TEAM 13 – NO-CONTACT GAP MEASUREMENT DEVICE

Samuel Giaquinto, Matthew Nagy, Forrest Parker

Sponsor - Dr. Zheng; Advisor - Dr. Shih

OUTLINE

- Background Information on Rolling Machine
- Need Statement and Goal Statement
- Objectives and Constraints
- House of Quality
- Previous Design Concepts
- Final Design Concept 1 – Capacitance Sensor
- Final Design Concept 2 – Strain Gauges
- Budget Analysis
- Gantt Chart and Future Plans

ROLLING MACHINE

Figure 1. Rolling Machine

Figure 2. Looking down on rollers

Figure 3. Safety Feature

Presenting:
Matt N.

PRO-E MODEL

- Pro-E model with relevant dimensions.
- Only the important dimensions needed for the design.
- To scale.
- Measurements taken from the machine.

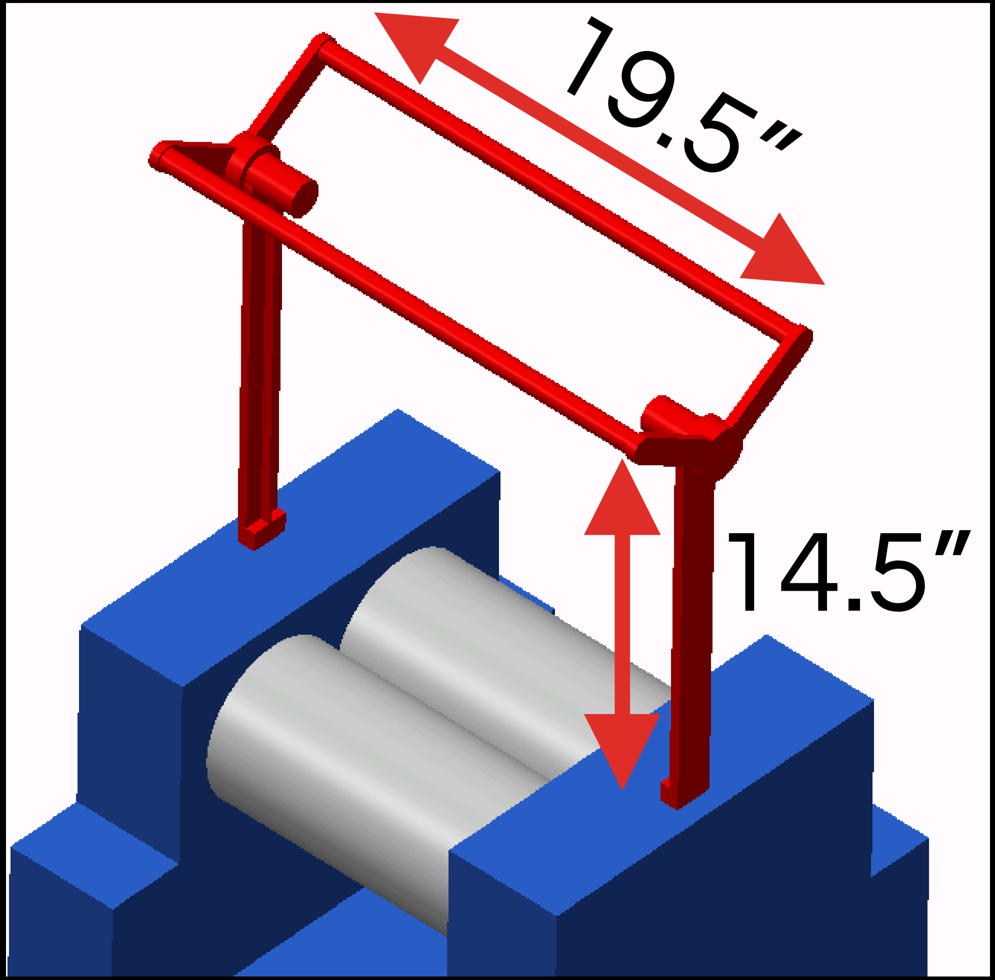


Figure 4. Pro-E Model of Machine

Presenting:
Matt N.

NEED STATEMENT AND GOAL STATEMENT

Need

- The current use of feeler gauges to gap a pair of rollers is unreliable, time consuming, and potentially damaging.

Goal

- A non-invasive way of measuring the distance needs to be created.

Presenting:
Matt N.

OBJECTIVES / CONSTRAINTS

- Maximize maneuverability in the applied system.
- Use sensors to measure the gaps of the rollers up to two microns.
- Can be removable or detachable and easily reassembled.
- No contact with the rollers themselves.
- System must have resistance to heat (rollers heat up to 300 Celsius)
- Total Cost: $1,500
- Reliable with a life of up to five years.

Presenting:
Matt N.

HOUSE OF QUALITY

		Engineering Characteristics					
Customer needs	Importance	Material	Precision	Portability	Durability	Software/User Compatibility	
No Contact	5	1	5	5	1	2	
Easily Maneuverability	3	3	1	5	2	1	Key
Able to Perform in High Heat Environment	2	5	3	1	5	2	5 - Strong Relationship
Accurate Readings	4	1	5	2	1	5	1 - Weak Relationship
Internal Power Source	1	1	4	5	2	2	
	Priority Σ(Importance* Rating)	29	58	55	27	39	
	Ranking	**4**	**1**	**2**	**5**	**3**	

Figure 5. House of Quality

Presenting:
Matt N.

FINITE ELEMENT ANALYSIS

- Air space above the hot rollers simplified into 2D
- Heat transfer physics used with steel rollers and air medium

Table 1: Properties of Air	Value
Thermal Conductivity	0.024 $Wm^{-1}K^{-1}$
Density	1.225 kgm^{-3}
Heat Capacity	1.006 $kJkg^{-1}K^{-1}$

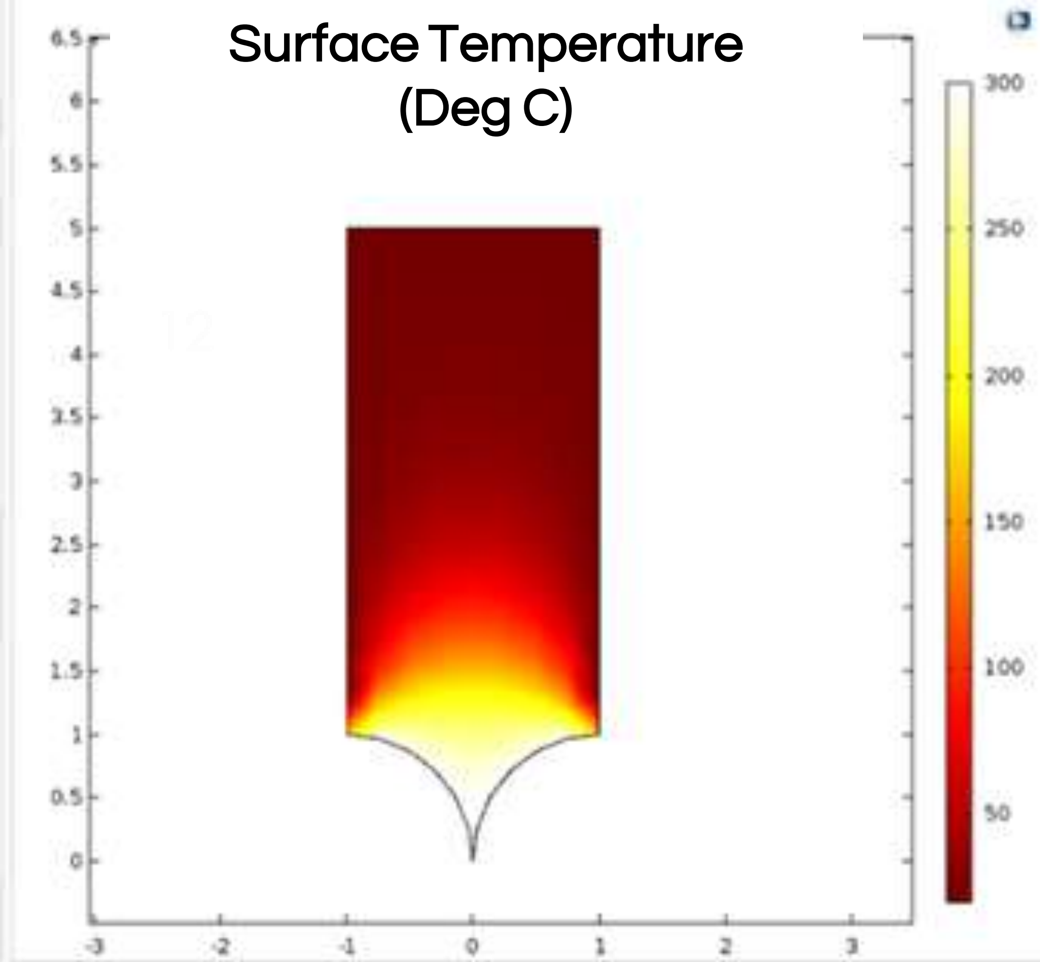


Figure 6. FEA for Heat Transfer

Presenting:
Matt N.

Previous Design Concepts

- Laser Triangulation
- High Resolution Photography
- Long Distance Microscopes

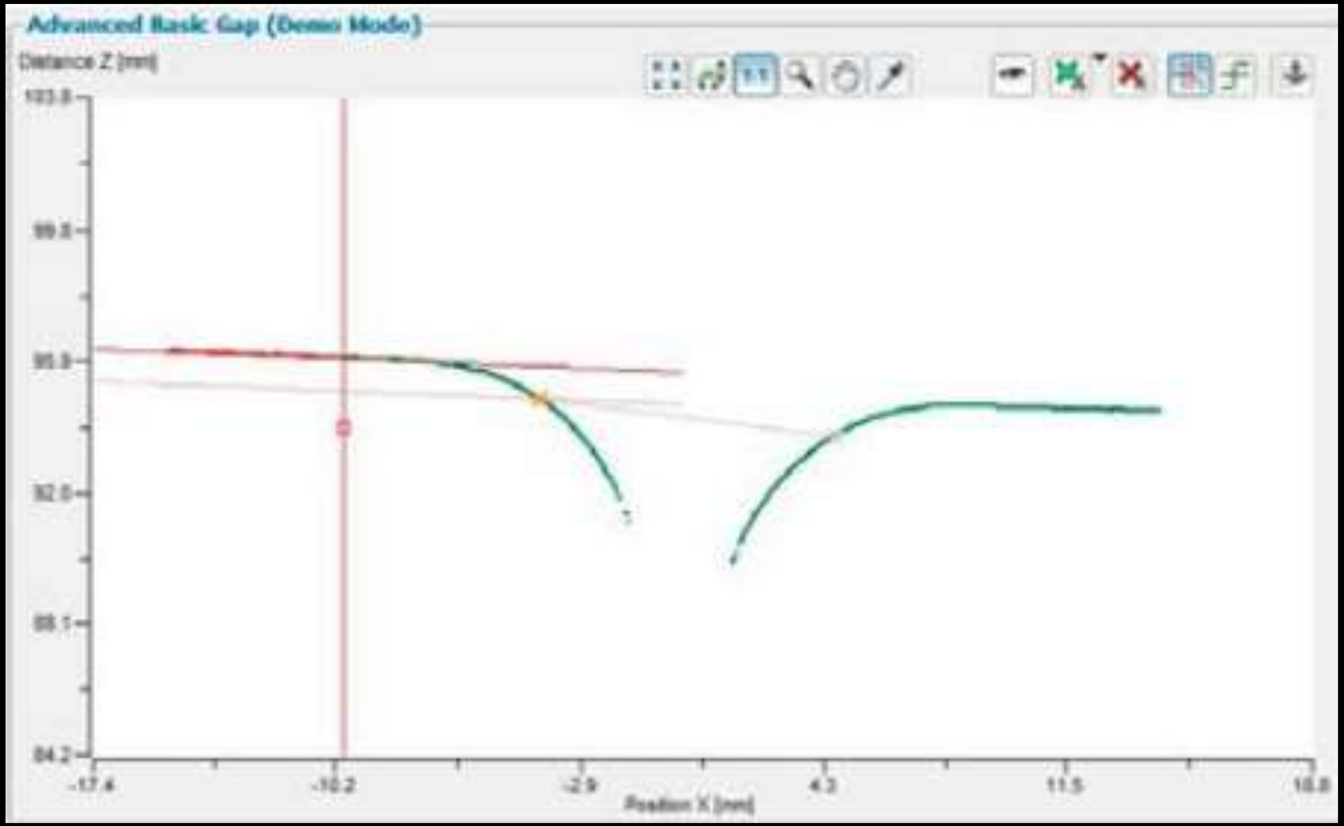


Figure 7. Laser triangulation Data

Presenting:
Matt N.

CAPACITANCE SENSOR

- Keyence EX-422V capacitance displacement sensor
- Resolution of 2 μm
- Working distance of 0-10 mm.
- 20 displays per second
- Cost : $342 per sensor

Figure 8. Sensor Head

Figure 9. Keyence Controller

Presenting:
Forrest P.

CAPACITANCE SENSOR

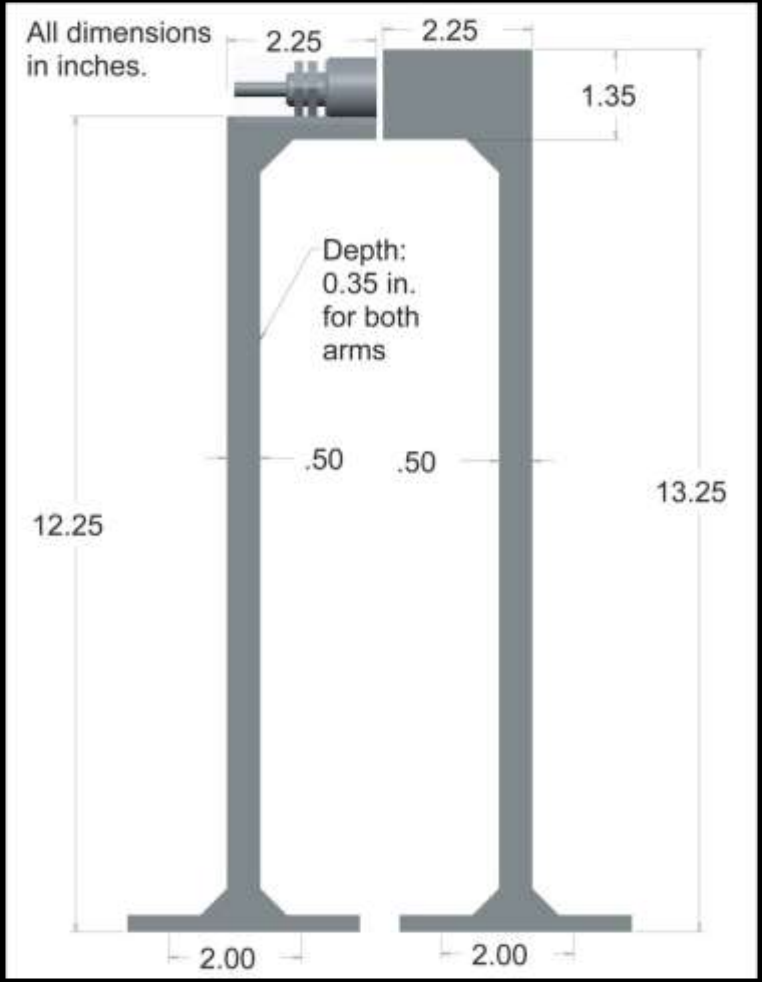


Figure 10. Roller Frame Arm Mount Design

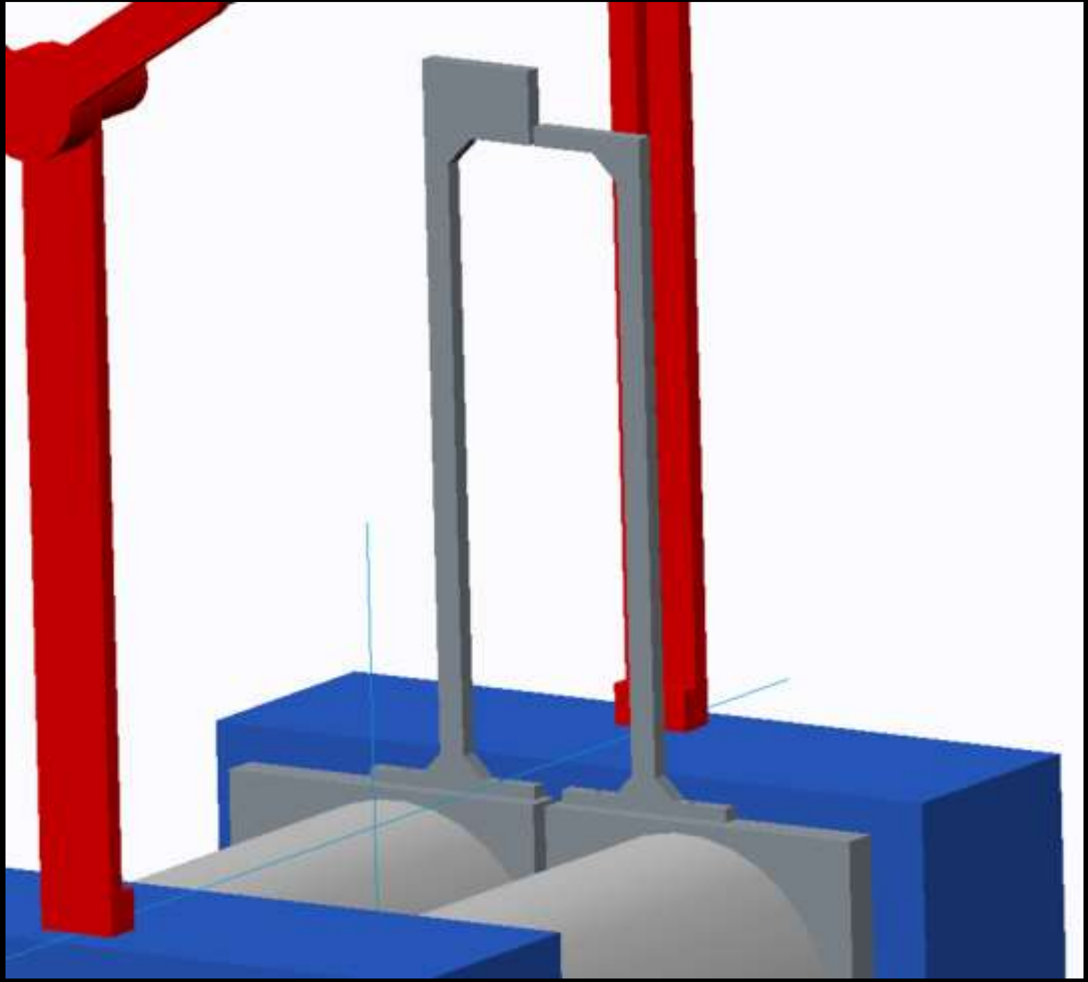
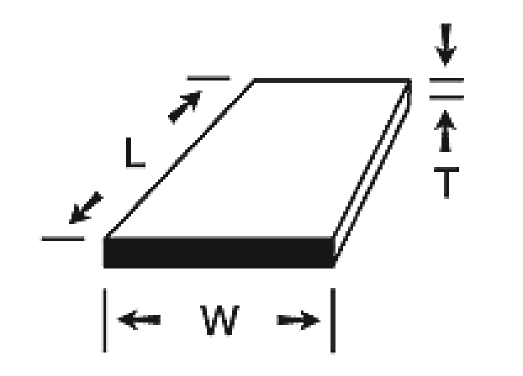


Figure 11. Arms Shown Mounted to Blocks

Presenting:
Forrest P.

MOUNTING ARMS

- Aluminum 6061
- Two solid plates of aluminum to be machined
- $44.20 per plate



Dimension Name	Value
Thickness	0.75 inches
Width	14.1 inches
Length	5.50 inches

Figure 12. Aluminum Plate Sizing Data

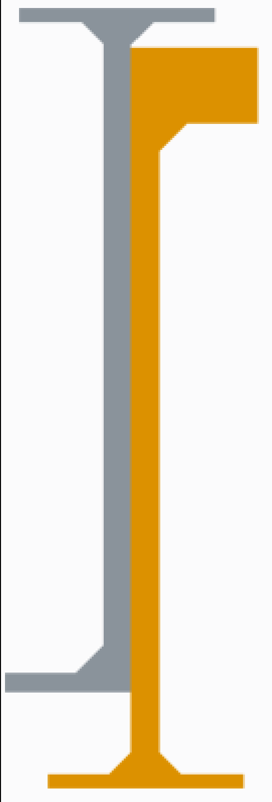


Figure 13. Shop Drawing Layout

Presenting: Forrest P.

SENSOR MOUNTING CONDITIONS

- Mounting metal or mounting fasteners must not be in the metal-free zone
- For cylindrical, unshielded sensors the typical metal-free zone extends to an area of two times the sensing range of the device

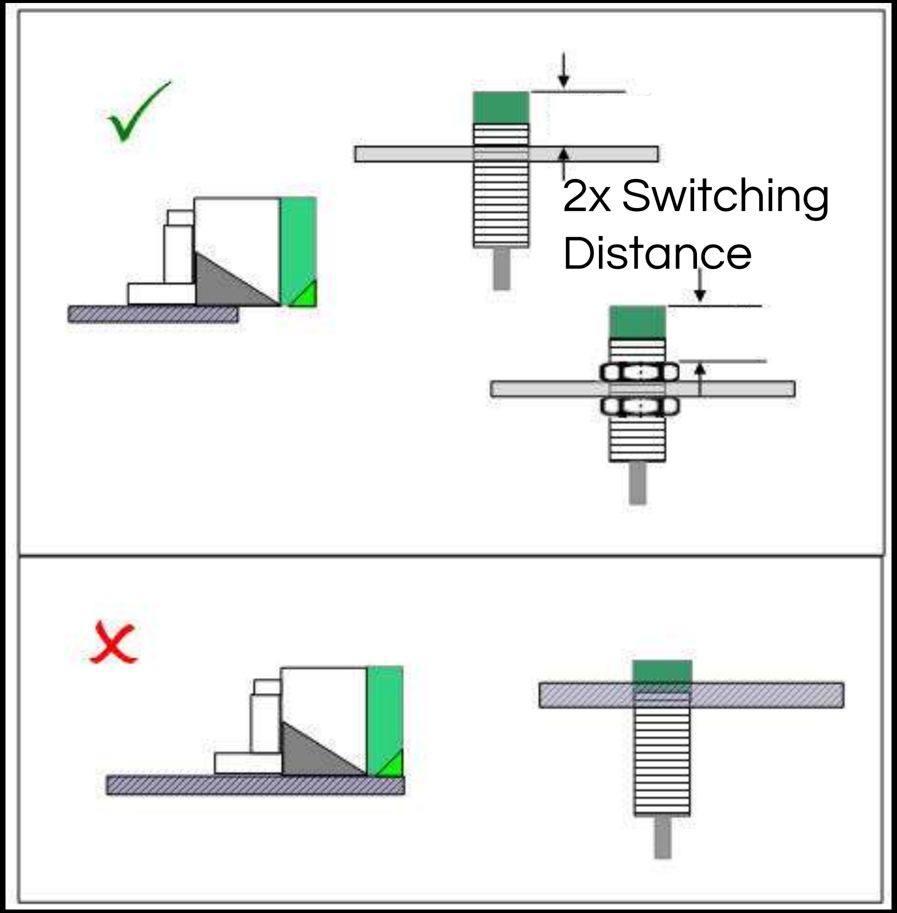


Figure 14. Schematic on Proper Sensor Mounting

Presenting:
Forrest P.

LCR Meter

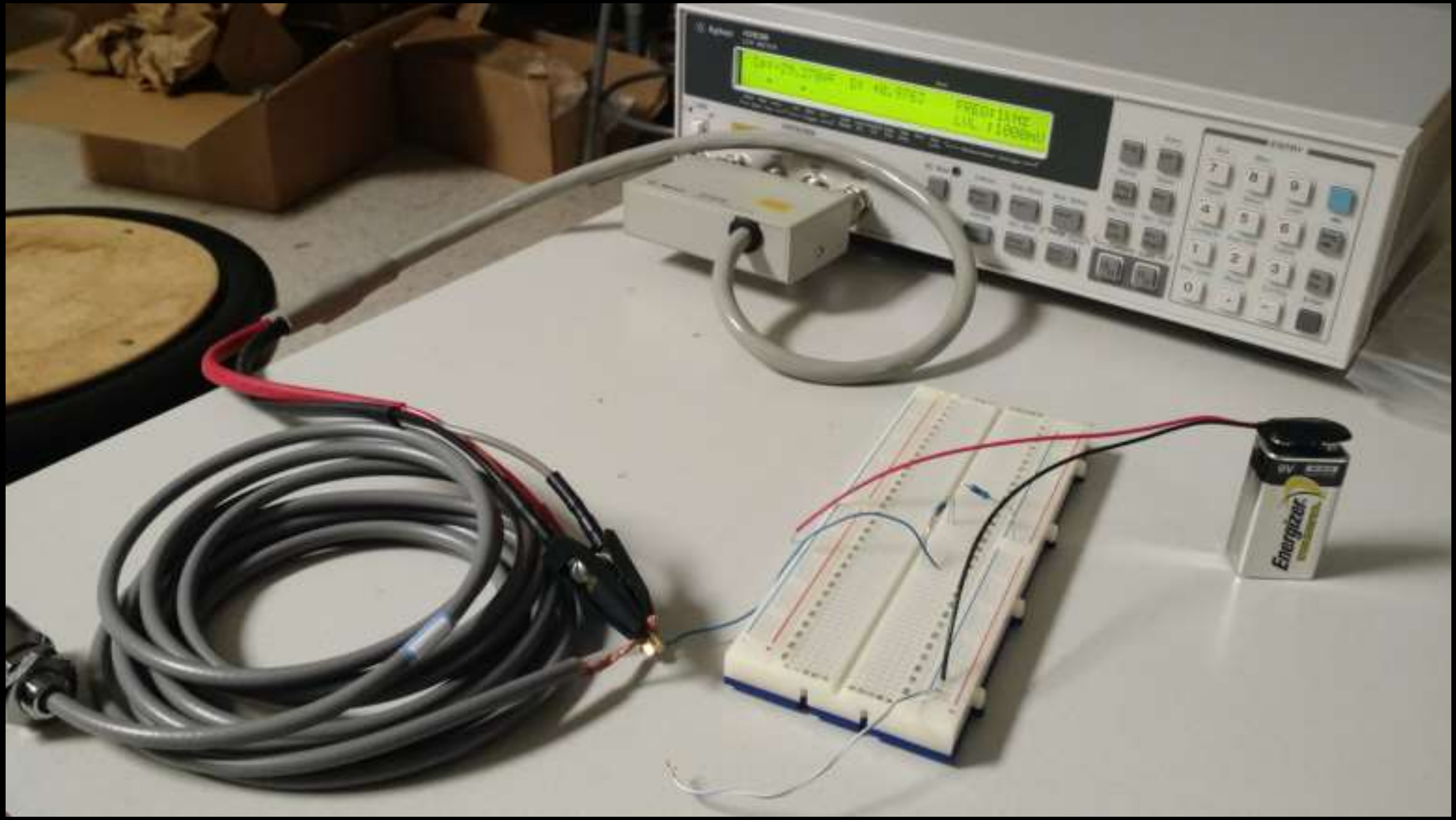


Figure 15. LCR Meter reading inductance change.

Design Concept – Strain Gauge

- Strain Gauges mounted to a cantilever beam that will be displaced proportional to the roller blocks
- Variance in resistance results in a varying voltage, which can be used to determine displacement

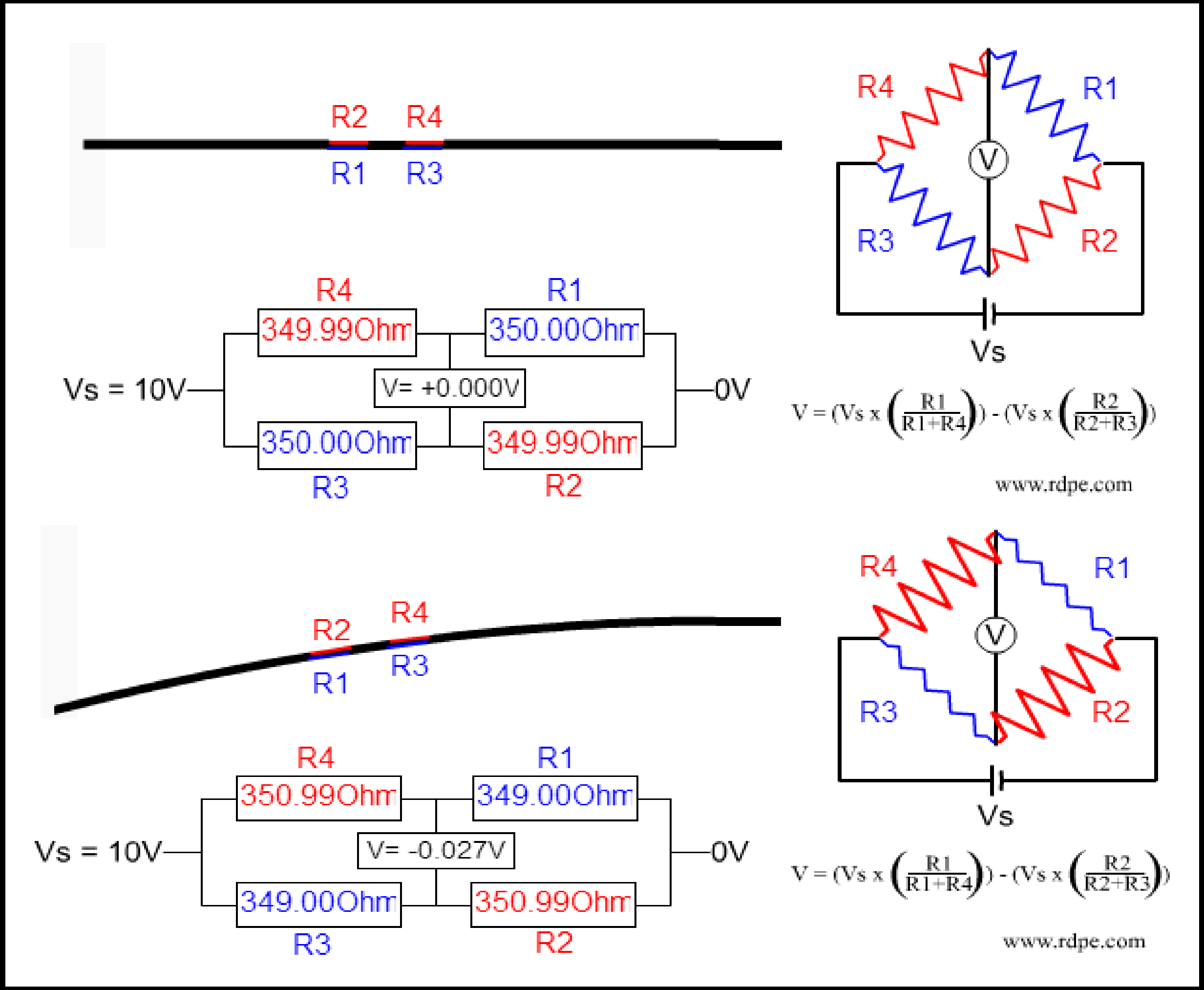


Figure 16. Strain Gauge Wheatstone Bridge.

Presenting:
Forrest P.

Design Concept – Strain Gauge

- Cantilever Design Calculations
- Directly related to thickness, inversely related to length
- Not a function of Modulus of Elasticity
- Suggested $\frac{L}{t} > 10$

Point Force on Beam Fixed on One Side

$$\delta_B = \frac{Fa^3}{3EI}$$ δ_B = Deflection of Beam

$$\epsilon = \frac{6M}{bt^2E}$$ ϵ = Bending Strain

M = Moment (M = Fd) F = Force

E = Modulus of Elasticity I = Moment of Inertia ($I = \frac{bt^3}{12}$)

Figure 17. Equations used in Cantilever Design.

Presenting:
Forrest P.

Design Concept – Strain Gauge

- Half-bridge strain gauge circuits will be used in testing, full-bridge used in application
- Heat affects cancel if properly mounted to beam and placed in circuit
- Signal Conditioning and amplification will be necessary to read signal output
- Amplifies 1.5mV/V

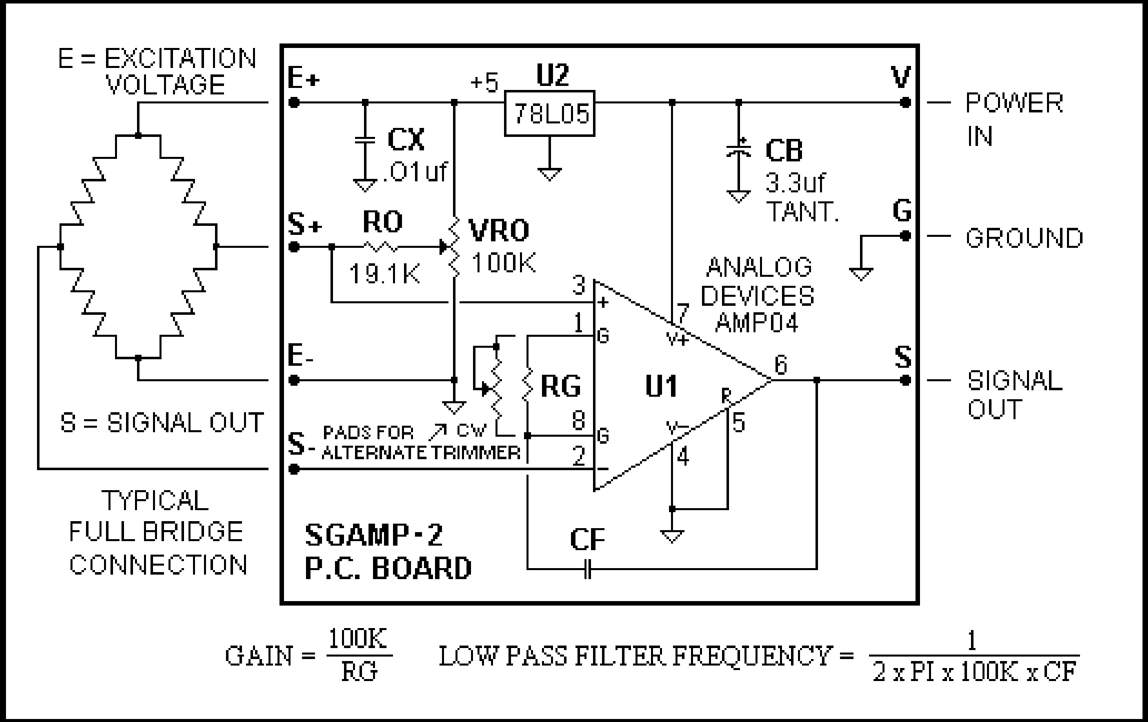


Figure 18. Signal Conditioning and Amplification Circuit.

Presenting:
Forrest P.

MICROCONTROLLER

Arduino UNO R3

- 14 digital input/output pins
- 16 MHz crystal oscillator

Inputs:

- Roller temp through keypad
- Capacitance sensor, strain gauge

Outputs:

- Left and right gap measurements
- Calculated center gap

Presenting:
Forrest P.

Figure 19. Arduino UNO

Figure 20. LCD for Printed Outputs

STRAIN GAUGE ARM DESIGN 1

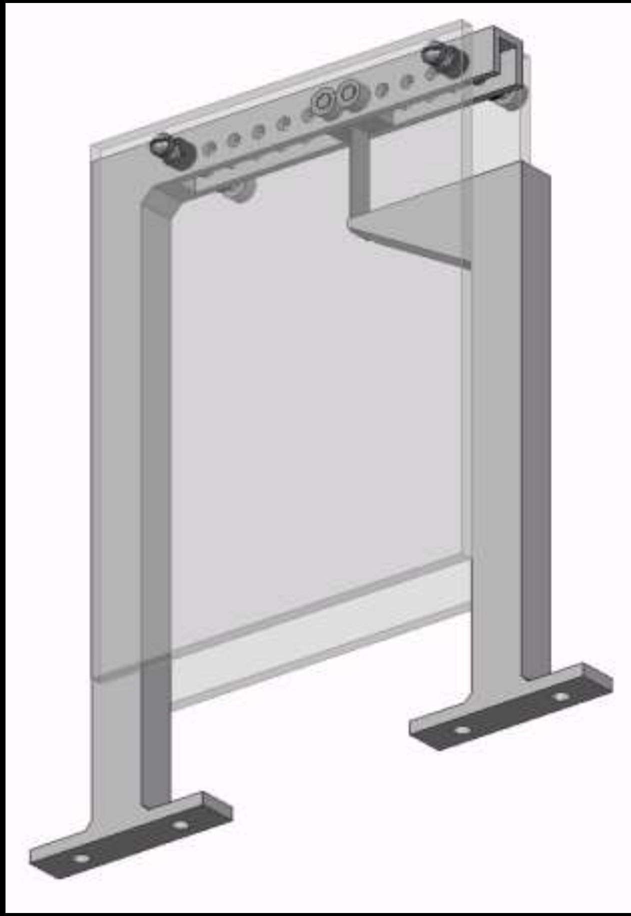


Figure 21. 3D view of the Plexiglas shielding.

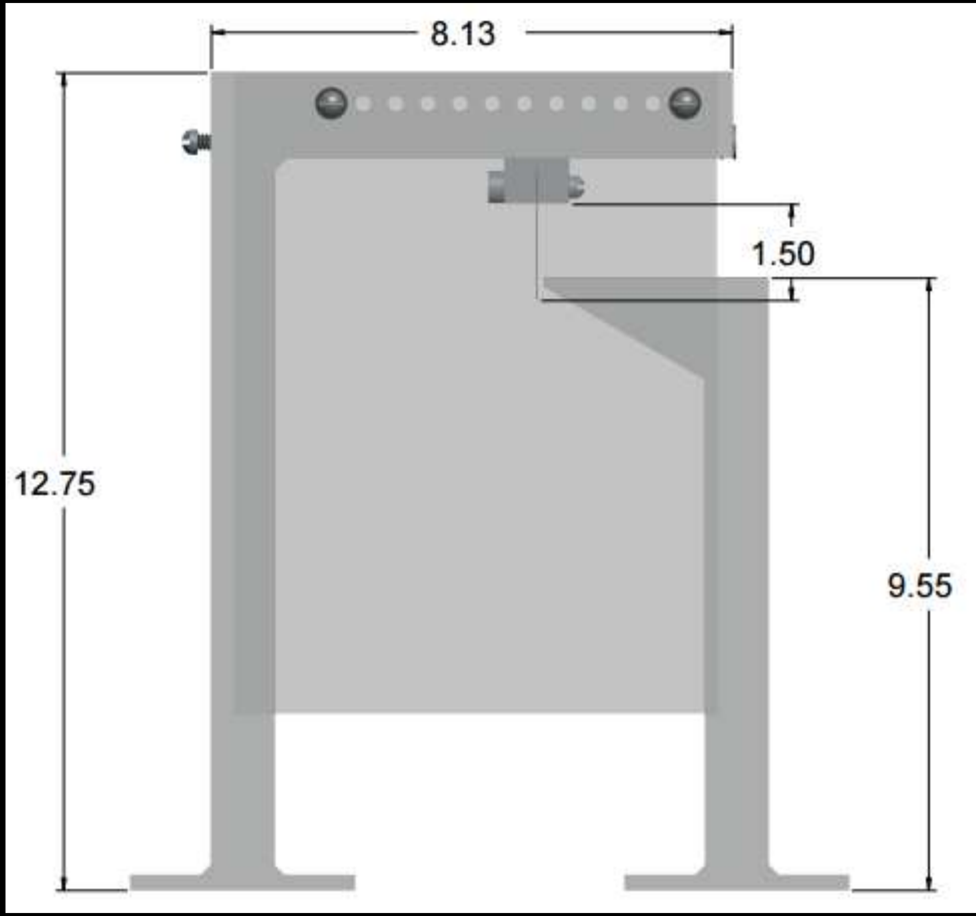


Figure 22. 2D view with dimensions.

Presenting:
Sam G.

STRAIN GAUGE ARM DESIGN 2

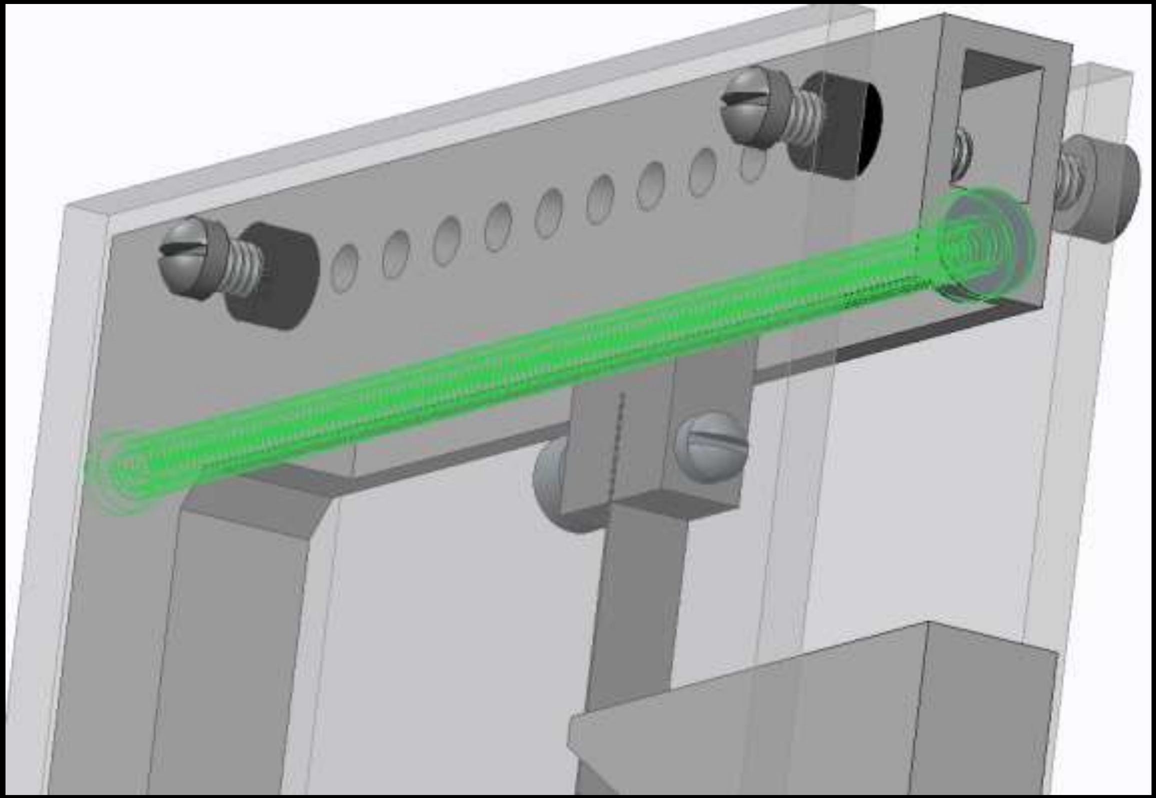


Figure 23. Screw is restricted from moving laterally, mounted block restricted from rotating.

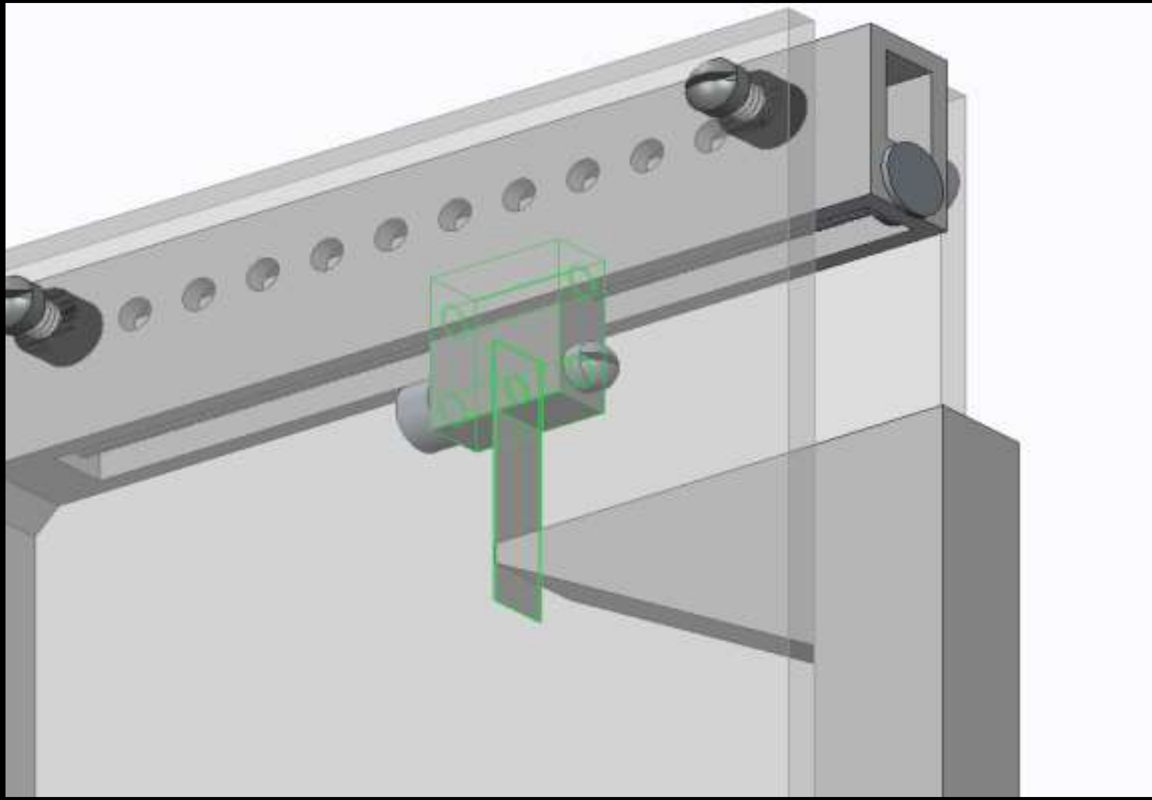
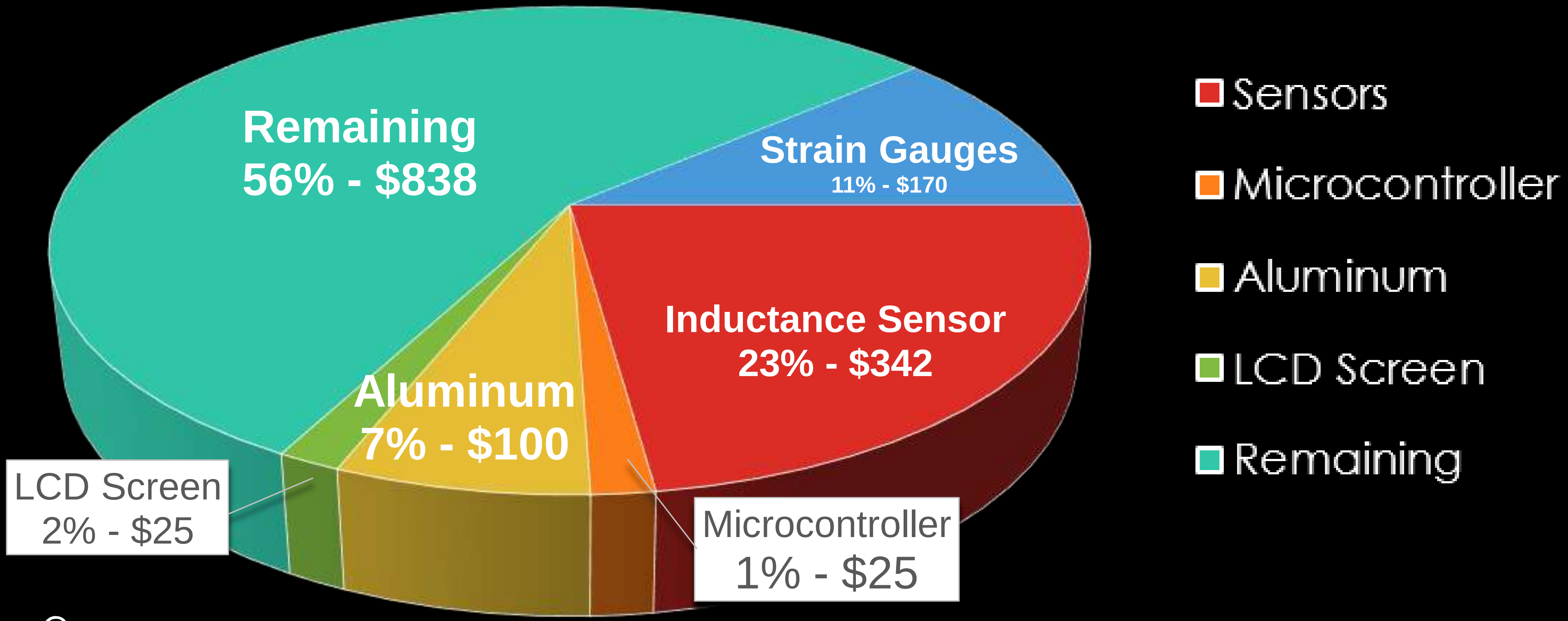


Figure 24. Mounted block pinches cantilever into place.

Sam G.

Budget Analysis

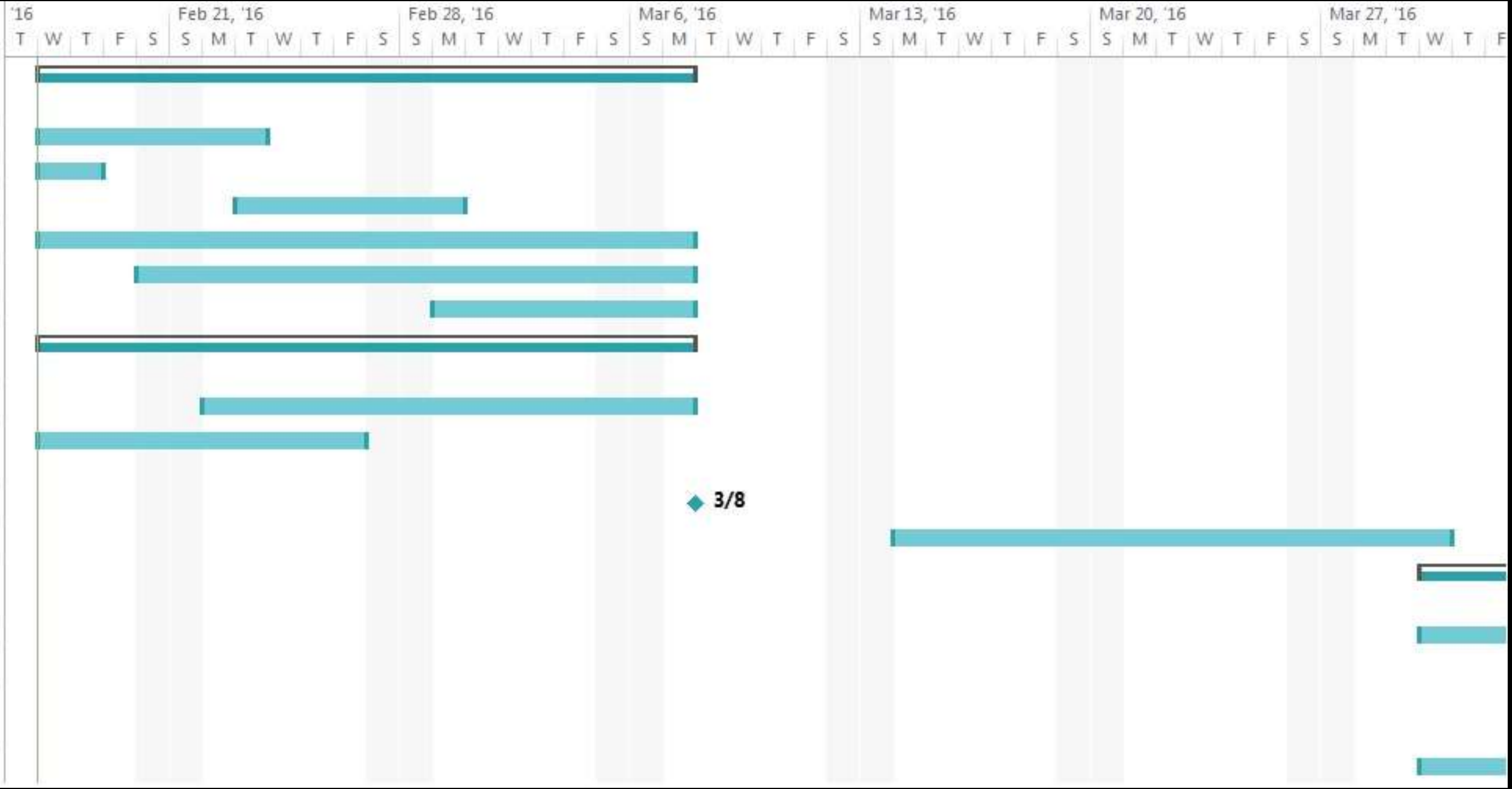
ALLOCATED BUDGET = $1,500



Sam G.

GANTT CHART 1/2

	Task Name	Duration
1	**Finalize Design (Strain)**	**14 days**
2	Signal Conditioning	5 days
3	Stain Gauges	2 days
4	Heat Anaylsis	5 days
5	Pro-E Model	14 days
6	Mounting Parameters	12 days
7	Testing Strain Gauges	6 days
8	**Inductive Sensor**	**14 days**
9	Testing Inductance	11 days
10	Signal Conditioning (Inductance)	8 days
11	**Choose Final Design**	**0 days**
12	**Order Purchases**	**13 days**
13	**Installation and Calibration**	**20 days**
14	Coding	5 days
15	Installation	5 days
16	Uninstall and Recalibration	2 days
17	Data Collection	20 days

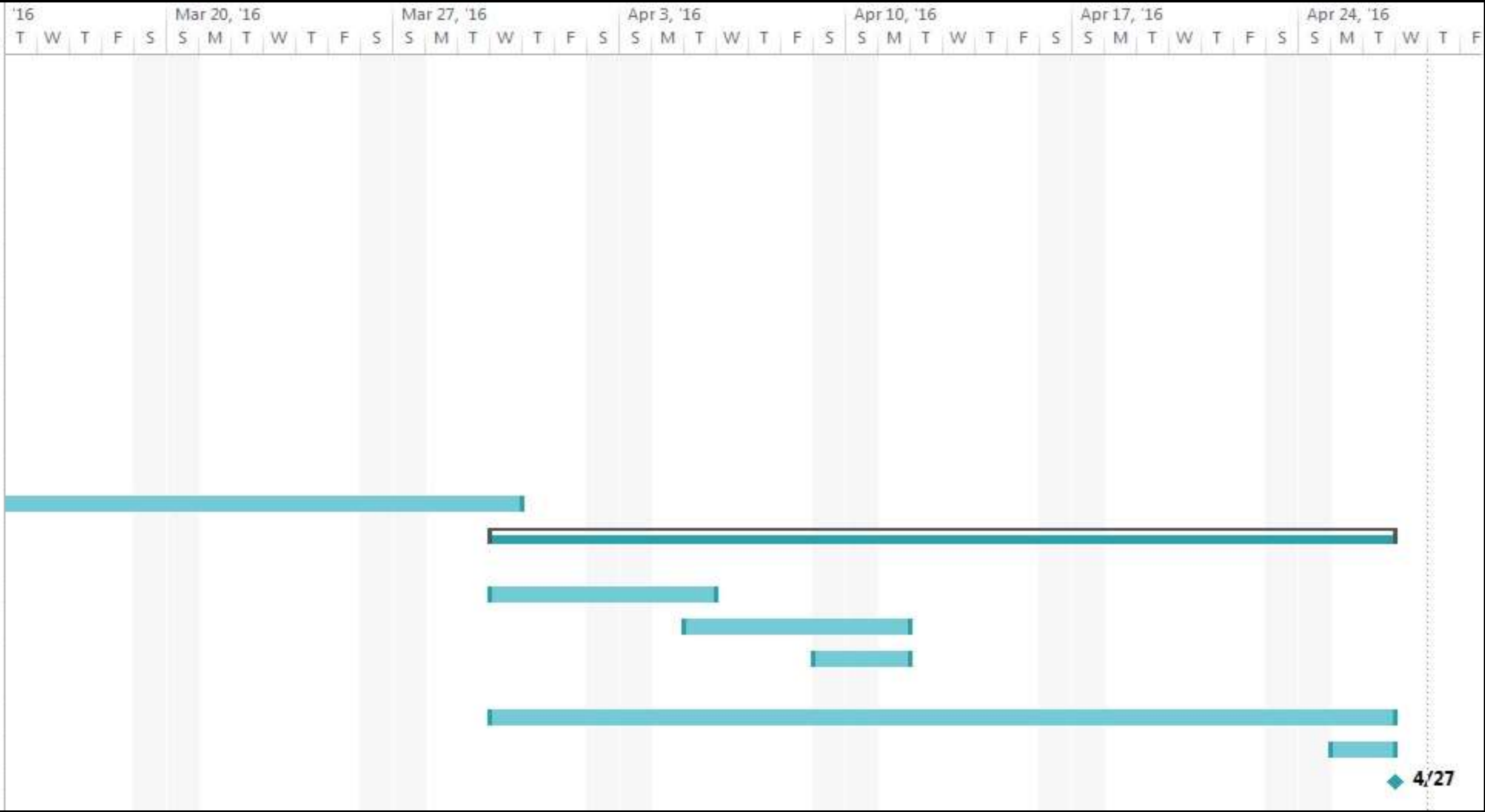


Presenting:
Sam G.

Figure 25. Gantt Chart

GANTT CHART 2/2

	Task Name	Duration
1	**Finalize Design (Strain)**	**14 days**
2	Signal Conditioning	5 days
3	Stain Gauges	2 days
4	Heat Anaylsis	5 days
5	Pro-E Model	14 days
6	Mounting Parameters	12 days
7	Testing Strain Gauges	6 days
8	**Inductive Sensor**	**14 days**
9	Testing Inductance	11 days
10	Signal Conditioning (Inductance)	8 days
11	**Choose Final Design**	**0 days**
12	**Order Purchases**	**13 days**
13	**Installation and Calibration**	**20 days**
14	Coding	5 days
15	Installation	5 days
16	Uninstall and Recalibration	2 days
17	Data Collection	20 days
18	Final Reinstallation	2 days
19	**Design Completed**	**0 days**



Presenting:
Sam G.

Figure 26. Gantt Chart

Future Plans

- Research and experimentation with the Keyence sensor
  - Signal conditioning
  - LCR Meter
- Acquire strain gauge adhesive
- Purchase signal conditioning chip for strain gauge
- Decide on final design after experimentation
- FEM to determine heat transfer through the arms for the final design
  - Insulation Material Selection

Presenting:
Sam G.

SUMMARY

- Identified the need for the no-contact gap measurement for rolling machine.
- Address the objectives and constraints of the project.
- Set up a House of Quality to determine important engineering characteristics.
- Prototyping and experimenting with 2 final designs.
- Set up a Gantt chart outlining future project plans.

Presenting:
Sam G.

REFERENCES

- http://www.micro-epsilon.com/download/products/dat--gapCONTROL--en-us.pdf
- http://wiki.raspberrytorte.com/index.php?title=File:CloseUpCameraModuleRev1_3.jpg
- http://www.directindustry.com/prod/third-dimension/product-16646-217545.html
- http://www.industrologic.com/sga2man.htm
- http://www.rdpe.com/ex/hiw-sglc.htm
- http://www.ni.com/white-paper/3642/en/