TECH ELECTIVE FAIR

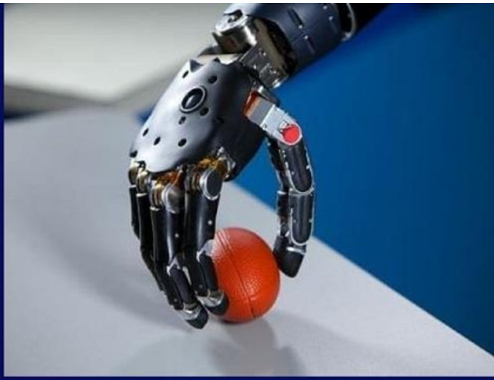
SNACKS PROVIDED!

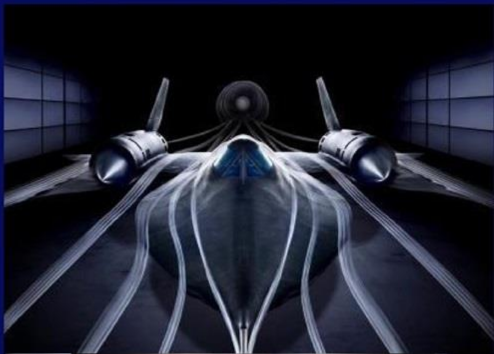
Come chat with professors about your MechE class options!

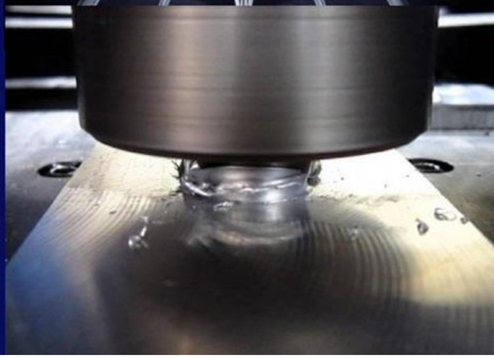
APRIL 3RD

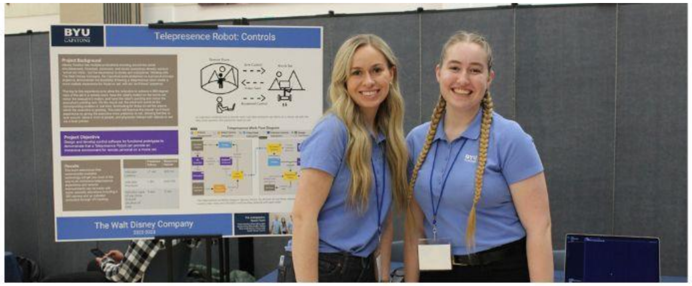
4:00-5:30 pm

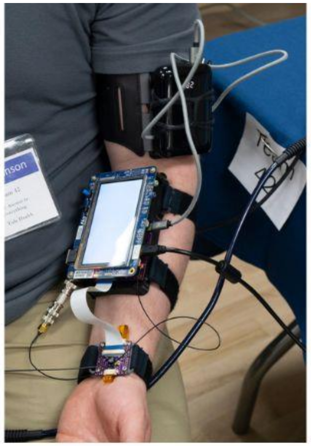
EB Club Commons





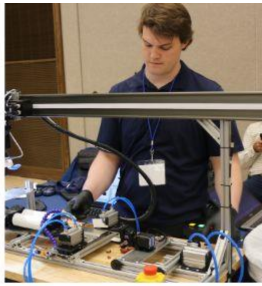






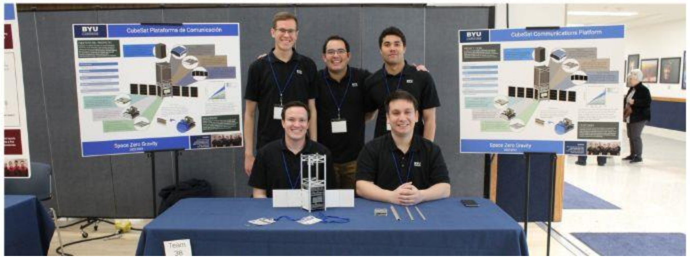
Stop by and check out over 50 unique student projects!

Free treats while you explore the projects



CAPSTONE DESIGN FAIR

THURSDAY, APRIL 4
WSC BALLROOM
11AM - 1 PM



Devotional: Flashes of Light

Described an experience driving over a bridge at dawn while on a business trip in Asia. While crossing the bridge, he couldn’t see the surrounding scenery due to concrete walls on both sides of the bridge. When he arrived at the other side, he was surprised to look back and recognize boats, buildings, and everything else in the harbor, even though he hadn’t consciously seen it. He realized there were sub-inch wide gaps in the wall. Somehow, he had “seen” the scenery through the blur of gray concrete. Somehow in his mind, he had stitched together the flashes of light that came through the slits in the concrete.

“I knew more than I knew I knew. As we drive through life’s journey, we’ll see flashes of light.”

CS Lewis, as a professor was an atheist. “One day his brother gave him a ride to a zoo. He said “I was driven to Whipsnade one sunny morning. When we set out I did not believe that Jesus Christ is the Son of God, when we reached the zoo, I did.”

Elder Steven J. Lund, Sep 20, 2022 Devotional

22 – Advanced Stage Uncertainty

Announcements

- 3rd Milestone due March 29 (Design Stage Uncertainty Analysis)
- 4th Milestone due April 2 (Project Presentation)
  - Student grades for each presentation due April 4
- 5th Milestone due April 9 (Project Report Draft due)
- Peer Review of Draft Project Report (in class) April 11
- Project Final Report due April 17
- In LS, go to Drive Access in the Content folder, then click on Final Project

Presentation Schedule

	Section	Member #1	Member #2	Member #3	2-Apr	4-Apr
Group1.1	1	Denver Toner	Jacob Boyer	Christian Devey	X	
Group1.2	1	Brian Stewart	Caleb Becker	Chase Christopherson	X	
Group1.3	1	Davis Wing	Natalie Jones	Matt Bozer	X	
Group2.1	2	Lexie Rhodes	Rachel Day	Bentley Cook	X	
Group2.2	2			Erik Villa	X	
Group2.3	2	Kirsten Steele	Ashley Quinn	Kaj Call	X	
Group2.4	2	Chase Williams	Noa Leituala	Hans Klomp	X	
Group3.1	3	Seth Nelson	Simon Calabuig	Jake Limburg		X
Group3.2	3	Ayden Bennett	Spencer Peterson	Callan Bradford		X
Group3.3	3	Corinne Jackson	Spencer Shirley	Jackson Jones		X
Group4.1	4	Parker Breit	Mark Griffitts	Connor Crandall		X
Group4.2	4	Michelle Arias	Rylee McLaughlin			X
Group2.X	2	Jacob Cox	Vincent Carter			X

Presentation Grade Sheet

NAME:

from 1 to 10 from 1 to 10

	Date	Order	Team Members			Slide Quality	Presentation Quality
0	4/2 and 4/4 2024	1					
0		2					
0		3					
0		4					
0		5					
0		6					
0		7					
0		8					
0		9					
0		10					
0		11					
0		12					
0		13					
0		14					
0		15					
0		16					

https://docs.google.com/spreadsheets/d/1g9_LBir5QW5tF9nTUx66_AEpSB0vbg9X/edit?usp=drive_link&ouid=109260467525861689247&rtpof=true&sd=true

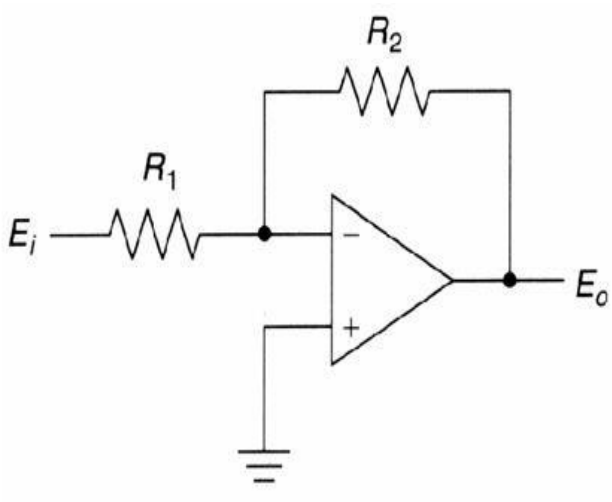
Part of your grade for the presentation will consist of how rigorously you graded your peers.

Final Project Presentation Rubric

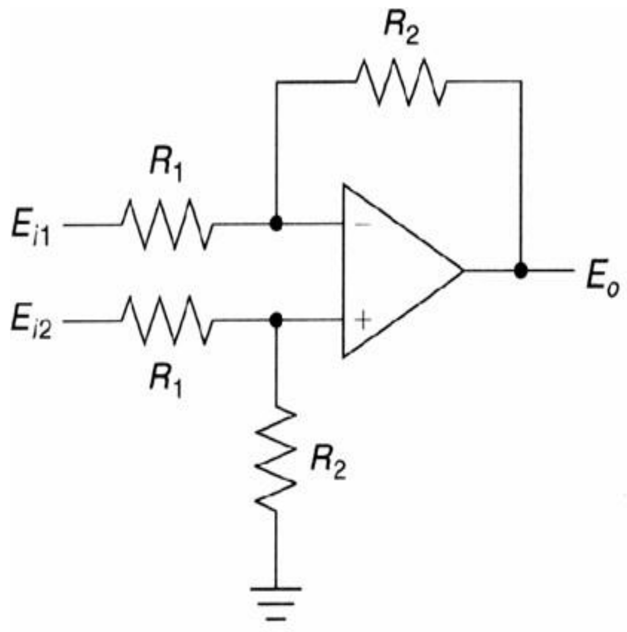
	Criteria	Unsatisfactory (0-5)	Partially Proficient (6 - 7)	Proficient 8-9)	Exemplary (10)
Slide Quality	***Content and Organization***	Choppy, confusing and format was difficult to follow. Transistions of ideas were abrupt and seriously distracted the audience. Includes little essential information.	Somewhat organized. Ideas were not presented coherently. Includes some essential information but not enough.	Presented in a thoughtful manner with good organization. Most transitions easy to follow, but at times ideas were unclear. Includes all essential information.	Extremely well organized. Logical format that was easy to follow. Flowed smoothly from one idea to another. Showed deep understanding of the methods and the resulting data.
	Technical Integrity	Data and methods didn't make sense. Data didn't match conclusions.	Some data made sense and matched the data gathering method. Some did not. Conclusions had some correlation with data, but serious gaps remained unexplained.	Data and conclusions made sense and all questions were adequately resolved.	Conclusions were not only correct but demonstrated deep understanding of how correlated with the data set. Audience learned something new that was not obvious from an initial assessment of the data.
	Criteria	**Unsatisfactory (0-5)**	**Partially Proficient (6 - 7)**	**Proficient 8-9)**	**Exemplary (10)**
Presentation Quality	***Technical Quality***	Presentation not well planned. Presentation significantly longer or shorter than time allotment. One or more team member significantly dominated the time and/or content.	Presentation was somewhat planned and practiced. Transitions are rudimentary. Presentation slightly longer or shorter than time allotment. One or more team members dominated somewhat the time and/or content.	Presentation was well planned. Fit well in the time allotment. Each team member presented about the same amount of time and content.	Presentation was well planned and the time was well spent. The presentation fit well within the allotted time and each presenter equally shared presentation time and content.
	Overall Presentation	Presentation is unclear and/or confusing.	Audience mostly understands the experiment and conclusions, but still left with some unresolved issues or questions with the data.	Audience is left with a good overall understanding of the experiment and conclusions. No unresolved questions or issues remain with the data.	Audience is left with a strong understanding of the topic and feels like they learned something unique and important. All questions and data issues completely resolved.

Equations Sheet for Final Exam

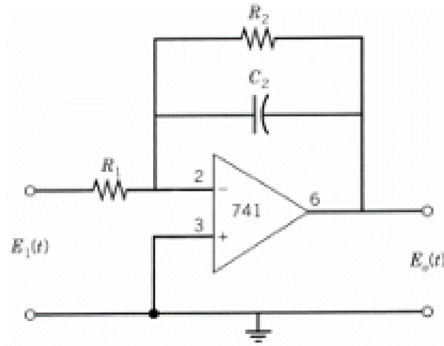
https://drive.google.com/file/d/1ThXOuNyjQwwlUv0a88xCEwhWiSb0me9/view?usp=drive_link



$$E_o = -E_i[R_2/R_1]$$

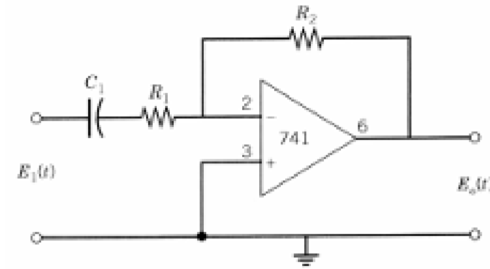


$$E_o = (E_{i2} - E_{i1})[R_2/R_1]$$



$$K = \frac{-R_2}{R_1} \qquad M(f) = \frac{1}{\sqrt{1+(f/f_c)^2}}$$

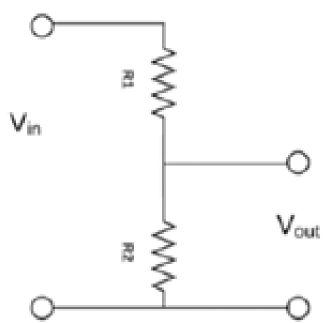
$$f_c = \frac{1}{2\pi R_2 C_2}$$



$$K = \frac{-R_2}{R_1}$$

$$M(f) = \frac{1}{\sqrt{1+(f_c/f)^2}}$$

$$f_c = \frac{1}{2\pi R_1 C_1}$$

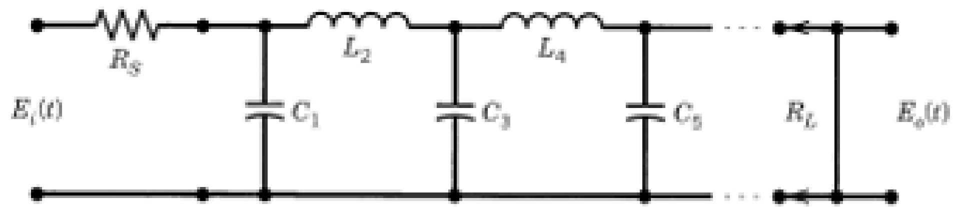


$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}^{+} + \frac{R_1}{R_1 + R_2} V_{in}^{-}$$

Table 4.4 Student-*t* Distribution

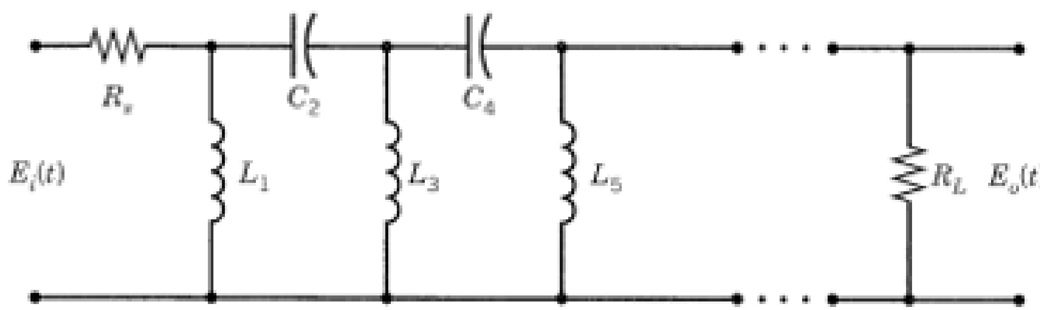
ν	t_{50}	t_{90}	t_{95}	t_{99}
1	1.000	6.314	12.706	63.657
2	0.816	2.920	4.303	9.925
3	0.765	2.353	3.182	5.841
4	0.741	2.132	2.770	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.499
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
11	0.697	1.796	2.201	3.106
12	0.695	1.782	2.179	3.055
13	0.694	1.771	2.160	3.012
14	0.692	1.761	2.145	2.977
15	0.691	1.753	2.131	2.947
16	0.690	1.746	2.120	2.921
17	0.689	1.740	2.110	2.898
18	0.688	1.734	2.101	2.878
19	0.688	1.729	2.093	2.861
20	0.687	1.725	2.086	2.845
21	0.686	1.721	2.080	2.831
30	0.683	1.697	2.042	2.750
40	0.681	1.684	2.021	2.704
50	0.680	1.679	2.010	2.679
60	0.679	1.671	2.000	2.660
∞	0.674	1.645	1.960	2.576

kth-order low-pass filter



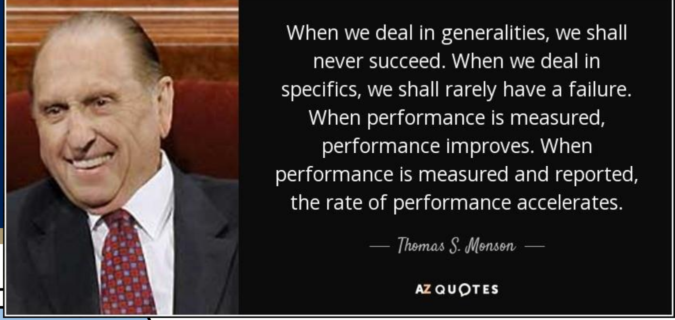
$$M(f) = \frac{1}{\sqrt{1 + (f / f_c)^{2k}}}$$

kth-order high-pass filter



$$M(f) = \frac{1}{\sqrt{1 + (f_c / f)^{2k}}}$$

Big Picture View



PART I

Generic Measurement System

Sensing/ Transduction → Signal Conditioning → Output/ Storage

PART II

Spectral Analysis

- Frequency Analysis
- FFT
- Aliasing

Measurement System Response Types

- Zero-Order
- First-Order
- Second-Order

PART III

Uncertainty Analysis

- Statistical Tools
- Sensitivity Analysis
- Advanced Stage Uncertainty

Final Exam

Labs

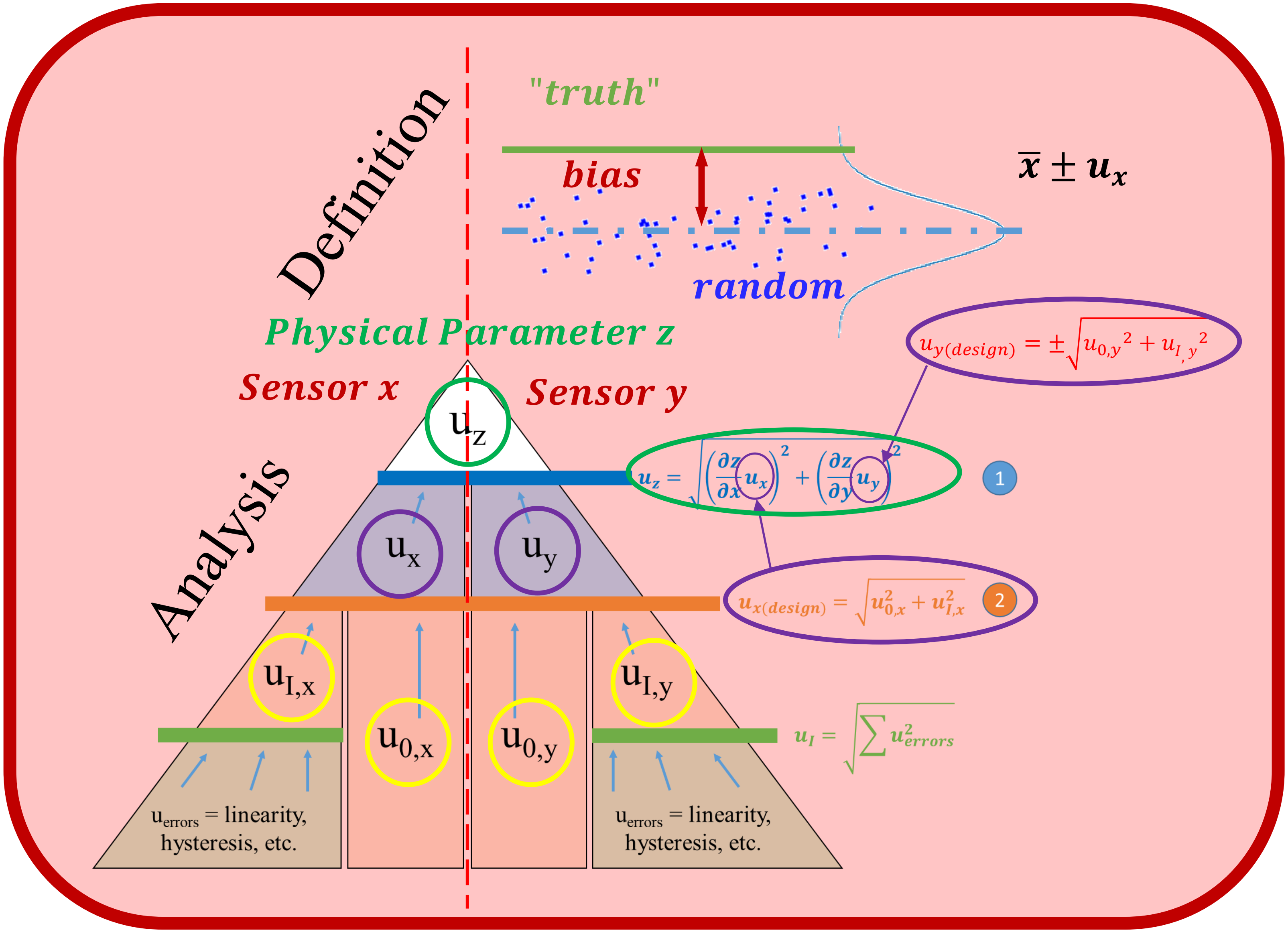
1. Thermocouple
2. Strain Gage
3. Pressure/Temp
4. Accel Integration
5. Density Uncertainty
6. Frequency Analysis
7. 3D Imaging

Memo report
Memo report revise

Project

Final Project/Report

Uncertainty Overview



Advanced Stage

- After you take measurements
  - Include noise, u_{noise}
- Let's consider doing our own calibration
  - Find instrument uncertainty, u_I, from a curve fit

$$u_R = \pm\sqrt{(u_I)^2 + (u_0)^2 + \cdots + (u_{noise})^2}$$

Advanced Stage

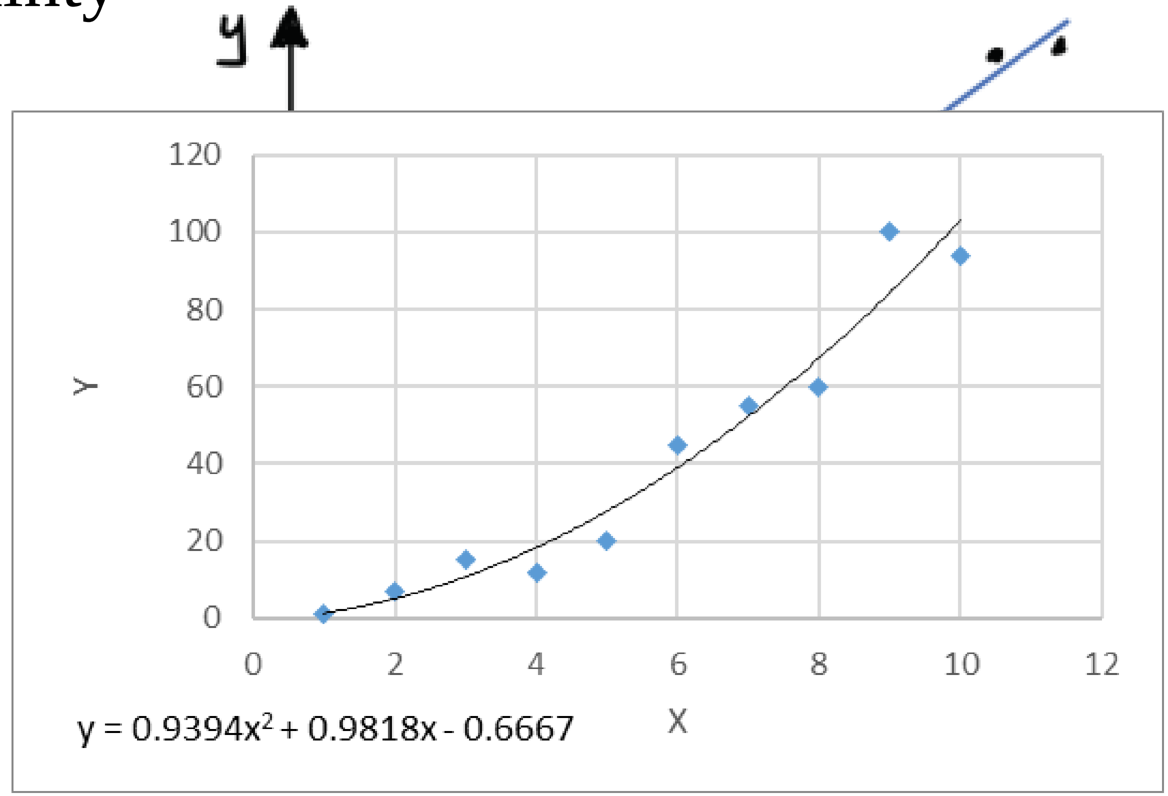
- Instrument uncertainty

$$u_I = \pm t_{95,\nu} s_{yx}$$

$$s_{yx} = \sqrt{\frac{1}{\nu}\sum_{i=1}^{N}(y_i - y_{ci})^2}$$

$$\nu = N - (m + 1)$$

order of the fit



This is another way to estimate Instrument uncertainty, improve accuracy (calibrate), in the relevant measurement range!

Advanced Stage

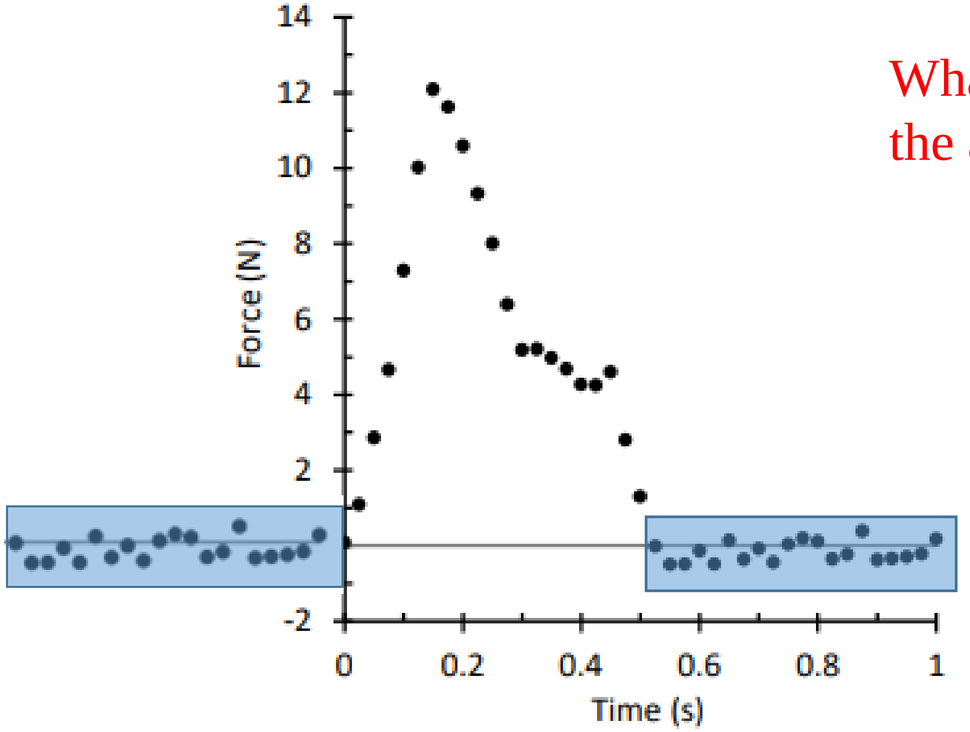


Fig. 3: Measured force vs. time data for the model rocket engine.

What does the data before and after the actual test represent?

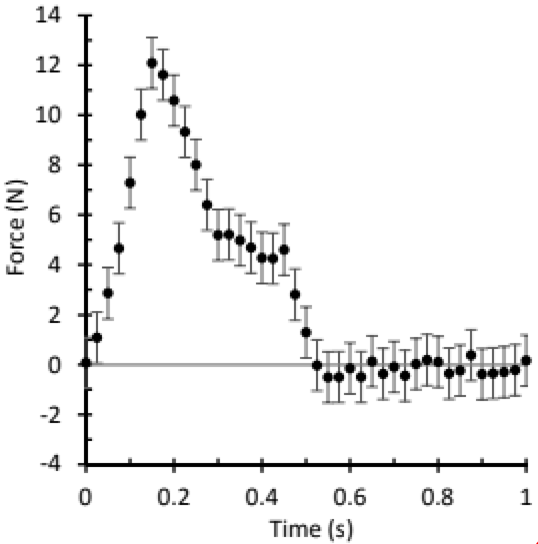


Fig. 7: Force vs. time data with error bars denoting $\pm u_F$.

Advanced Stage

$$s_x$$

- Uses $\bar{x}$ to calculate s_x from data
  - thus ν = N-1

$$s_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

$$s_{yx}$$

- Regression, use data once to calculate average
- Use average to minimize error of regression **line**
  - Since $\nu = N - (m+1)$
  - ν = N-2

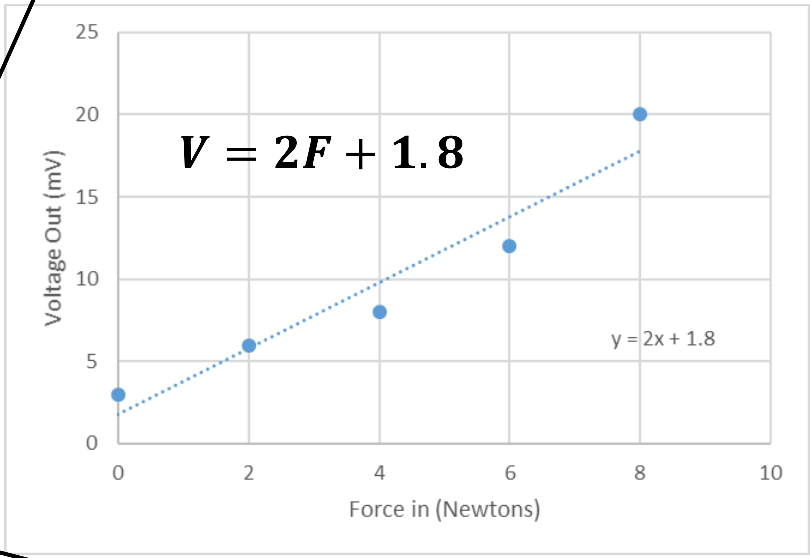
$$s_{yx} = \sqrt{\frac{1}{\nu}\sum_{i=1}^{N}(y_i - y_{ci})^2}$$

Example #1

- Have cantilever beam with strain gages. We add weight to the end of the bar and measure voltage out, using a digital system with a resolution of 1 mV.

Force (N)	Voltage (mV)
0	3
2	6
4	8
6	12
8	20

Force (N)	Voltage (mV)
0	1
0	3
0	0
0	2
0	1



$$u_V = \pm\sqrt{(u_I)^2 + (u_0)^2 + \cdots + (u_{noise})^2}$$

- Find u_V

$$u_{Noise} = \pm t_{95,\nu} s_x$$

$$u_I = \pm t_{95,\nu} s_{yx} \qquad s_{yx} = \sqrt{\frac{1}{\nu}\sum_{i=1}^{N}(y_i - y_{ci})^2}$$

$$u_o = \pm\,(resolution)$$

$$s_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Example #1

Table 4.4 Student's t Distribution

ν	t_{50}	t_{90}	t_{95}	t_{99}
1	1.000	6.314	12.706	63.657
2	0.816	2.920	4.303	9.925
3	0.765	2.353	3.182	5.841
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9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
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18	0.688	1.734	2.101	2.878
19	0.688	1.729	2.093	2.861
20	0.687	1.725	2.086	2.845
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50	0.680	1.679	2.010	2.679
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∞	0.674	1.645	1.960	2.576

Force (N)	Voltage (mV)
0	3
2	6
4	8
6	12
8	20

Force (N)	Voltage (mV)
0	1
0	3
0	0
0	2
0	1

$\boldsymbol{V = 2F + 1.8}$ Resolution = 1 mV

$$u_I = \pm t_{95,\nu} s_{yx}$$

$$s_{yx} = \sqrt{\frac{1}{\nu}\sum_{i=1}^{N}(y_i - y_{ci})^2}$$

$$u_{Noise} = \pm t_{95,\nu} s_x$$

$$s_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Example #1

$$u_V = \pm\sqrt{(u_I)^2 + (u_0)^2 + \cdots + (u_{noise})^2}$$

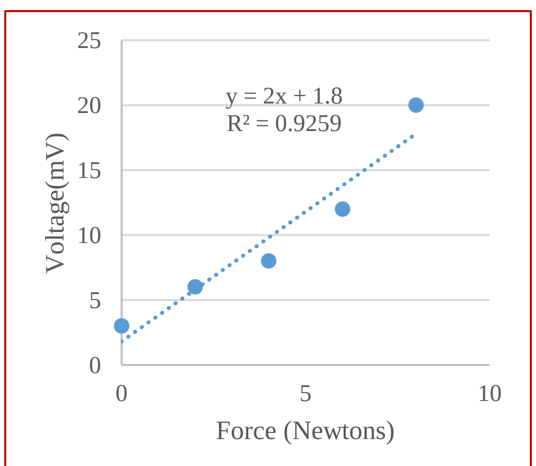
$u_I = \pm t_{95,v} s_{yx} = \pm 6.57mV$ (s_{yx} = 2.066, $t_{95,3}$= 3.182)

$u_0 = \pm resolution = \pm 1mV$

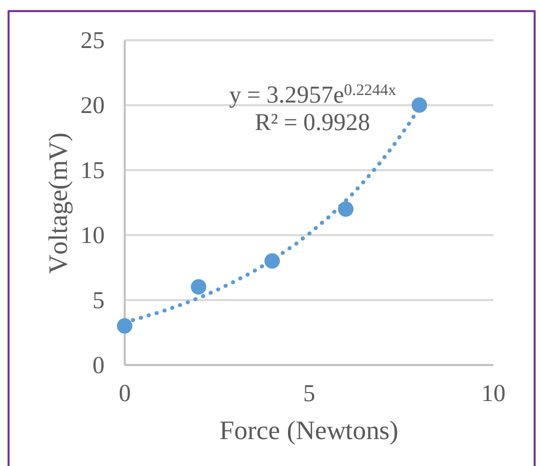
$u_{Noise} = \pm t_{95,v} s_x = \pm 3.16mV$ ($s_x = 1.14$, $t_{95,4}$= 2.770)

$u_V = \pm 7.36\ mV$

A



B



Difference between A vs B?

Which is better?

Why?

Example #2 Mini Baja

LPPS-22 Series Linear Potentiometer Position Sensor with Rod Ends

$$u_V = \pm\sqrt{(u_I)^2 + (u_0)^2 + \cdots + (u_{noise})^2}$$

$$u_0 = \pm resolution = 1mV$$

$$u_{NL} = .01 * 10V = 100\ mV$$

$$u_{Temp} = .0003 * 10V(95 - {}^{-}40) = 165\ mV$$

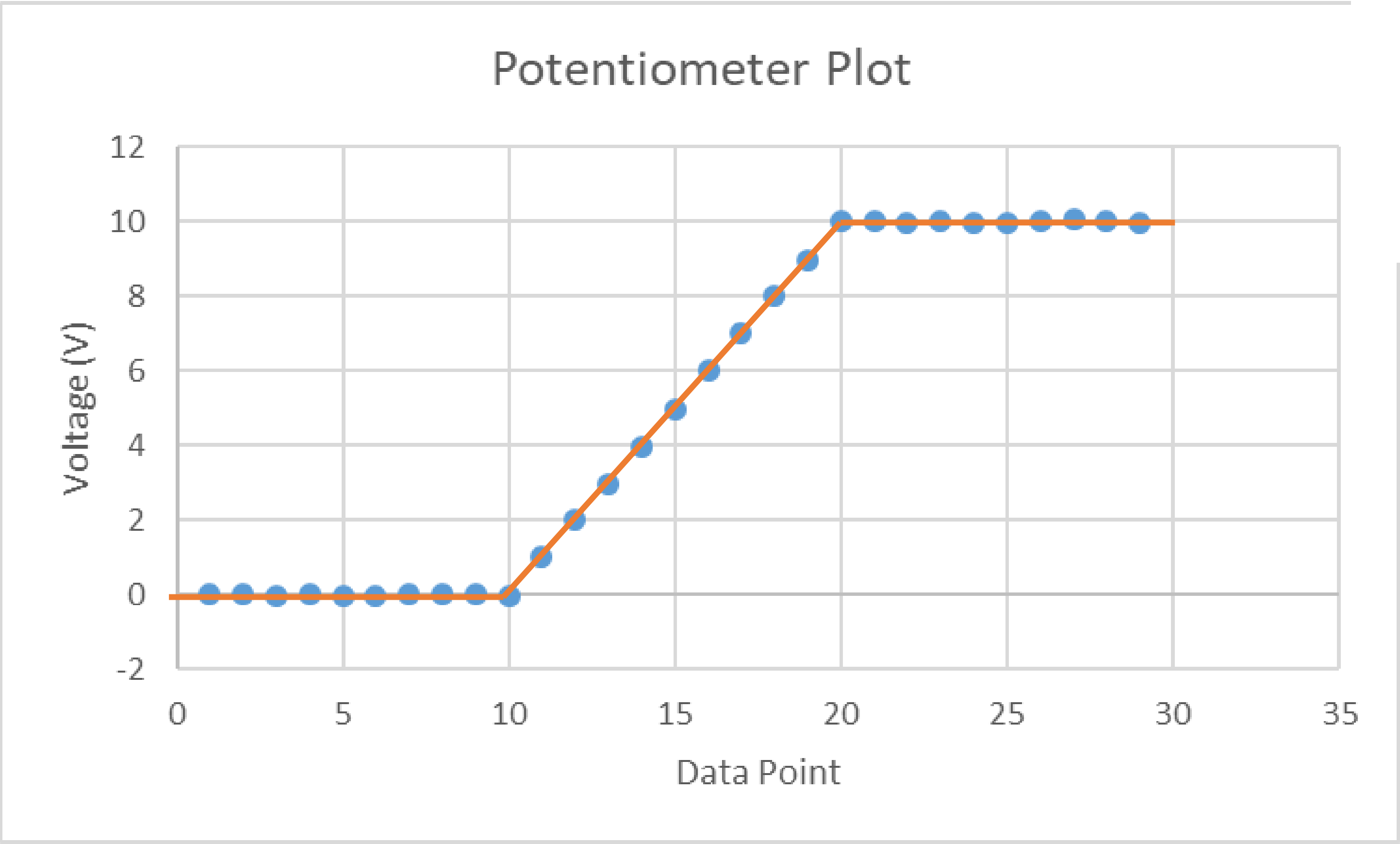
$$u_V = \pm\sqrt{(100mV)^2 + (165mV)^2 + (1mV)^2 \ldots + (u_{noise})^2} = 193\ \text{mV + noise}$$

Specifications $V_{in} = 10VDC$

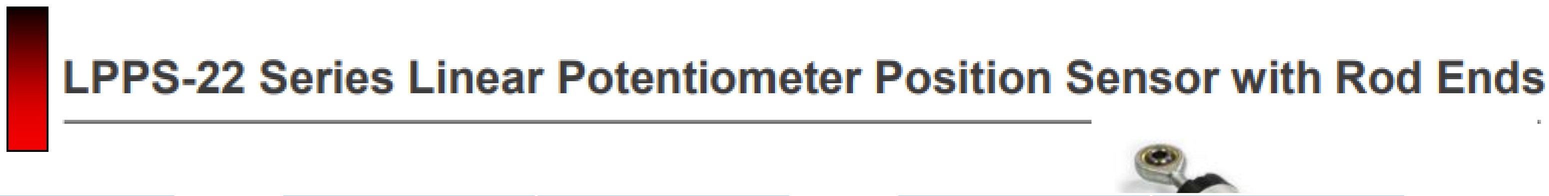
Output:	0 to 100% of Input Voltage (potentiometer circuit)
Non-Linearity, Full Stroke: Best Fit Straight Line (BFSL)	±0.50% (typical), ±1.0% (max)
Operating Temperature:	-40 to +95°C (-40 to +203°F)
Temperature Coefficient:	≤ +/- 0.03% of FS / °C

Example #2 Mini Baja

LPPS-22 Series Linear Potentiometer Position Sensor with Rod Ends



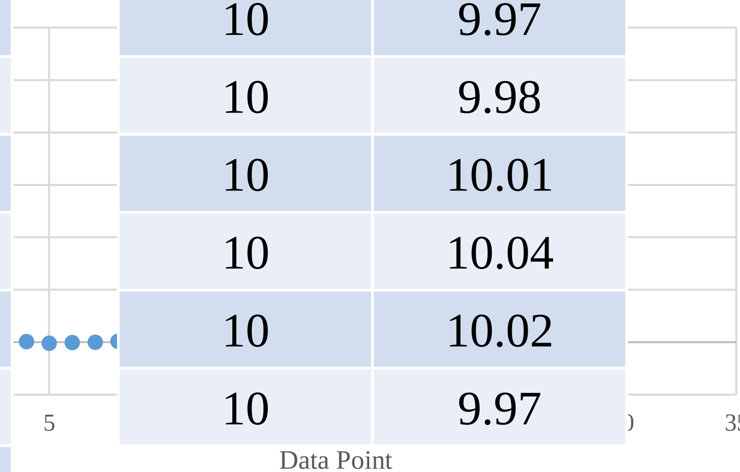
Example #2 Mini Baja



Displacement (inches)	Voltage (Volts)
0	0.01
0	0.03
0	-0.02
0	0.02
0	-0.04
0	-0.01
0	0
0	0.03
0	0.01
0	-0.02

Displacement (inches)	Voltage (Volts)
0	-0.02
1	1.01
2	2.03
3	2.97
4	3.99
5	4.98
6	6.01
7	7
8	8.03
9	8.98
10	10

Displacement (inches)	Voltage (Volts)
10	10
10	10.03
10	9.07
10	10.03
10	9.97
10	9.98
10	10.01
10	10.04
10	10.02
10	9.97



Example #2 Mini Baja

LPPS-22 Series Linear Potentiometer Position Sensor with Rod Ends

Displacement (inches)	Voltage (Volts)
0	0.01
0	0.03
0	-0.02
0	0.02
0	-0.04
0	-0.01
0	0
0	0.03
0	0.01
0	-0.02

$s_{x,0} = 0.023V$

$$s_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

$$\mathrm{N} = 10$$

$$s_{pool} = \sqrt{\frac{(n_1-1){s_1}^2 + (n_2-1){s_2}^2}{n_1 + n_2 \ - 2}}$$

$$s_{pool} = \sqrt{\frac{(9){s_1}^2+(9){s_2}^2}{18}} = 0.0257$$

$$t_{95,18} = 2.101$$

$$u_{Noise} = \pm t_{95,\nu} s_x = \pm 0.054\ V$$

Displacement (inches)	Voltage (Volts)
10	10
10	10.03
10	9.97
10	10.03
10	9.97
10	9.98
10	10.01
10	10.04
10	10.02
10	9.97

$s_{x,10} = 0.027V$

Example #2 Mini Baja

LPPS-22 Series Linear Potentiometer Position Sensor with Rod Ends

Displacement (inches)	Voltage (Volts)
0	-0.02
1	1.01
2	2.03
3	2.97
4	3.99
5	4.98
6	6.01
7	7
8	8.03
9	8.98
10	10

$$s_{yx} = \sqrt{\frac{1}{\nu}\sum_{i=1}^{N}(y_i - y_{ci})^2}$$

$$\nu = 9$$

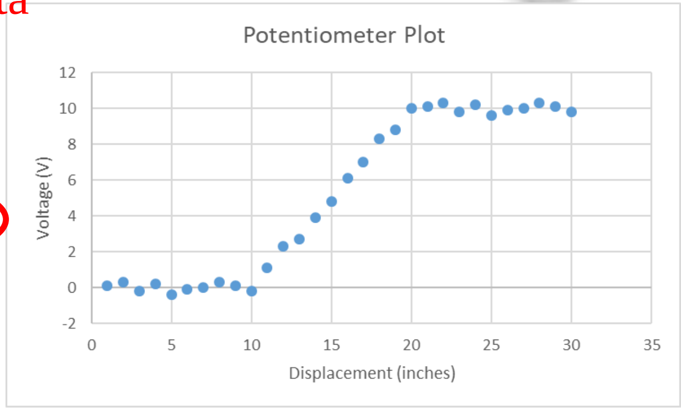
$$s_{yx} = 0.021V$$

$$t_{95,9} = 2.262$$

$$u_I = \pm t_{95,\nu} s_{yx} = \pm 0.048V$$

New u_I based on data

$$u_{Noise} = \pm 0.054\,V$$



$$u_V = \pm\sqrt{(u_I)^2 + (u_0)^2 + \cdots + (u_{noise})^2}$$

$$u_V = \pm 72mV$$

(compared to 193mV + noise)

Questions?