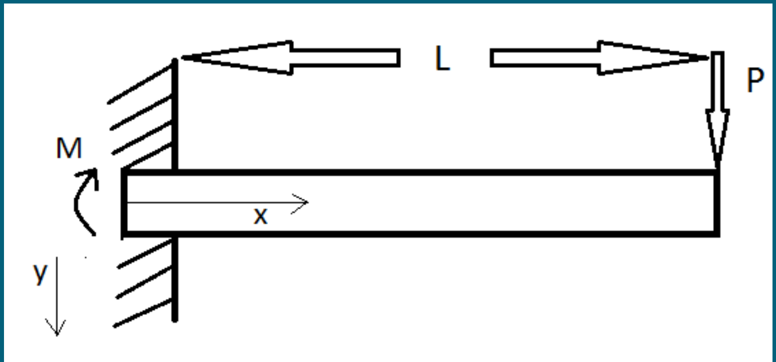
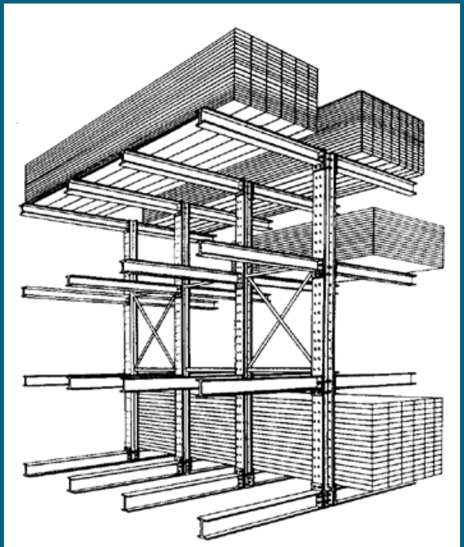
Introduction



Cantilever Beam



Members that are slender and support loadings that are applied perpendicular to their longitudinal axis are called **beams.**

One such beam is the **cantilever beam** which is fixed at one end and free at the other.

Cantilever beams are very structurally popular and can be found anywhere from pool diving boards to bridges

Theory

For most problems the flexural rigidity will be constant along the length of the beam. Assuming this to be the case the founding equations for the deflection of the elastic curve are as shown

$$(1) \quad EI\frac{d^4v}{dx^4} = -w(x)$$

$$(2) \quad EI\frac{d^3v}{dx^3} = V(x)$$

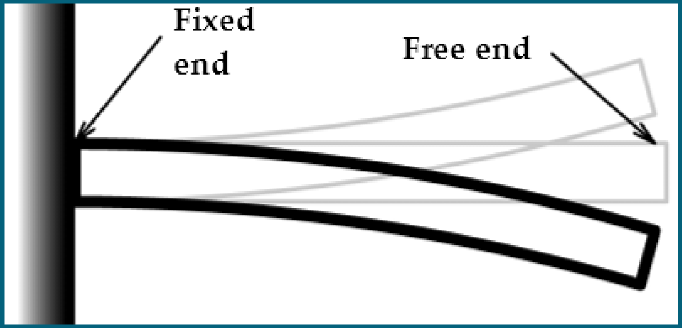
$$(3) \quad EI\frac{d^2v}{dx^2} = M(x)$$

After successive integration and knowing the boundary conditions of the problem we can obtain the deflection of the cantilever beam.

$$\left.\begin{matrix} v(0)=0 \\ \theta(0)=0 \end{matrix}\right\} \Rightarrow \begin{cases} v = \dfrac{PL^3}{3EI} \\ \theta = \dfrac{PL^2}{2EI} \end{cases} \Leftrightarrow \theta = \frac{3v}{2L}$$

Theory

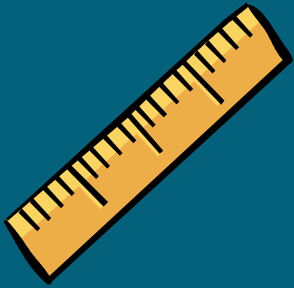
One of the many problems in cantilever beams is stress, which characterizes the behavior of the member under an external load. The stress can be conveniently related to the strain using Hooke's Law



$$(4) \quad E\varepsilon = \sigma$$

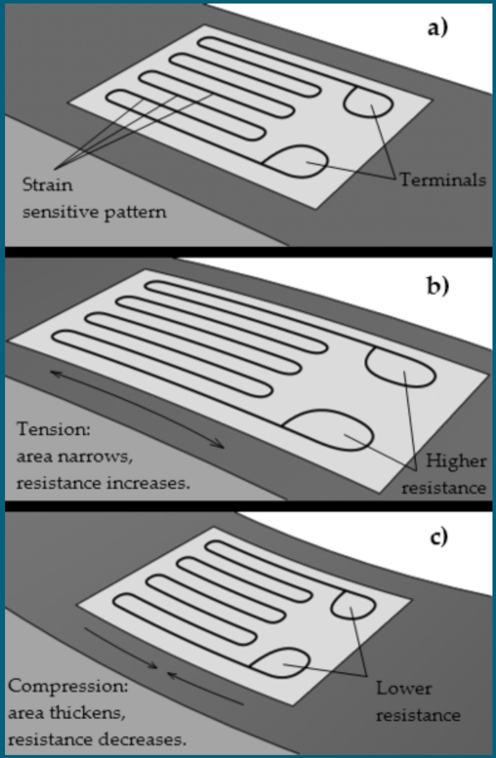
This is very powerful in that the stress can now be related to the change is physical deformation (ε) and the material property of the beam (E)

Ways to Measure



There are a few ways that one can measure the strain. The most obvious way is by hand measuring the deformation. But a more convenient way is by measuring using a strain gage

A strain gage works on a very simple principle; as the member it is adhered to elongates, so will the strain gage thereby causing the strain sensitive patterns to become thinner and more resistant to the flow of electricity.

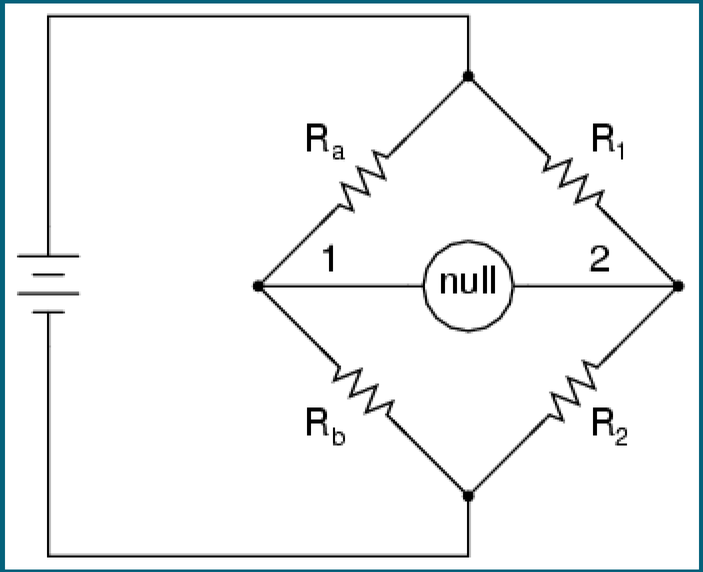


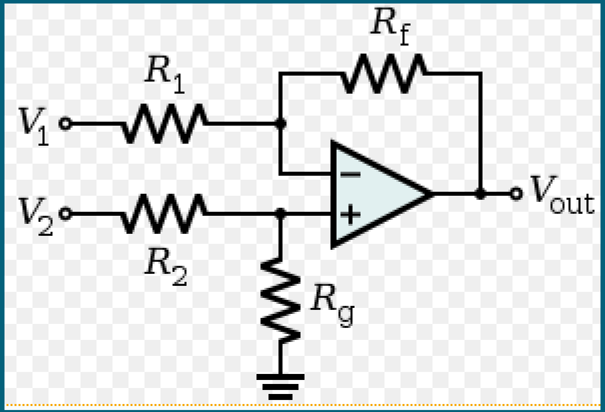
The change in resistance in the strain gage is directly proportional to the change in length of the specimen

$$\varepsilon = \frac{1}{F} \cdot \frac{\Delta R}{R} \qquad (5)$$

How to use it

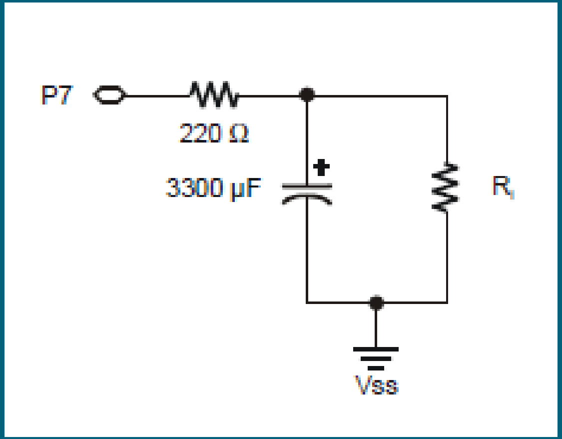
One of the most common ways of using a strain gage is by incorporating it in a what's called a Wheatstone Bridge. Sizing each resistor accordingly will allow for a noticeable voltage difference across points 1 and 2 whenever there is a change in resistance in the strain gage. This difference may be further amplified using a difference amplifier. This method however would require many accurate components





How to use it

A simpler way to achieve the same goal of measuring the strain is by using the command Rctime in basic stamp along with the strain gage as the resistor and an appropriately sized capacitor.



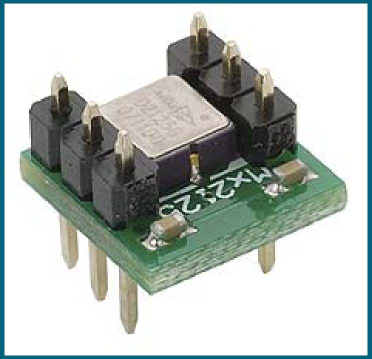
The command Rctime works by initially setting the state of a pin to charge or discharge the capacitor and then changing the state of that pin so that the capacitor may discharge or charge. The time is takes for this to happen is proportional to the resistance being measured and can be expressed by equation (5)

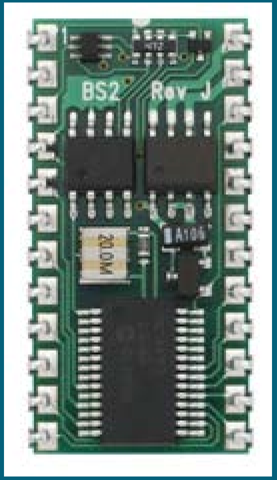
$$(6) \quad t = -RC \ln\left(\frac{V_f}{V_s}\right)$$

Basic Stamp returns this time in 2µs multiples

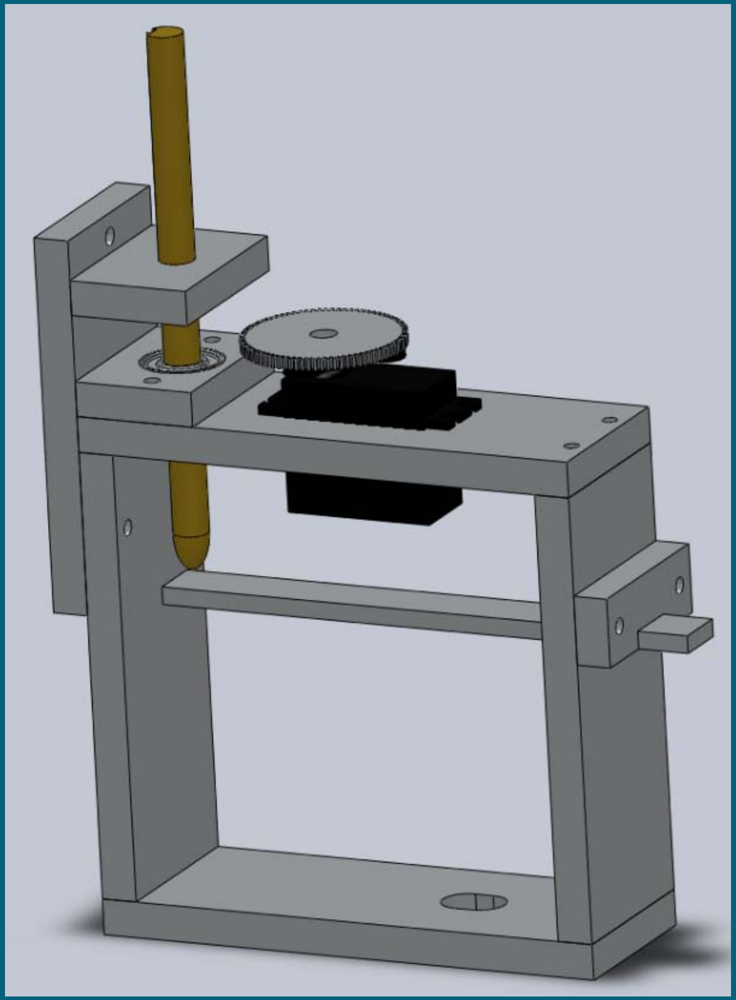
Materials Used

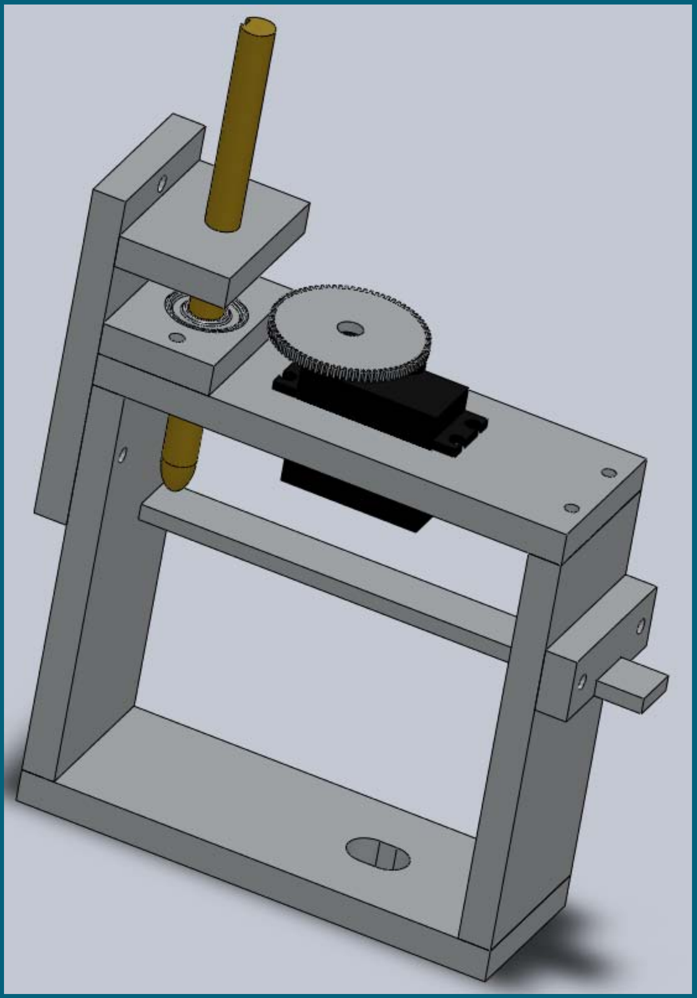
- Basic Stamp 2 Module
- Aluminum 6063
- LCD Display
- Push Button
- Tilt Sensor
- Capacitor
- Resistors
- Continuous Rotation Servo
- Jumper Wires
- Strain Gage



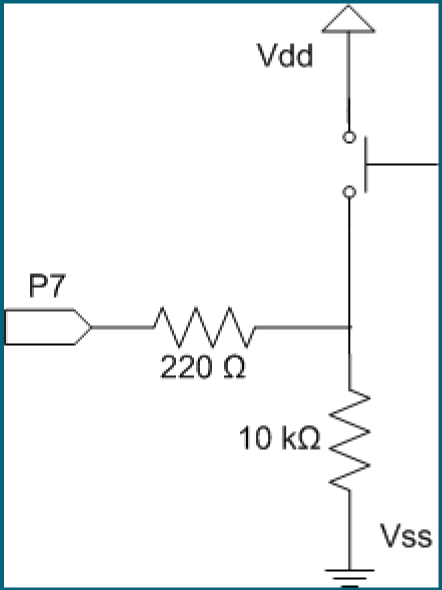


Design

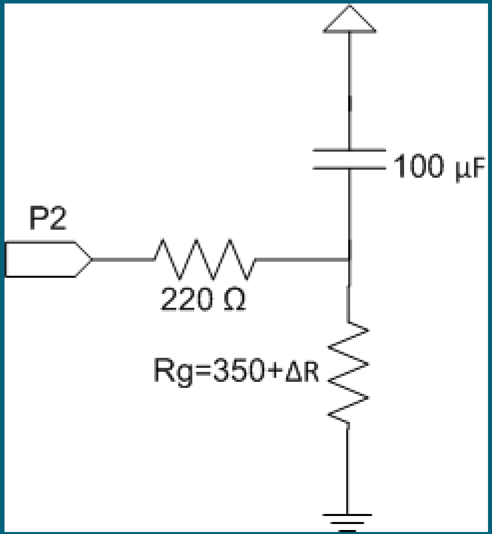




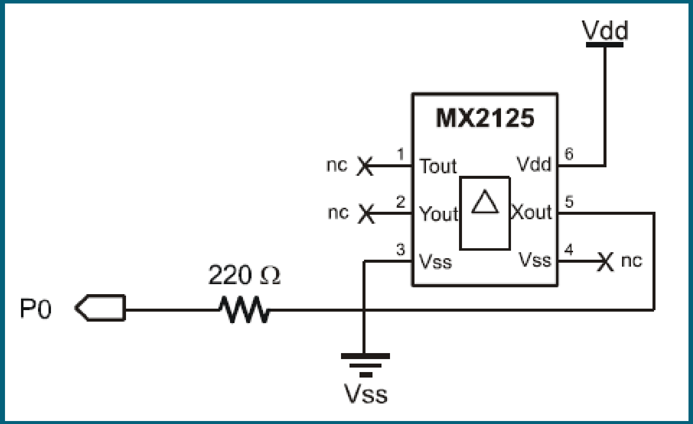
Circuit



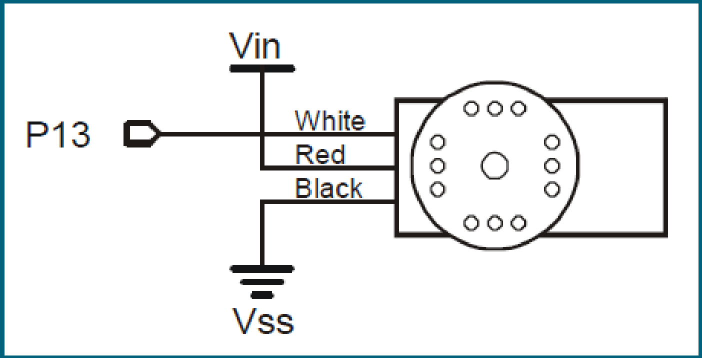
Push button NO active HIGH



RC circuit with strain gage as R



Memsic Accelerometer



Continuous Servo Motor

Number Scaling

Number scaling was a necessary procedure in the project due to BS2's inability to perform floating point math. To compensate for this much of the data to be processed was scale up of down

$$\varepsilon = \frac{1}{F} \cdot \frac{\Delta R}{R} = \frac{1}{F} = \frac{m(t_2 - t_1)}{mt_1 + 1630} \cdot \frac{1}{F} \cdot \frac{1}{10}$$

$$\frac{46(t_2 - t_1) + 0.8(t_2 - t_1)}{\left(\frac{t_1}{1000} + 10\right) + 0.7 + \Phi} = \frac{46(t_2 - t_1) + (t_2 - t_1) ** 52429}{\left(\frac{t_1}{1000} + 10\right) * 256 + 184 + \Omega * 256}$$

Program

```
Main:

GOSUB Get_User_Data    'Allow user to enter necesary data

DEBUG CRSRXY, 0,3, "Initial Gage Resistance: "
GOSUB Get_Resistance   'Calculate gage resistance
t_i=time               'Store initial resistance(in basicTime)

DEBUG  CRSRXY, 0,0, "Normalizing tilt..."
PAUSE 3000


normTilt=0
GOSUB Read_X_Tilt
normTilt=xTilt


finish=0
DO
  GOSUB Read_X_Tilt  ' reads G-force and Tilt

  GOSUB Angle_Display  ' Display tilt angle

  IF (finish=0) THEN
  GOSUB Servo_Forward_Control  ' Angle controlled actuator
  ENDIF

    IF ((ABS xTilt/100)>=desired_Angle AND finish=0) THEN   'Allow angle stabilization before
     counter=counter+1        'taking final resistance
     IF (counter=25) THEN
        DEBUG CRSRXY, 0,5,"Final Gage Resistance: "
        GOSUB Get_Resistance
        t_f=time
        GOSUB Get_Gage_Strain
        finish=1
     ENDIF
    ELSE
      counter=0
    ENDIF
```

Program

```
    IF (finish=1 AND IN7=1) THEN
   FOR counter = 1 TO 100
    PULSOUT 13, 800
    PAUSE 100
    NEXT

      DEBUG CR,"done"
   GOTO main
   ENDIF

LOOP

Program_End:
DO
IF IN8 = 1  THEN
   FOR counter = 1 TO 200
   PULSOUT 13, 800
    PAUSE 100
    NEXT
    ENDIF
LOOP

END



' -----[ Subroutines ]-----------------------------------------------------

'------[Obtain user data and options]--------------------------------------
Get_User_Data:
  DEBUG CLS,"Enter angle (in degrees) at which to measure the strain: "
  DEBUGIN DEC desired_Angle
    SEROUT 15, 84, [22, 12]
    PAUSE 5
    SEROUT 15, 84, ["Desired Angle:", DEC desired_Angle]
  DEBUG CLS,"Thank you..."
  PAUSE 1000
  DEBUG CLS
RETURN
```

Program

```
Get_Resistance:
HIGH 2
  PAUSE 1500
  RCTIME 2,1,time
  Resistance=time**9961+1630
  DEBUG DEC Resistance/10,".",DEC1 Resistance,CR
RETURN


Get_Gage_Strain:
  answer=((46*(t_f-t_i))+((t_f-t_i)**52429))/(((((t_i/1000)+11)*256)+(((((t_i//10000)/100)*256)/100)+184))/256)

  IF (answer<100) THEN
    SEROUT 15, 84, [13, " Strain:0.000", DEC answer]
    DEBUG CR,"The experimental strain is: 0.000",DEC answer
  ELSE
    SEROUT 15, 84, [13, " Strain:0.00", DEC answer]
    DEBUG CR,"The experimental strain is: 0.00",DEC answer
  ENDIF
RETURN


Angle_Display:
  Display:
  DEBUG CRSRXY, 0,0, "X Tilt...... "
  DEBUG DEC (ABS xTilt / 100),".", DEC2 (ABS xTilt), DegSym, 11, CLREOL
  PAUSE 20
RETURN


Read_X_Force:
  PULSIN 0, 1, xRaw ' read pulse output
  xRaw = xRaw * 2 ' convert to microseconds
  ' g = ((t1 / 0.01) - 0.5) / 12.5% ' correction from data sheet
  '
  xmG = ((xRaw / 10) - 500) * 8 ' convert to 1/1000 g
RETURN
```

Program

```
Read_X_Tilt:
  GOSUB Read_X_Force
  LOOKDOWN ABS xmG, <=[174, 344, 508, 661, 2000], idx
  LOOKUP idx, [57, 58, 59, 60, 62], mult
  LOOKUP idx, [32768, 10486, 2621, 30802, 22938], frac
  xTilt = (mult * (ABS xmG / 10) + (frac ** (ABS xmG / 10)))-normTilt


  Check_SignX:
  IF (xmG.BIT15 = 0) THEN XT_Exit ' if positive, skip
  xTilt = -xTilt ' correct for g force sign
  XT_Exit:
RETURN


Servo_Forward_Control:
  IF((ABS xTilt / 100) >= desired_Angle)  THEN
  LOW 15
  ELSE
  PULSOUT 13, 100
  PAUSE 0
  ENDIF
RETURN
```

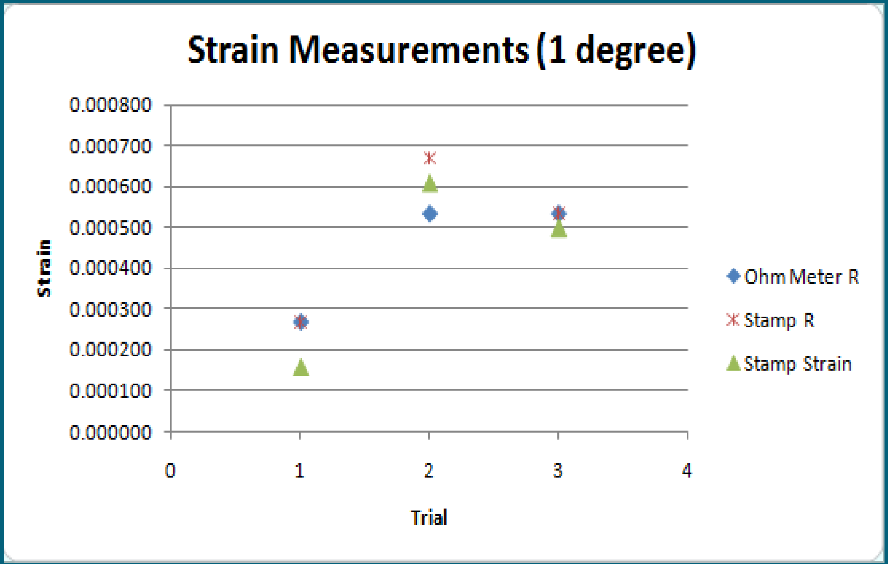
Results

1 degree	Ohm Meter R			Basic Stamp R			Basic Stamp Strain
	R1	R2	Strain	R1	R2	Strain	
Trial 1	350.3	350.5	0.000267	350.6	350.8	0.000267	0.00016
Trial 2	350.3	350.7	0.000535	349.9	350.4	0.000669	0.00061
Trial 3	350.3	350.7	0.000535	350.3	350.7	0.000535	0.00050
Average			0.000446			0.000490	0.000423

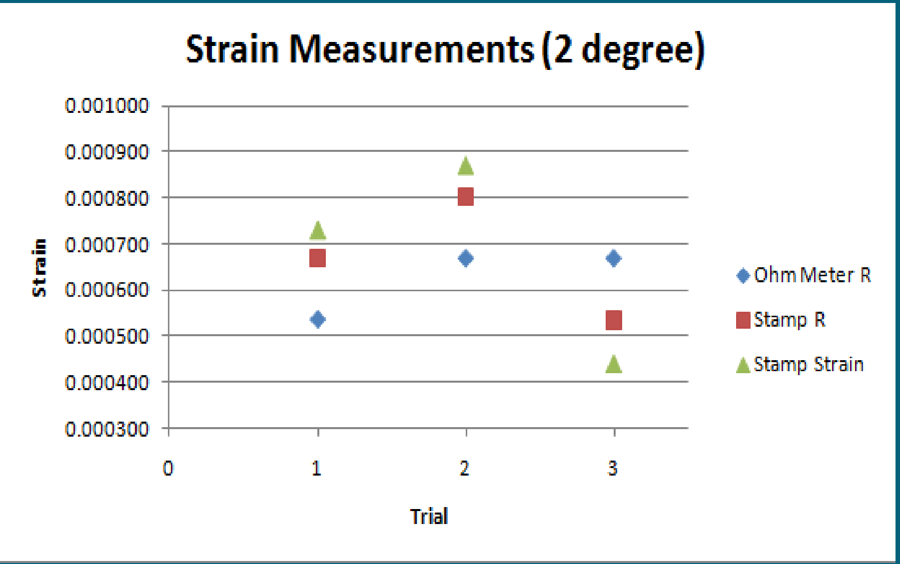
2 degree	Ohm Meter R			Basic Stamp R			Basic Stamp Strain
	R1	R2	Strain	R1	R2	Strain	
Trial 1	350.3	350.7	0.000535	350.3	350.8	0.000669	0.00073
Trial 2	350.3	350.8	0.000669	350.2	350.8	0.000802	0.00087
Trial 3	350.3	350.8	0.000669	350.7	351.1	0.000534	0.00044
Average			0.000624			0.000668	0.000680

3 degree	Ohm Meter R			Basic Stamp R			Basic Stamp Strain
	R1	R2	Strain	R1	R2	Strain	
Trial 1	350.3	351.1	0.001070	350.4	351.6	0.001604	0.00111
Trial 2	350.3	351.0	0.000936	350.3	352.2	0.002540	0.00258
Trial 3	350.3	350.9	0.000802	351	351.6	0.000801	0.00075
Average			0.000936			0.001648	0.001480

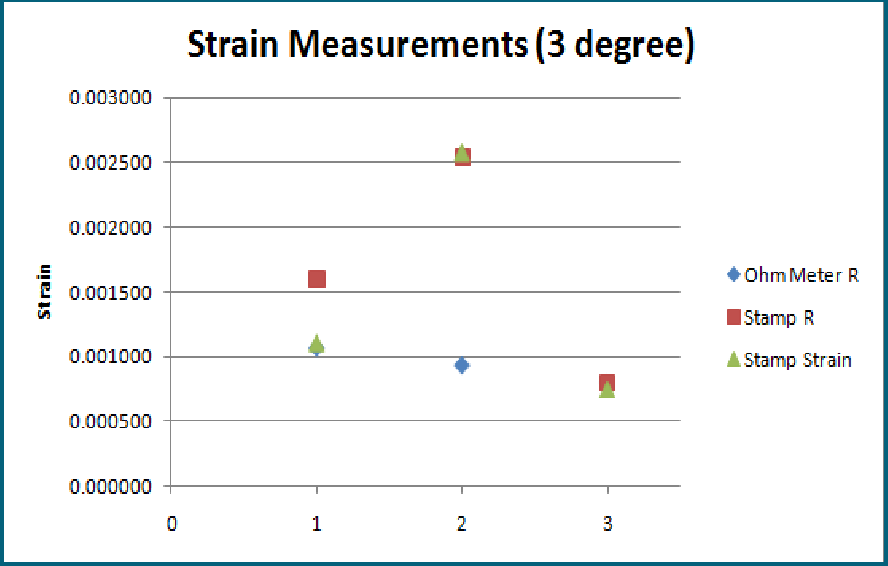
Results



Strain Measurements (1 degree)
0.000800
0.000700
0.000600
0.000500
0.000400
0.000300
0.000200
0.000100
0.000000
Strain
0
1
2
3
4
Trial
Ohm Meter R
Stamp R
Stamp Strain



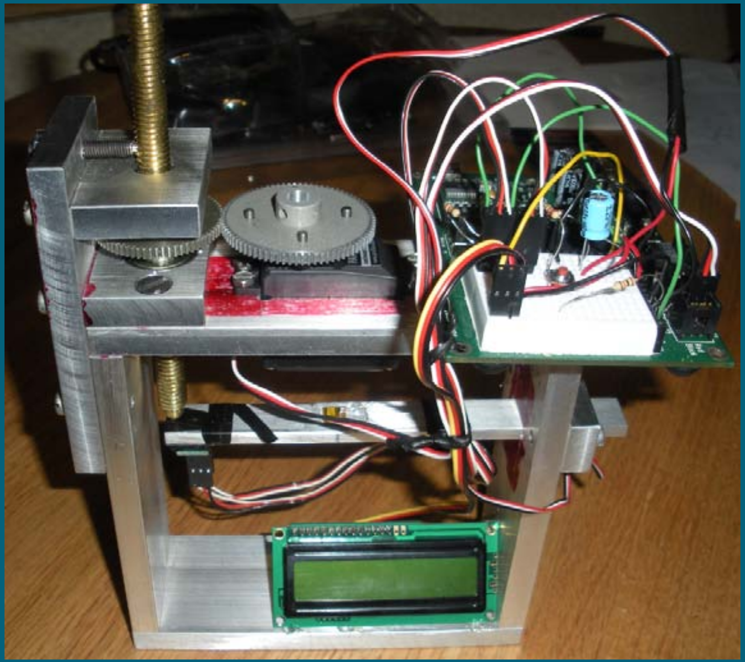
Strain Measurements (2 degree)
0.001000
0.000900
0.000800
0.000700
0.000600
0.000500
0.000400
0.000300
Strain
0
1
2
3
Trial
Ohm Meter R
Stamp R
Stamp Strain

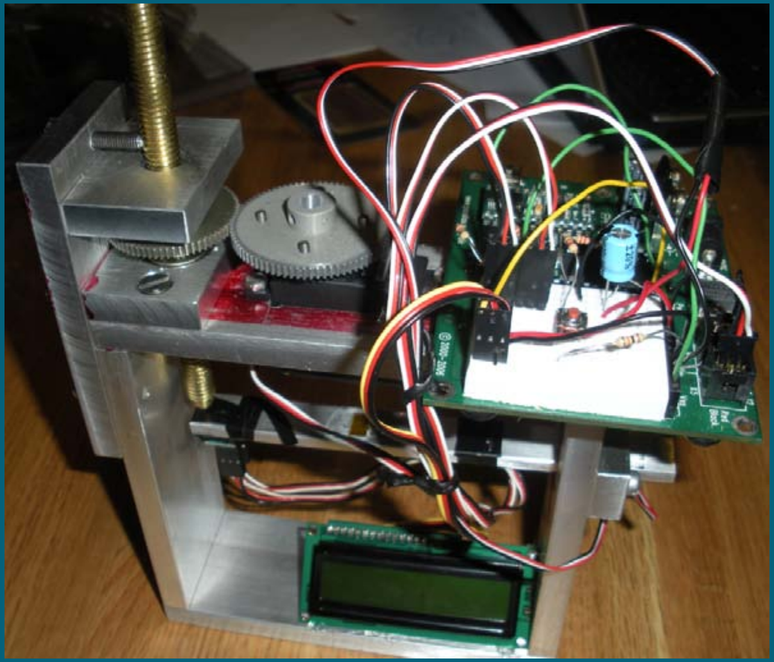


Strain Measurements (3 degree)
0.003000
0.002500
0.002000
0.001500
0.001000
0.000500
0.000000
Strain
0
1
2
3
Ohm Meter R
Stamp R
Stamp Strain

Conclusion

- Agreeable data acquisition
- Presence of acquisition errors
- Filters/ Algorithm to be considered
- Better accelerometers to be considered
- Servo with more torque to be considered





Questions?