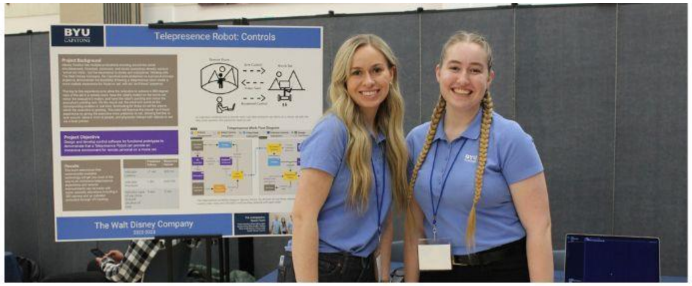
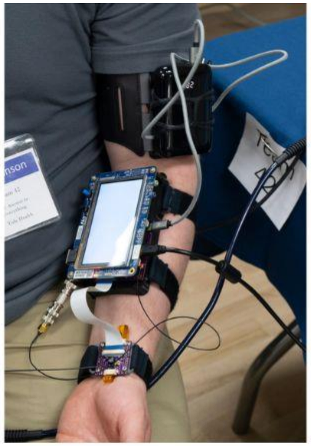
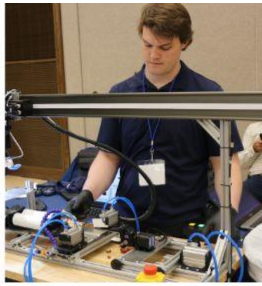




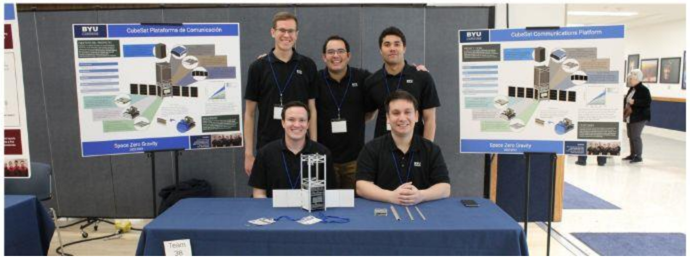
Stop by and check out over 50 unique student projects!

Free treats while you explore the projects



CAPSTONE DESIGN FAIR

THURSDAY, APRIL 4
WSC BALLROOM
11AM - 1 PM



Spiritual Thought – What is Truth?

John 18:37 …To this end was I born, and for this cause came I into the world, that I should bear witness unto the truth. Every one that is of the truth heareth my voice.

38 Pilate saith unto him, What is truth? …

D&C 93:24 And truth is knowledge of things as they are, and as they were, and as they are to come;

D&C 93:26 The Spirit of truth is of God. I am the Spirit of truth, and John bore record of me, saying: He received a fulness of truth, yea, even of all truth;

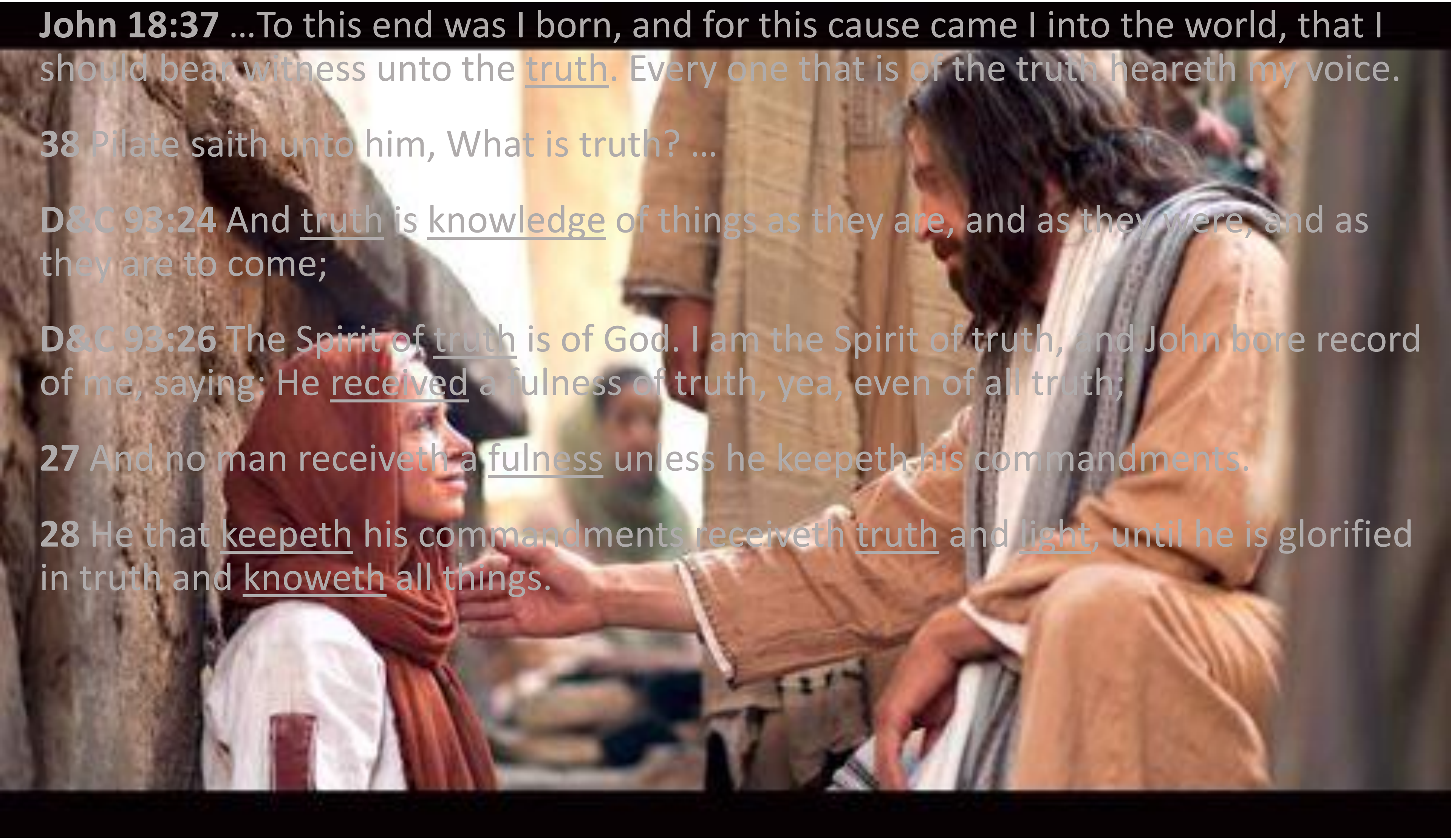
27 And no man receiveth a fulness unless he keepeth his commandments.

28 He that keepeth his commandments receiveth truth and light, until he is glorified in truth and knoweth all things.

In the context of Pres Reese's comments at today's devotional, and Elder Taylor's analogy of a 3-act play, what truths do we have?

What is our purpose? What truths do you seek?

Spiritual Thought – What is Truth?



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19 – Uncertainty in measurements - overview

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

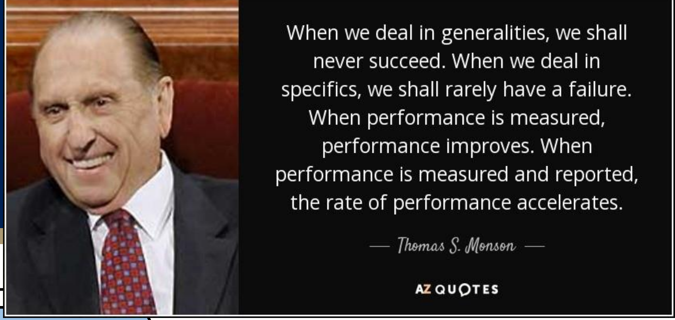
NAME:

	Date	Order	Team Members			Slide Quality (from 1 to 10)	Presentation Quality (from 1 to 10)
0		1					
0		2					
0		3					
0		4					
0		5					
0		6					
0		7					
0	**4/2 and 4/4 2024**	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.

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

<u>Labs</u>

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

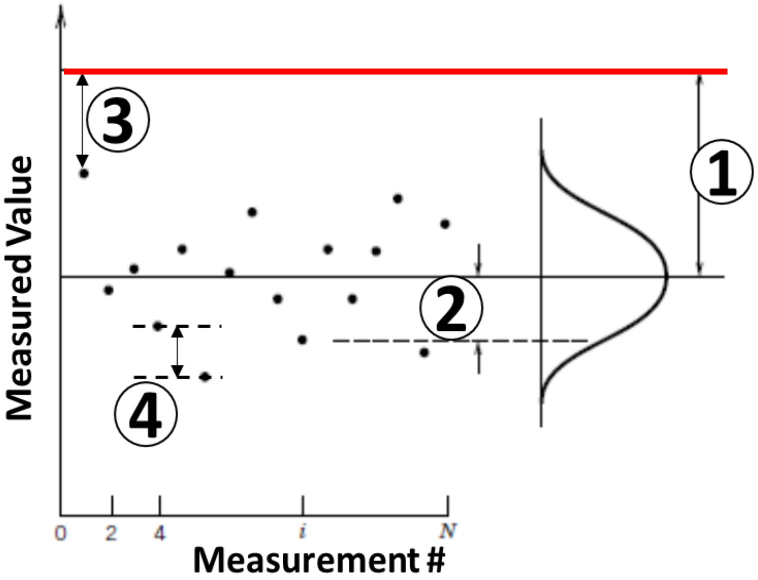
Memo report
Memo report revise

<u>Project</u>

Final Project/Report

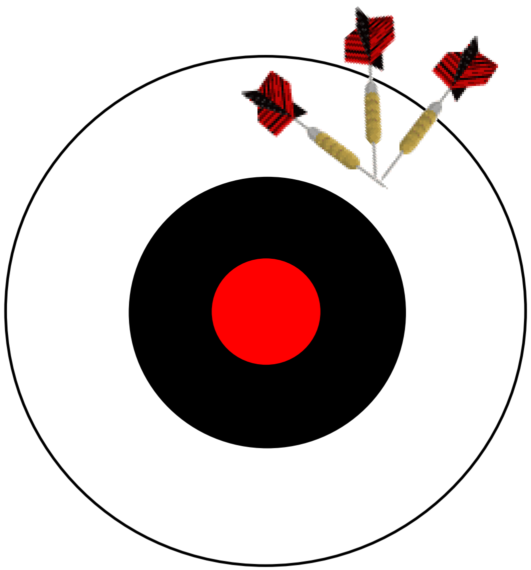
Uncertainty

- **What is Uncertainty?** **Estimate** of the range of error
- Why not just call it error (instead of uncertainty)?
  - Because we rarely know the true value.
- So, where's the uncertainty on the graph?
- How do we minimize uncertainty?

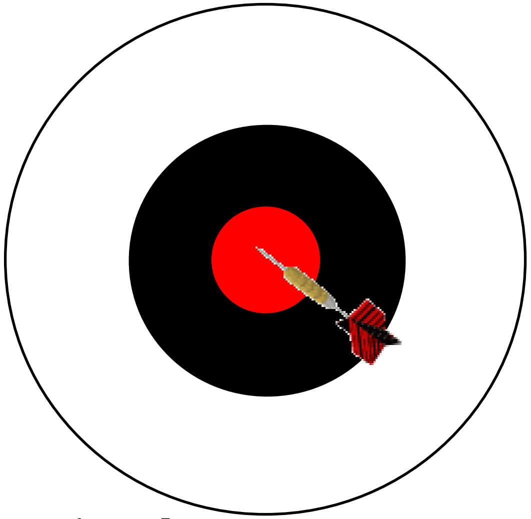


Accuracy vs Precision

Imagine that the bullseye is the true value we want to measure and each dart is an individual measurement …

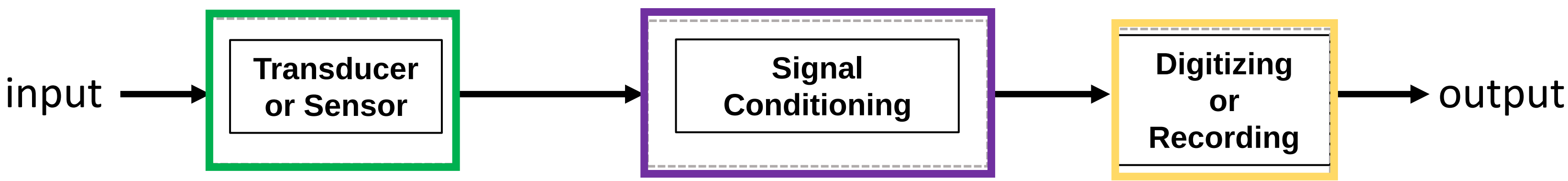


2. Precision (how little scatter)



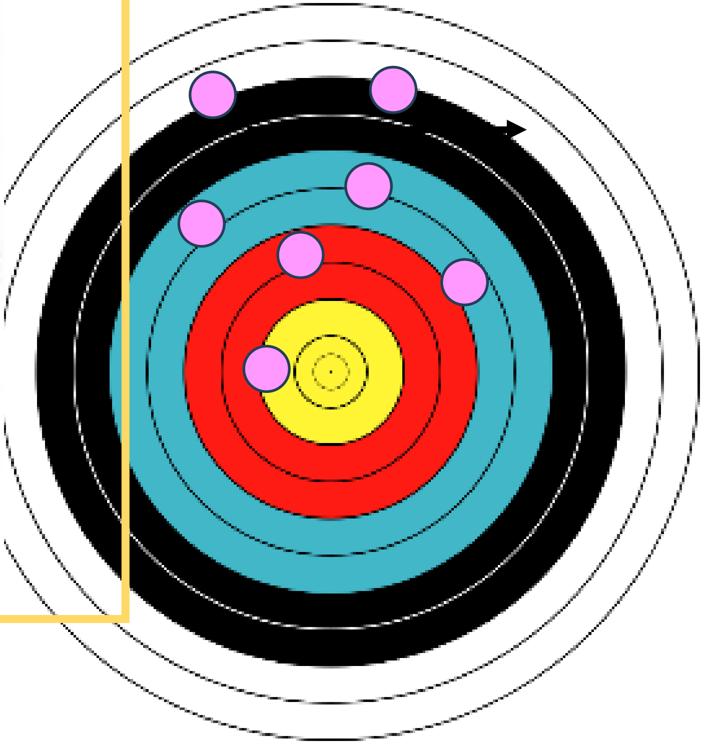
1. Accuracy (how close to the truth)

Practice

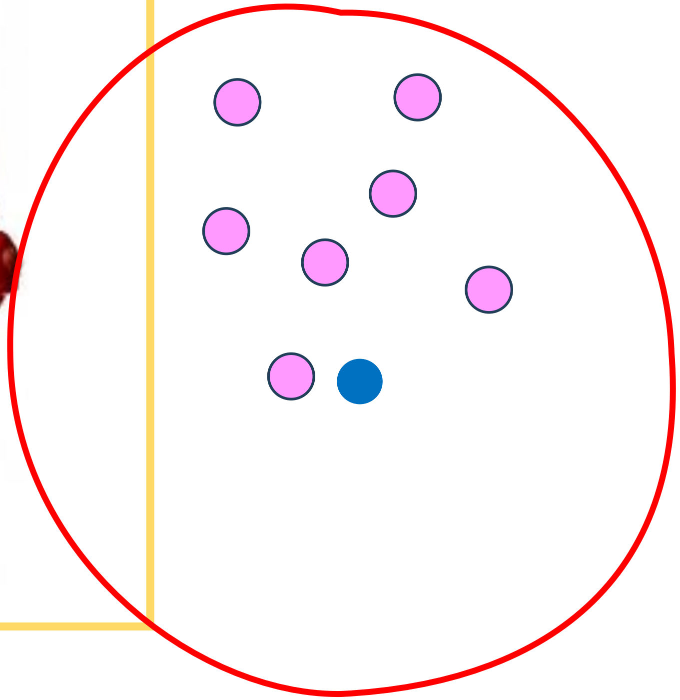


Let’s generate some data!

Practice



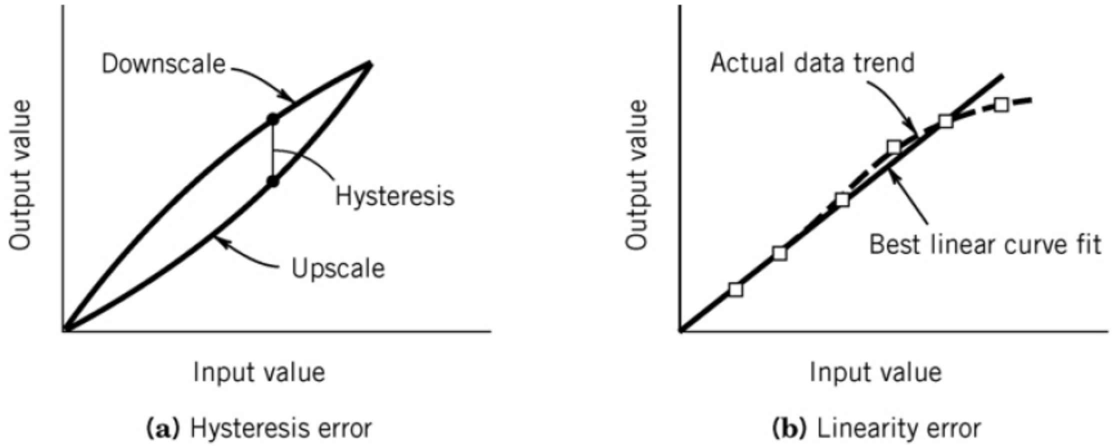
Practice



- Where is the true value?
- What is the uncertainty?
- Why is there uncertainty?

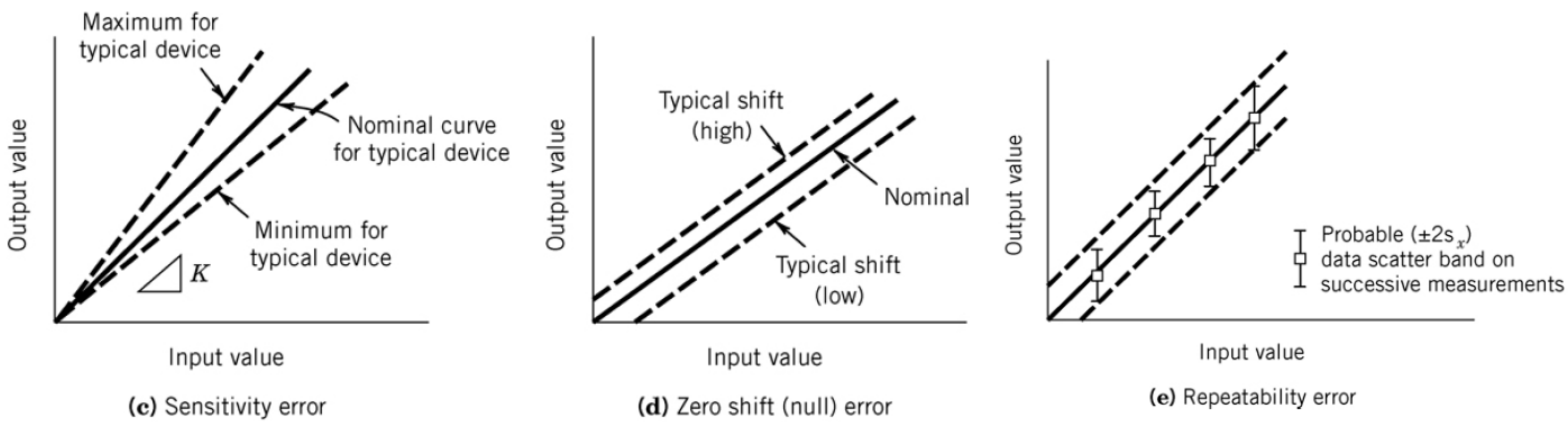
Is there a bias?

Some Common Errors



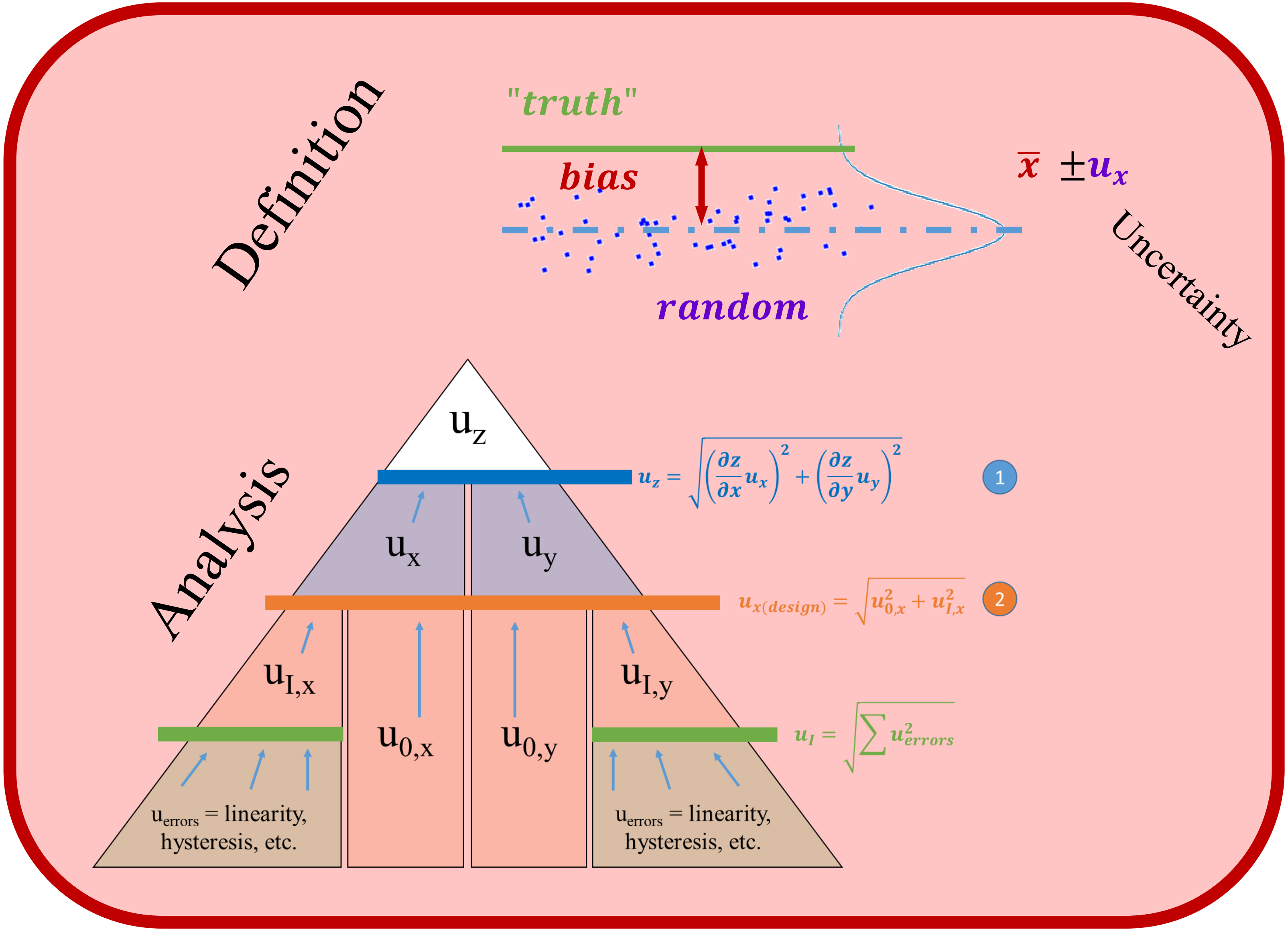
(a) Hysteresis error
(b) Linearity error

Error -> Uncertainty



(c) Sensitivity error
(d) Zero shift (null) error
(e) Repeatability error

Uncertainty Overview



Course Outcome

6. Uncertainty Analysis

Students should be able to perform a basic uncertainty analysis for a measurement system.

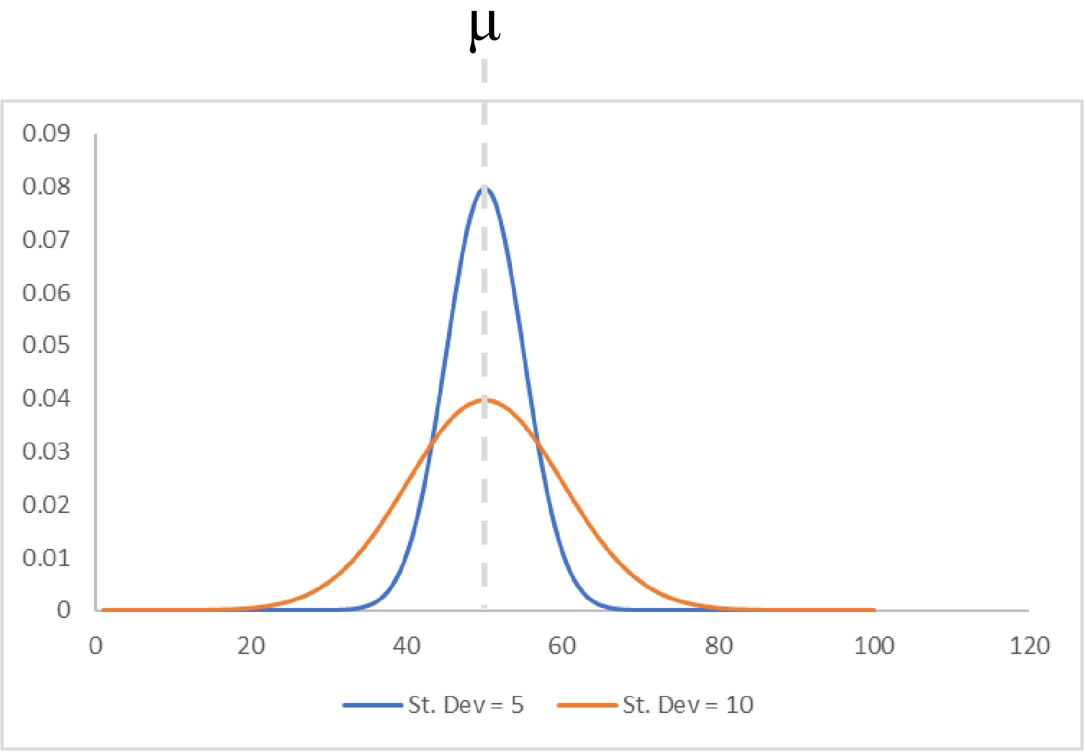
Weekly Outcome

- Stats Review and Uncertainty Analysis
  - Calculate 95% confidence intervals
  - Calculate basic statistics such as averages, standard deviations, standard errors, and standard errors of the mean
- Design Stage Uncertainty Analysis
  - Use root-sum-squares (RSS) method to estimate design stage uncertainty based on a combination of errors, such as linearity, hysteresis, repeatability, zeroth order uncertainty
  - Determine zeroth order uncertainty for analog and digital systems – the uncertainty in reading the instrument
  - Calculate instrument uncertainty from spec sheet data

From instrument resolution: analog u_0 = resolution/2 (or least count/2) ; digital u_0 = bit resolution

Statistics Review

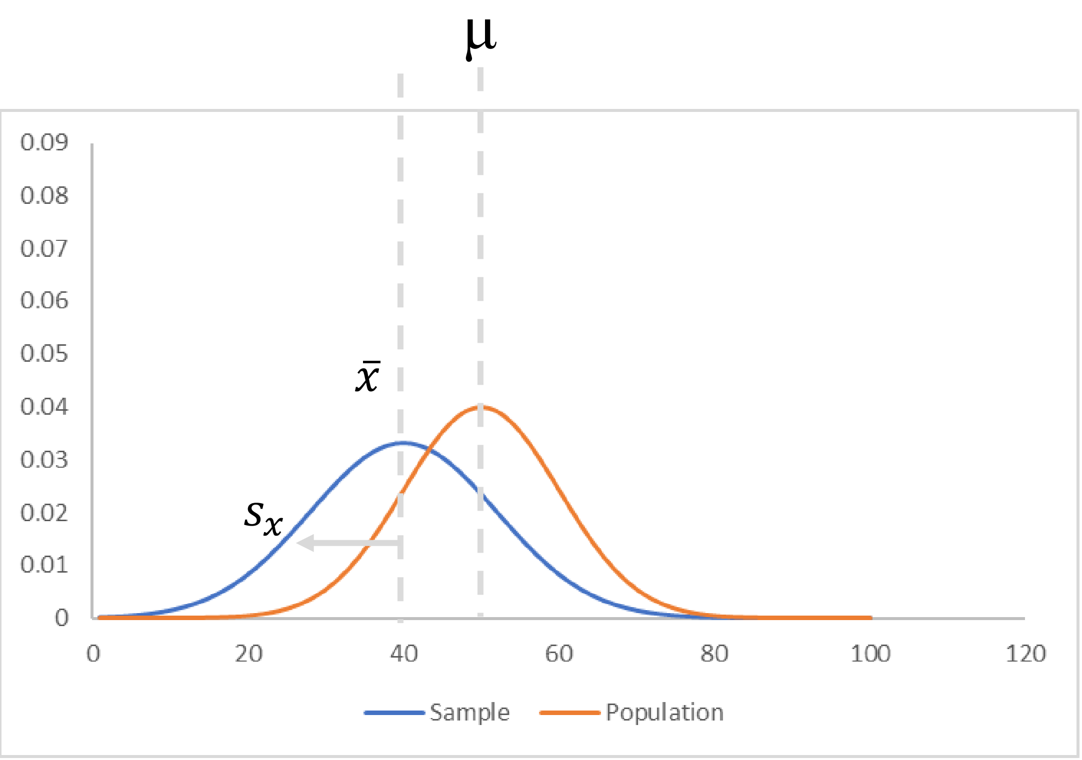
1. You should be confident in your ability to understand, explain, and compute (where relevant) the following fundamental statistical terms and concepts:
   1. population
   2. normal distribution
   3. population mean
   4. variance σ^2
   5. standard deviation σ



Statistics Review

1. You should be confident in your ability to understand, explain, and compute (where relevant) the following fundamental statistical terms and concepts:
    1. population
    2. normal distribution
    3. population mean
    4. variance σ^2
    5. standard deviation σ
    6. sample mean $\bar{x}$
    7. sample standard dev. s_x

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



Statistics Review

Example 1: We have a class of 60 students, with average height of 180 cm, st dv of 10 cm. We measure 5 students with the following height: 180 175 170 170 140 cm
Calculate:

1. sample mean
2. sample standard deviation

$\bar{x} = 167\ cm$

$s_x = 15.7\ cm$

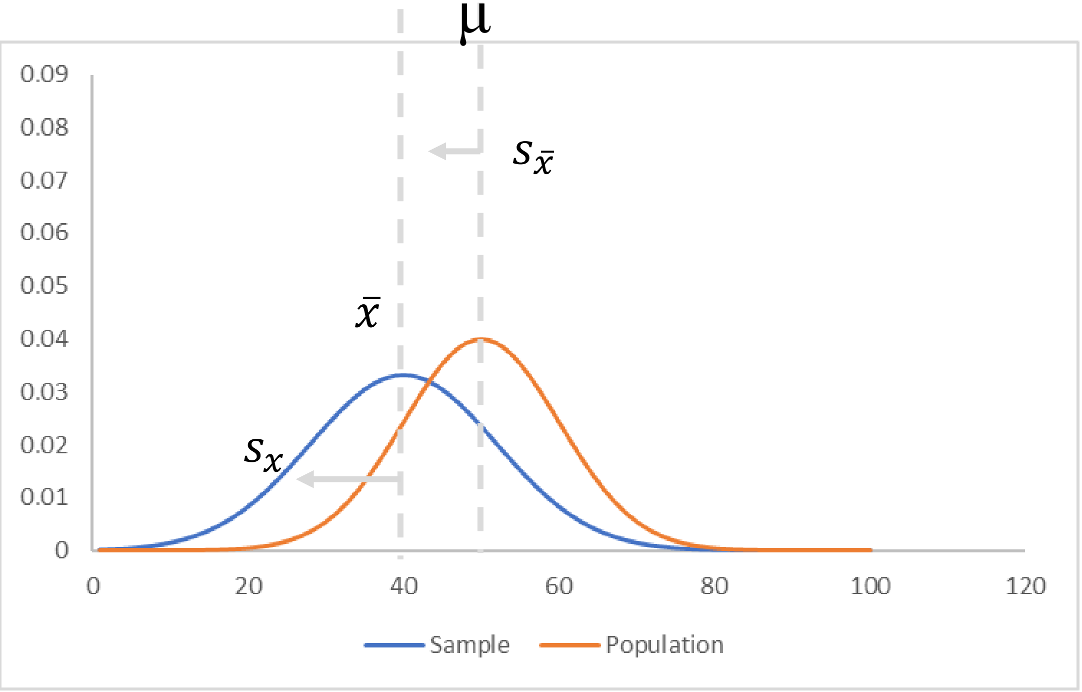
$$s_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Statistics Review

7. Standard deviation of sample vs standard deviation of means

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

$$s_{\bar{x}} = \frac{s_x}{\sqrt{N}}$$

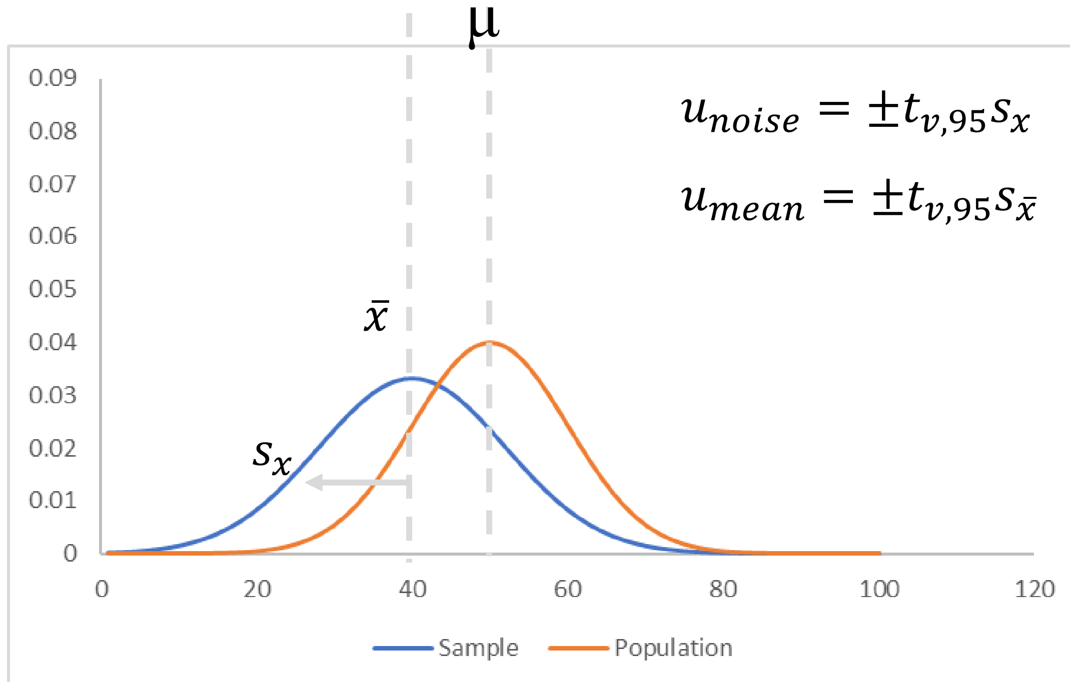


Statistics Review

8. the 95% confidence interval for random sampling from a population
9. the 95% confidence interval of the population mean (also referred to as the standard error of the mean)

Table 4.4 Student's t Distribution

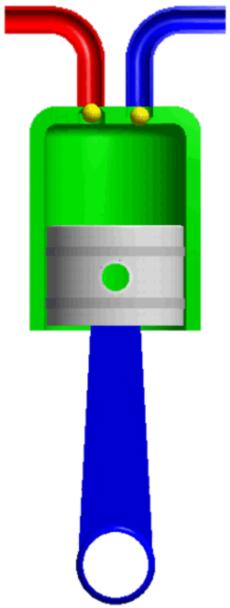
ν	t_{50}	t_{90}	t_{95}	t_{99}
1	1.000	6.314	12.706	63.657
2	0.816	2.920	4.303	9.925
3	0.765	2.353	3.182	5.841
4	0.741	2.132	2.770	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.499
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
11	0.697	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



ν = degrees-of-freedom = N-1

Piston Example

- You are a piston head manufacturer:
  - You make 1000 piston heads a day
  - Critical measurement is OD (in mm)
  - Measure 5 parts, twice a day

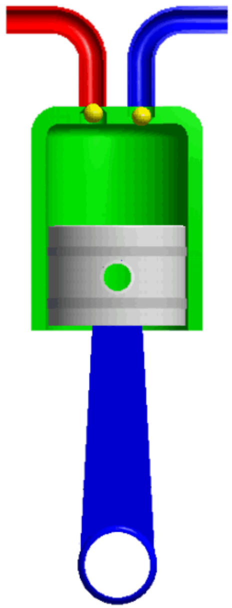


  - Population
  - population mean (also referred to as the expected value)
  - variance
  - population standard deviation

Piston Example

- You are a piston head manufacturer:
  - You make 1000 piston heads a day
  - Critical measurement is OD (in mm)
  - Measure 5 parts, twice a day : 50, 52, 51, 48, 50

  - Find:
    - sample mean
    - sample standard deviation
    - the 95% confidence interval for random sampling from a population
    - the 95% confidence interval of the population mean (also referred to as the standard error of the mean)



Distribution

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

$$s_{\bar{x}} = \frac{s_x}{\sqrt{N}}$$

N = number of samples

$$u_{noise} = \pm t_{v,95} s_x \qquad v = dof = N - 1$$

$$u_{mean} = \pm t_{v,95} s_{\bar{x}}$$

$$\bar{x} = 50.2\ mm$$

$$s_x = 1.48\ mm$$

$$s_{\bar{x}} = 0.66\ mm$$

$u_{noise} = \pm 4.10\ mm$ (variation of samples)

$u_{mean} = \pm 1.83\ mm$ (variation of sample mean)

50, 52, 51, 48, 50

Table 4.4 Student's t Distribution

v	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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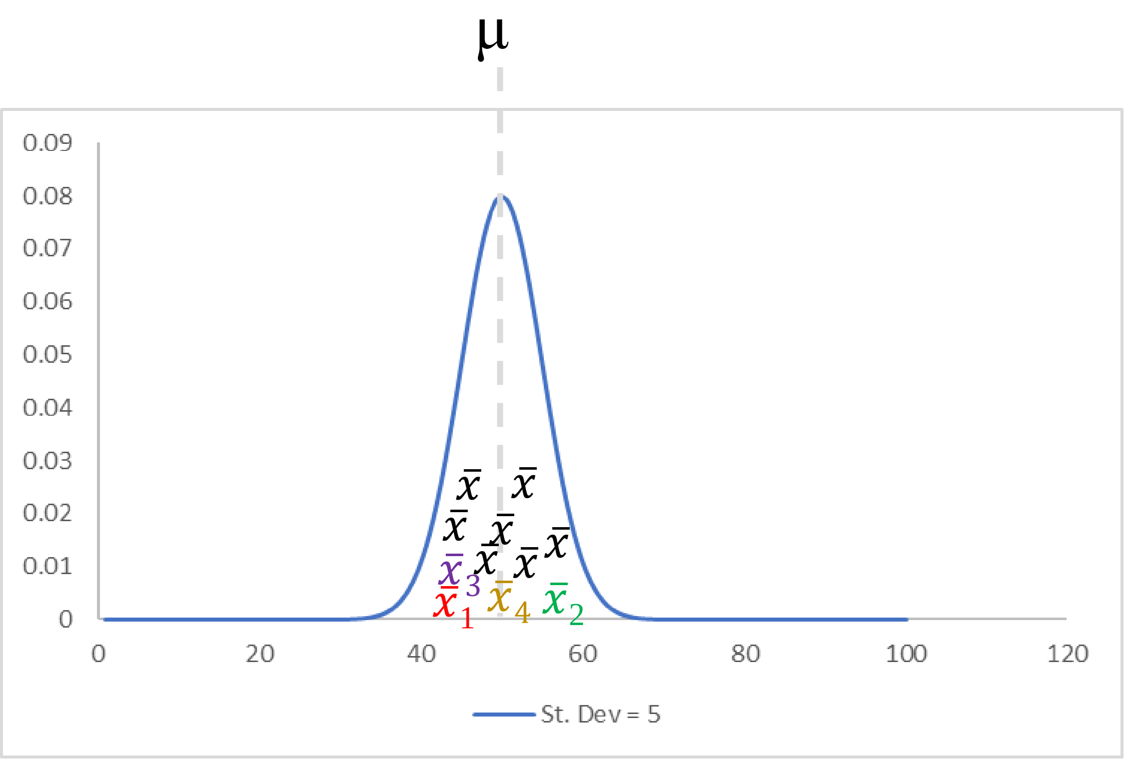
50	0.680	1.679	2.010	2.679
60	0.679	1.671	2.000	2.660
∞	0.674	1.645	1.960	2.576

Central Limit Theorem

- Why do we care about u_{mean}?

For the piston manufacturer on the previous slide, will generate 2 sample means ($\bar{x}$) per day, resulting in a pretty decent gaussian distribution in about a month or so.

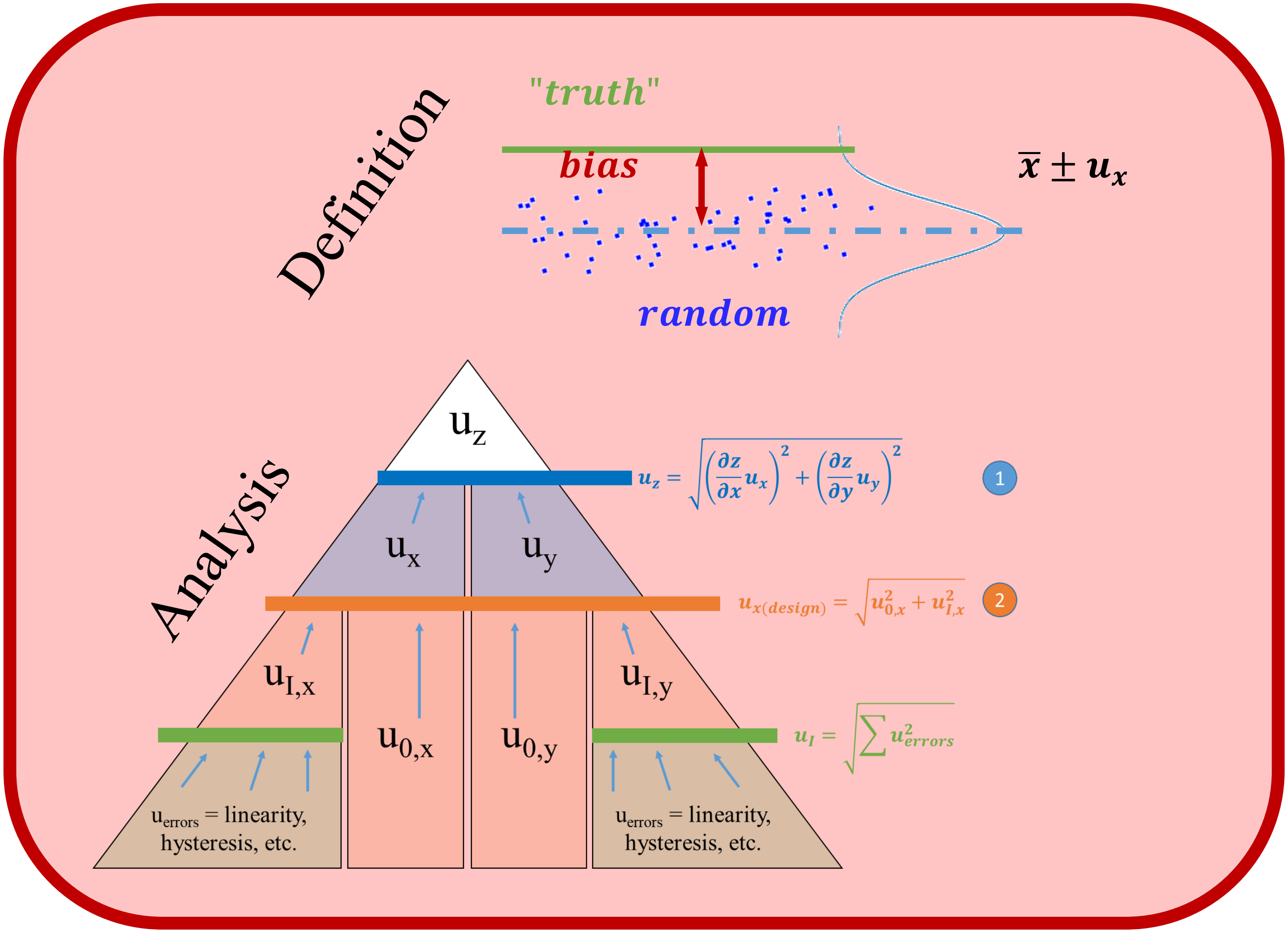
The central limit theorem states that if you take sufficiently large samples from a population, the samples' means will be normally distributed, even if the population isn't normally distributed.



Questions?

20 –Design Stage Uncertainty – Propagation of Uncertainty

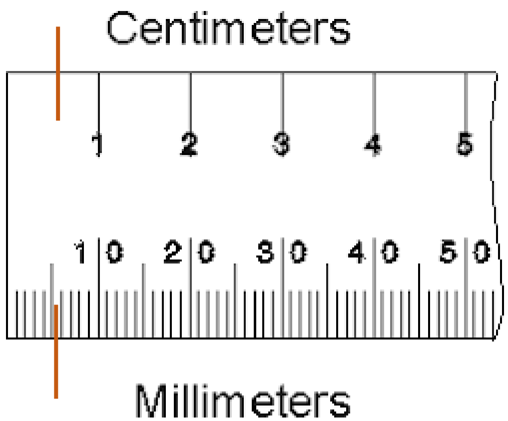
Uncertainty Overview



Design Stage Uncertainty

- Estimate uncertainty before experiment
  - Anything we can estimate before the experiment is design stage uncertainty

$$u_D = \pm\sqrt{{u_I}^2 + {u_o}^2}$$



- u_o zeroth order uncertainty
  - For analog system, $u_o = \pm\frac{1}{2}(resolution)$
  - For digital system, $u_o = \pm\,(resolution)$

Digital Resolution

$$resolution = \frac{range}{2^{bit}}$$

Design Stage Uncertainty

- Instrument uncertainty

$$u_I = ?$$

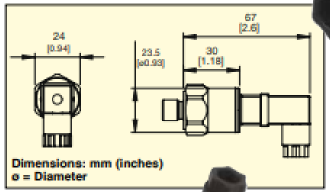
Compact Rugged Pressure Transmitters

OMEGA™

15 to 5000 psi, 1 to 345 bar
4 to 20 mA Output

PX119 Series 1 YEAR WARRANTY CE

- **Low Cost**
- **Compact Size**
- **0.50% BFSL Accuracy**
- **All Stainless Steel Body**



mini DIN style (connector included).

PX119, both models shown smaller than actual size.

The PX119 pressure transmitter series is ideally suited for material handling, industrial and mobile equipment applications where space constraints require a small body size. The body is machined from a single piece of stainless steel to provide added protection for the internal electronics. A piezoresistive ceramic sensor along with ASIC signal conditioning provide an excellent thermally compensated output.

Specifications

Accuracy: 0.50% BFSL Accuracy
Pressure Range: 15 to 5000 psi (345 bar)
Output/Supply Voltage: 4 to 20 mA: 8 to 30 Vdc
Output Connections: DIN 43650C (mini DIN)
Output Wiring: Pin 1: Supply +, Pin 2: Supply -
Long Term Drift: <0.3% FS @ 25°C (77°F)
Thermal Error:
- **7.5 psi ≥ 100 psi:** 0.01% FS/°F (0.018% FS/°C)
- **100 psi > 400 psi:** 0.009% FS/°F (0.016% FS/°C)
- **400 psi ≥ 1000 psi:** 0.011% FS/°F (0.019% FS/°C)
- **1000 psi > 3000 psi:** 0.012% FS/°F (0.021% FS/°C)
- **3000 psi ≥ 5000 psi:** 0.018% FS/°F (0.028% FS/°C)

Compensated Temperature: 0 to 85°C (32 to 185°F)
Operating Temperatures: -40 to 135°C (-40 to 257°F)
Process Connection: ¼ NPT male
Construction: 304 SS
Wetted Materials: 304 SS and Ceramic Al_2O_3, NBR Standard
Vibration: 10 g (20 to 2000 Hz) for <58 psi (4 bar); 20 g (20 to 500 Hz) for ranges >58 psi (4 bar)
Protection: Overvoltage, short circuit, reverse polarity
Response Time: 1 ms
Ingress Protection: IP65
Weight: 70 g (0.15 lb)

To Order

Ranges psi	Ranges bar	% Proof (FS)	% Burst (FS)	mini DIN Connection
Absolute Pressure				
0 to 15	0 to 1	193.4%	386.7%	**PX119-015AI**
0 to 30	0 to 2.1	193.4%	241.7%	**PX119-030AI**
0 to 100	0 to 6.9	290.1%	362.6%	**PX119-100AI**
0 to 150	0 to 10.3	193.4%	241.7%	**PX119-150AI**
0 to 300	0 to 21	193.4%	241.7%	**PX119-300AI**
0 to 600	0 to 42	241.7%	290.1%	**PX119-600AI**
0 to 1000	0 to 69	290.1%	362.6%	**PX119-1KAI**
0 to 1500	0 to 103	193.4%	241.7%	**PX119-1.5KAI**
0 to 3000	0 to 207	193.4%	241.7%	**PX119-3KAI**
0 to 5000	0 to 345	188.5%	188.5%	**PX119-5KAI**
Gage Pressure				
0 to 15	0 to 1	193.4%	386.7%	**PX119-015GI**
0 to 30	0 to 2.1	193.4%	241.7%	**PX119-030GI**
0 to 100	0 to 6.9	290.1%	507.6%	**PX119-100GI**
0 to 150	0 to 10.3	193.4%	338.4%	**PX119-150GI**
0 to 300	0 to 21	193.4%	338.4%	**PX119-300GI**
0 to 600	0 to 42	241.7%	362.6%	**PX119-600GI**
0 to 1000	0 to 69	290.1%	362.6%	**PX119-1KGI**
0 to 1500	0 to 103	193.4%	241.7%	**PX119-1.5KGI**
0 to 3000	0 to 207	193.4%	217.5%	**PX119-3KGI**
0 to 5000	0 to 345	188.5%	188.5%	**PX119-5KGI**

Ordering Examples: ***PX119-3KGI****, 3000 psi gage pressure transmitter with 4 to 20 mA output and mini DIN termination.*
PX119-015AI*, 15 psi absolute pressure transmitter with 4 to 20 mA output and mini DIN termination.*

Accessories

Model No.	Description
CA-319-4PC24-XXX-WP	Vented cable used for PX119 ≤100 psig, terminated in a clean dry area that is open to atmosphere for correct operation*
CA-319-4PC24-XXX	Standard cable for PX119 >100 psig and all absolute ranges, terminated in a dry location or sealed to prevent water from getting into the cable/sensor*
DP8PT	PLATINUM™ Series ⅛ DIN 4-digit single display panel meter

All* ***PX119* *are vented through a hole in the connector and through the mating connector. OMEGA recommends purchase and use of ready-made Cable Assemblies using part # structure* ***"CA-319-4PC24-XXX-WP"*** *(and non-WP version) as shown above, where* ***"XXX"*** *is the length in feet of the desired cable (e.g. "030" stands for 30 ft).*

Design Stage Uncertainty

- Instrument uncertainty

$$u_I = ?$$

$$u_{Accuracy}, u_{Drift}, u_{Thermal}$$

$$u_{Accuracy} = \pm 0.005(15-0) = \boxed{\pm 0.075\ psi}$$

$$u_{Drift} = \pm 0.003(15-0) = \boxed{\pm 0.045\ psi}$$

$$u_{Thermal} = \pm 0.0001 * Max\ temp\ range$$

$$= \pm 0.0001(257 - {}^{-}40) = \boxed{\pm 0.03\ psi}$$

$$u_I = \pm\sqrt{{u_{Accuracy}}^2 + {u_{Drift}}^2 + {u_{Thermal}}^2}$$

$$u_I = \pm\sqrt{0.075^2 + 0.045^2 + 0.03^2}$$

$$u_I = \pm 0.092\ psi$$

signal conditioning provide an excellent thermally compensated output.

Specifications

Accuracy: 0.50% BFSL Accuracy
Pressure Range: 15 to 5000 psi (345 bar)
Output/Supply Voltage: 4 to 20 mA: 8 to 30 Vdc
Output Connections: DIN 43650C (mini DIN)
Output Wiring: Pin 1: Supply +, Pin 2: Supply -
Long Term Drift: <0.3% FS @ 25°C (77°F)
Thermal Error:
7.5 psi ≥ 100 psi: 0.01% FS/°F (0.018% FS/°C)
100 psi > 400 psi: 0.009% FS/°F (0.016% FS/°C)
400 psi ≥ 1000 psi: 0.011% FS/°F (0.019% FS/°C)
1000 psi > 3000 psi: 0.012% FS/°F (0.021% FS/°C)
3000 psi ≥ 5000 psi: 0.018% FS/°F (0.028% FS/°C)
Compensated Temperature: 0 to 85°C (32 to 185°F)
Operating Temperatures: -40 to 135°C (-40 to 257°F)
Process Connection: ¼ NPT male
Construction: 304 SS
Wetted Materials: 304 SS and Ceramic Al_2O_3, NBR Standard
Vibration: 10 g (20 to 2000 Hz) for <58 psi (4 bar); 20 g (20 to 500 Hz) for ranges >58 psi (4 bar)
Protection: Overvoltage, short circuit, reverse polarity
Response Time: 1 ms
Ingress Protection: IP65
Weight: 70 g (0.15 lb)

psi	bar
Absolute Pressure	
0 to 15	0 to 1
0 to 30	0 to 2.1
0 to 100	0 to 6.9
0 to 150	0 to 10.3
0 to 300	0 to 21
0 to 600	0 to 42
0 to 1000	0 to 69
0 to 1500	0 to 103
0 to 3000	0 to 207
0 to 5000	0 to 345
Gage Pressure	
0 to 15	0 to 1
0 to 30	0 to 2.1
0 to 100	0 to 6.9
0 to 150	0 to 10.3
0 to 300	0 to 21
0 to 600	0 to 42
0 to 1000	0 to 69
0 to 1500	0 to 103
0 to 3000	0 to 207
0 to 5000	0 to 345

*Ordering Examples: **PX119-3KGI,** output and mini DIN termination.*
***PX119-015AI,** 15 psi absolute pres termination.*

Accessories

Model No.	Des
CA-319-4PC24-XXX-WP	Vent a cle corre
CA-319-4PC24-XXX	Stan rang prev
DP8PT	PLAT

*All **PX119** are vented through a hc OMEGA recommends purchase an structure "**CA-319-4PC24-XXX-WI** the length in feet of the desired cab*

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BFSL = best fit straight line

Design Stage Uncertainty

Exercise 3

Consider an analog position measuring device with the following errors:

$\pm 2\%$ repeatability
$\pm 1\%$ linearity
$\pm 0.5\%$ hysteresis

The percentages are expressed as a percentage of FSO, or "full scale output," which is the same as the instrument range. If the device has a full range of 10 cm and a resolution of 0.2 cm, what is the design-stage uncertainty? Give the answer in cm.

$$u_D = \pm\sqrt{{u_I}^2 + {u_o}^2}$$

$$u_o = \pm\frac{1}{2}(resolution) = 0.1cm$$

$$u_I = \pm\sqrt{{u_{repeatability}}^2 + {u_{linearity}}^2 + {u_{hysteresis}}^2}$$

$$u_I = \pm\sqrt{(.02 * 10)^2 + (.01 * 10)^2 + (.005 * 10)^2}cm$$

$$u_I = \pm 0.229cm$$

$$u_D = \pm\sqrt{0.229^2 + 0.1^2}cm = \pm 0.25cm$$

$$u_I = \pm\sqrt{2\%^2 + 1\%^2 + 0.5\%^2}$$

$$= \pm 2.29\%\ of\ FSO$$

$$u_I = \pm .0229(10) = \pm 0.229cm$$

Design Stage Uncertainty

- We have a load cell which has a full scale range of -50 to 50 N. It is connected to a perfect* digital voltmeter with a resolution of 0.1 mV. What is the uncertainty in mV?

$$Linearity\ error:\ \pm 1\%\ of\ full\ scale$$

$$Long\ term\ drift:\ \pm 1.732N$$

$$Static\ sensitivity:\ 0.25\ \ N/mV$$

* no uncertainty with respect to the voltmeter

$$u_D = \pm\sqrt{{u_I}^2 + {u_o}^2}$$

$$u_o = \pm(resolution) = \ \ 0.1\text{mV}$$

$$u_I = \pm\sqrt{{u_{linearity}}^2 + {u_{drift}}^2}$$

$$u_D = \pm\sqrt{\left(0.01 * 100N\frac{1mV}{0.25N}\right)^2 + \left(1.732N\frac{1mV}{0.25N}\right)^2 + 0.1mV^2}$$

$$u_D = \pm\sqrt{(4mV)^2 + (6.93mV)^2 + 0.1mV^2}$$

$$u_D = \pm 8mV$$

$$u_D = \pm\sqrt{(1N)^2 + (1.732N)^2 + 0.025N^2}$$

$$u_D = \pm 2N \Rightarrow \pm 8mV$$

Propagation of Uncertainty

$R = f(x_1, x_2, \dots, x_n)$

$$u_R = \pm\sqrt{\left(\frac{\partial R}{\partial x_1}u_{x_1}\right)^2 + \left(\frac{\partial R}{\partial x_2}u_{x_2}\right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n}u_{x_n}\right)^2}$$

For constantan alloy strain gage, $R = \frac{\rho L}{A}$

where ρ is resistivity, L is length, and A is cross-sectional area

$$\frac{\partial R}{\partial \rho} = \mathrm{L/A};\ \frac{\partial R}{\partial \mathrm{L}} = \rho/\mathrm{A};\ \frac{\partial R}{\partial \mathrm{A}} = -\ \frac{\rho L}{A^2}$$

Given: L = 7 in; A = 3.85e^{-7} in^2; ρ = 1.93e-5 Ω-in & u_x for each variable is 3%

$$u_R = \pm\sqrt{\left(\frac{7}{3.85\mathrm{e}^{-7}}(0.03 * 1.93\mathrm{e} - 5)\right)^2 + (1.93\mathrm{e}^{-5}/3.85\mathrm{e}^{-7}(0.03 * 7))^2 + \left(\frac{-1.93\mathrm{e}{-5} * 7}{(3.85\mathrm{e}^{-7})}(0.03)\right)^2}$$

$u_R = 18.2\ \Omega = 5.2\%$

$u_R = \pm\sqrt{3 * (\ 3\%)^2} = 5.2\%$

Gross exaggeration, but how does an 18 Ω error impact a strain gage measurement?

Where does uncertainly lead?

Lead design teams developing precision navigation systems (combination of inertial, GPS, magnetometer, video)

Which sensor provided the best information?

Why? What's the impact of 5% error?

Then why the magnetometer and inertial sensors?

Nephi had something better than a nav system. It also pointed to food, water, etc., and worked under extreme oceanic conditions.

How did Satan manage to "jam" it's functionality?

10 And it came to pass that as my father arose in
the morning, and went forth to the tent door, to
his great astonishment he beheld upon the ground
a round ball of curious workmanship; and it was of
fine brass. And within the ball were two spindles;
and the one pointed the way whither we should go
into the wilderness. 1 Nephi 16:10

Questions?