Introduction

MEMS 1049 Mechatronics

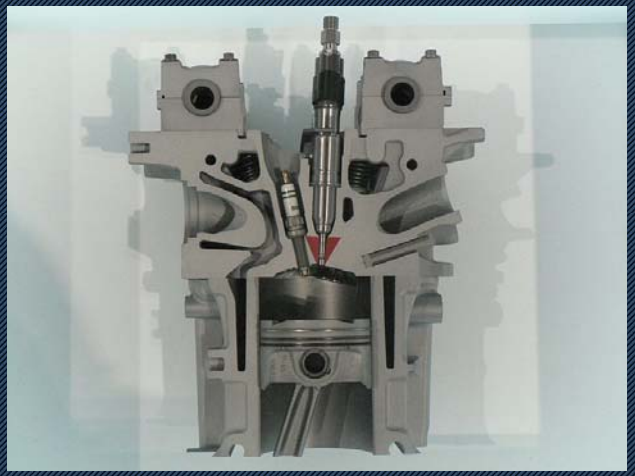
四川大學 匹兹堡学院

Outline

- Course Introduction
  - Goal
  - Definition
  - Components
  - Benefits
  - Topics
- Policy
  - Grading
  - Group
  - Late submission
  - Lab sessions
- Lab Guidelines

Goal

An introduction to mechatronics, or the interfacing of mechanical and electrical systems. Focus is on embedded controllers and their programming, actuators, sensors, and integration of these components to create a complete functional automated mechatronic system. Gain hands-on experience with mechatronic system modelling, control algorithm design and implementation.

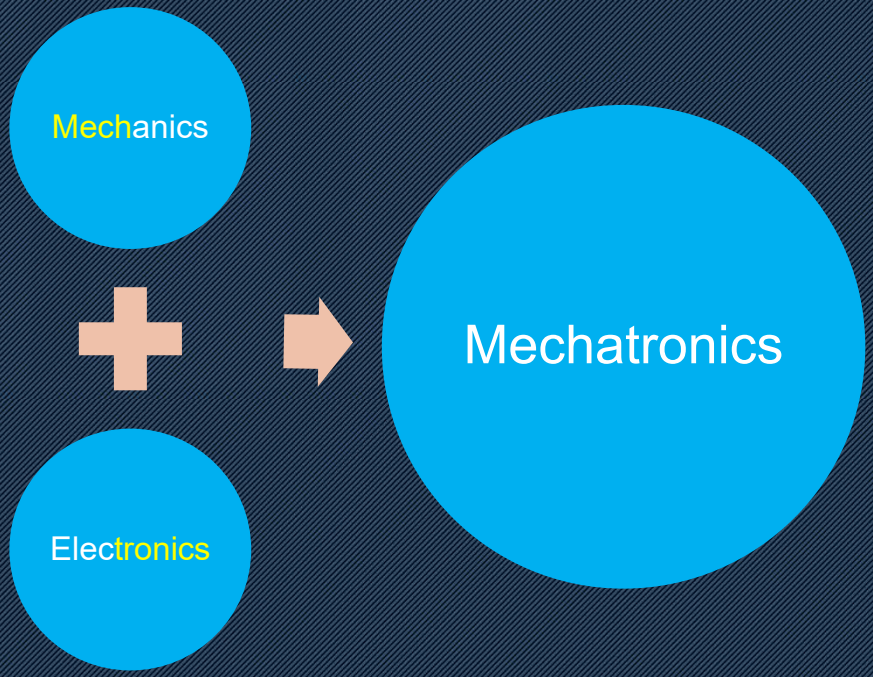


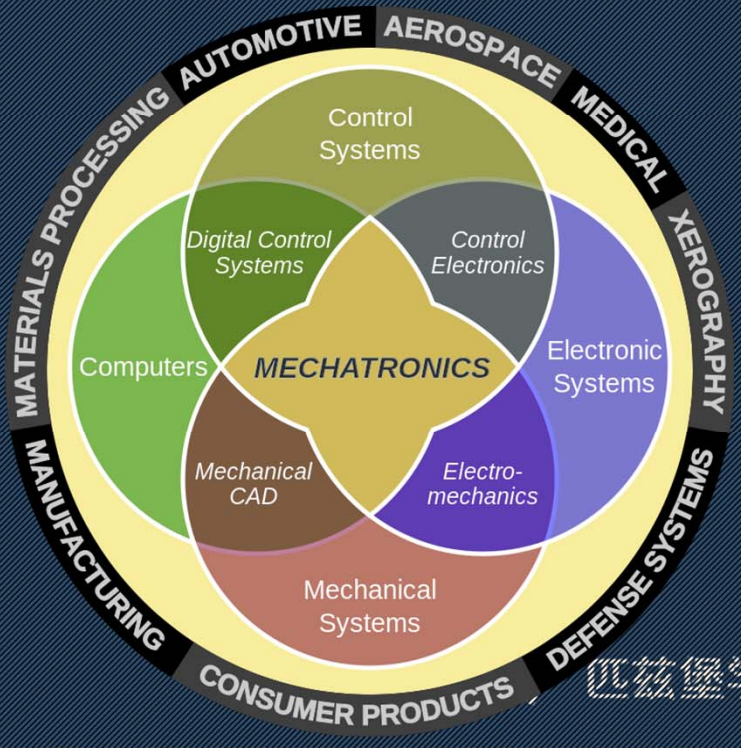
Definition: Mechatronics

https://mechatronics.colostate.edu/definitions/

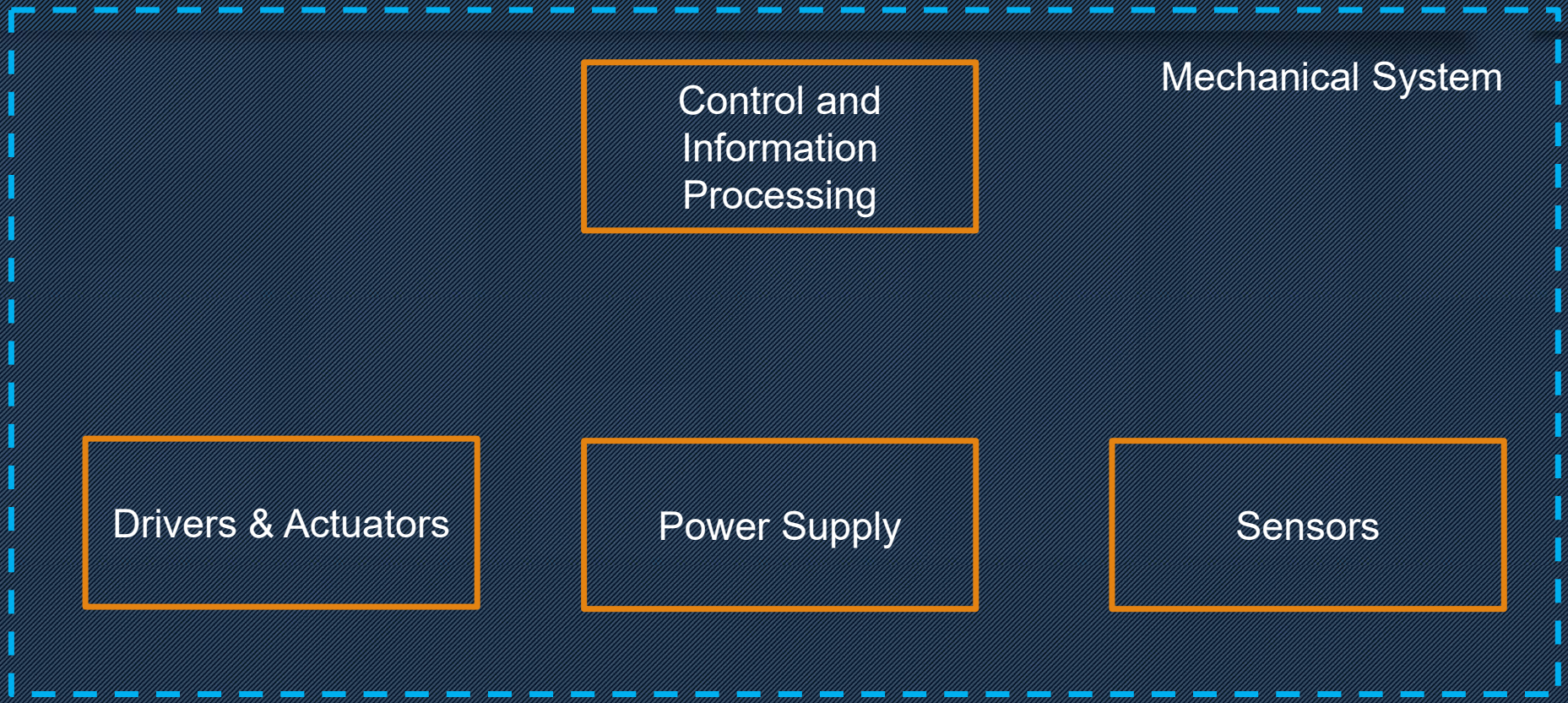
The word mechatronics originated in Japan and was created by Tetsuro Mori, an engineer of Yaskawa Electric Corporation.

Synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes.

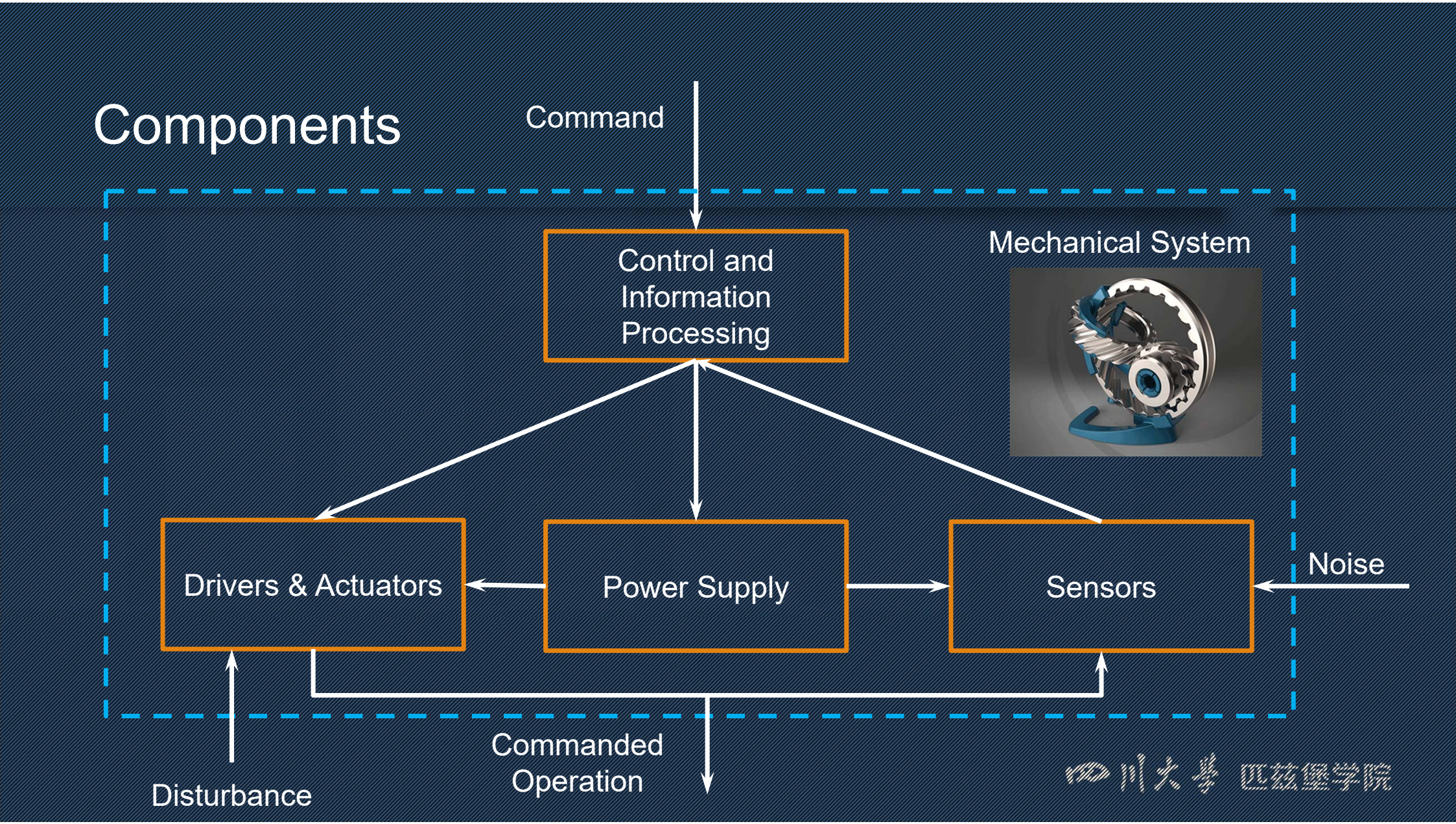




Components


Mechanical System
Control and Information Processing
Drivers & Actuators
Power Supply
Sensors

Components


Command
Control and Information Processing
Mechanical System
Drivers & Actuators
Power Supply
Sensors
Noise
Disturbance
Commanded Operation

Components Summary

- Mechanical System
- Power Supply
- Sensors
- Actuators
- Driver
- Control and Information Processing
- Interface

Benefits

- Higher precision
- Versatile functions
- Energy efficient
- Increased productivity
- Higher flexibility

Topics

Topic 1: Graphical Programming Tools

- Graphical Programming Tools Environment
- Application Programming
- Using Loops
- Data Structure
- Modularity

Topic 2: Sensors

- Angular Displacement
- Distance and Proximity
- Pressure
- Contact
- Inertial Measurement

Topic 3: Actuators

- DC Motor Modelling
- DC Motor Velocity Control
- DC Motor Position Control

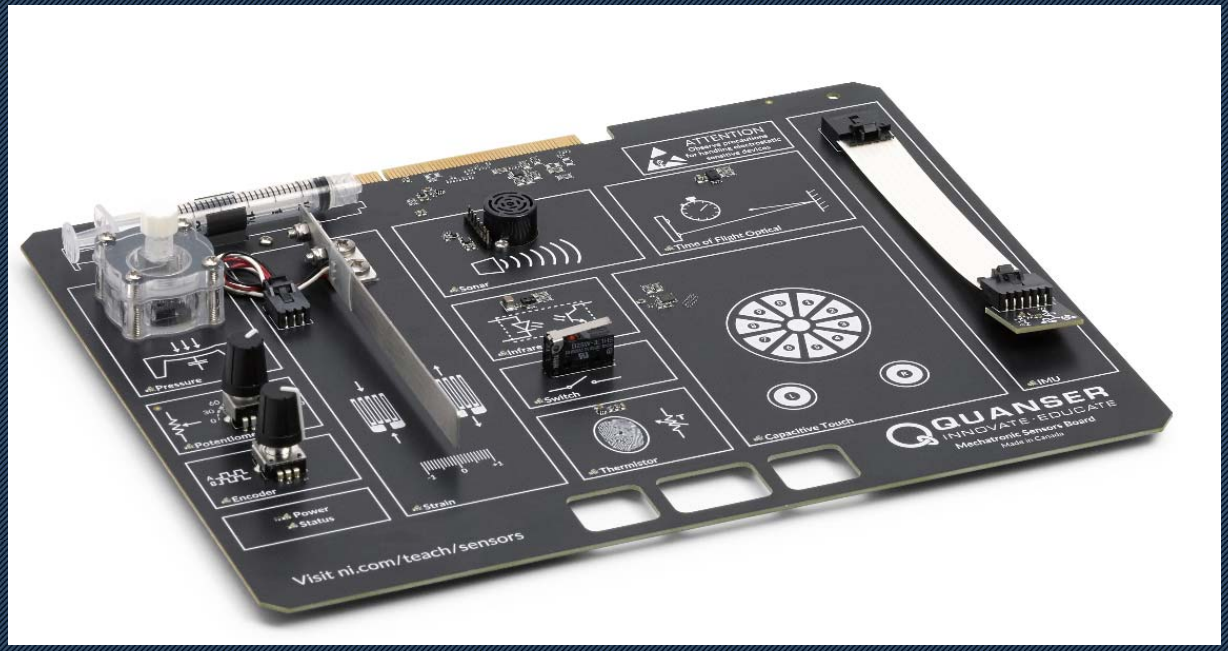
Topic 4: Control System

- Inverted Pendulum Modelling
- Pole Placement
- Optimal Control-Linear Quadratic Regulator
- Swing-Up Hybrid Control

Topic 1: Graphical Programming Tools

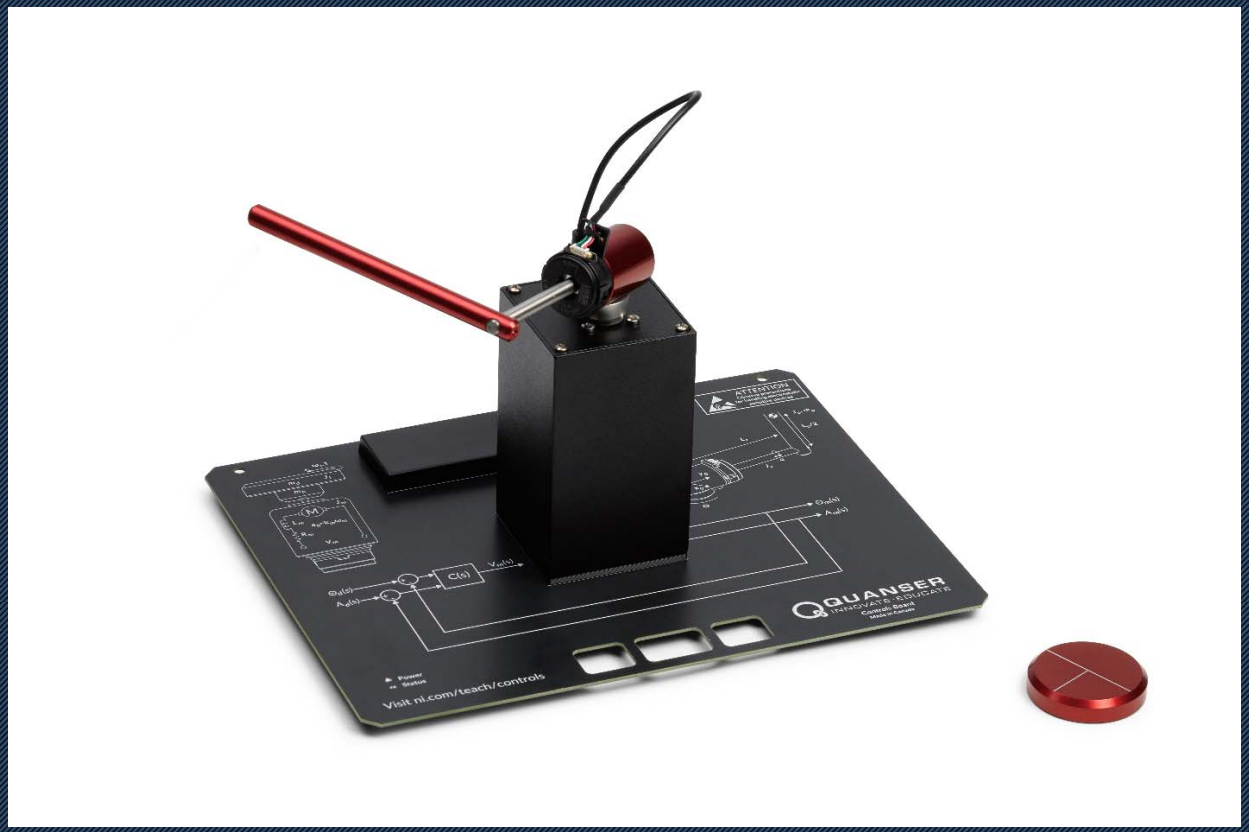
- LabVIEW Environment
- LabVEW Datatypes
- While Loop
- For Loop
- Timer
- SubVIs…

Topic 2: Sensors



- Angular displacement
- Distance and proximity
- Pressure
- Contact
- Inertial Measurement

Topic 3&4: Actuators & Control System



- DC Motor Modelling
- DC Motor Velocity/Position Control
- Inverted Pendulum Modelling
- Pole Placement
- Optimal Control
- Swing-Up Hybrid Control

Group

- Group
  - 4 students
  - 10 groups
  - Student ID
  - Lab session assigned

- Studio, lab reports, group project submission
  - One group member, do not repeat
  - Every group members' names
  - Same grade for every group member

Late Submission

- Studio
- Lab reports
- Group project

Late submission is allowed for the terms marked in yellow with the following rules

$$\text{Late submission full mark} = 100\% \times r^n$$

$r = 0.8$: discounted return coefficient

n : number of late weeks

Lab Sessions

- **Location:** Zone 3-116

- **Times:** Tuesday 8:30 AM– 10:00 AM
  Tuesday 1:30 PM– 3:00 PM

- Attendance is required, signup sheet

Lab Guidelines

- Lab Handouts
- Format Guidelines
  - Lab Memos
  - Full Report
- Lab Grading

Lab Handouts

- Print out and bring handout to lab
- Read the handout before the lab
- Focus on the following:
  - What is the objective of the experiment?
  - “For the Report” and “For the Discussion” sections of the handout.

Format Guidelines

- Memo Reporting
- Full Report
- IEEE Formatting Structure
  - Captions are placed above tables
  - Captions are placed below figures
  - Reference all tables and figures in the text
  - Cite figures and tables if copied from material
  - For Full Reports, table and figure follow their text reference
  - For Memos, tables and figures should be placed on separate pages following the main text.
  - Hand sketches are not acceptable and be sure to label axes when making figures of raw or calculated data.
- Memos and full reports are objective, scientific accounts of the experiment and its results. Avoid the use of personal pronouns (i.e. I, he, she, and we) in the report.
  - “I wired the protoboard according to the schematic shown in Figure 1. I measured the output voltage.”
  - “The protoboard was wired according to the schematic shown in Figure 1. The output voltage was measured.”

Format Guidelines

Captions are placed above tables

Captions are placed below figures

Table 1: Measured hardness (Rc) for samples A, B, & C.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Sample A	65.0	64.8	63.8	65.6	65.2
Sample B	54.0	55.2	54.7	49.0	53.2
Sample C	60.0	58.9	60.3	59.7	59.5

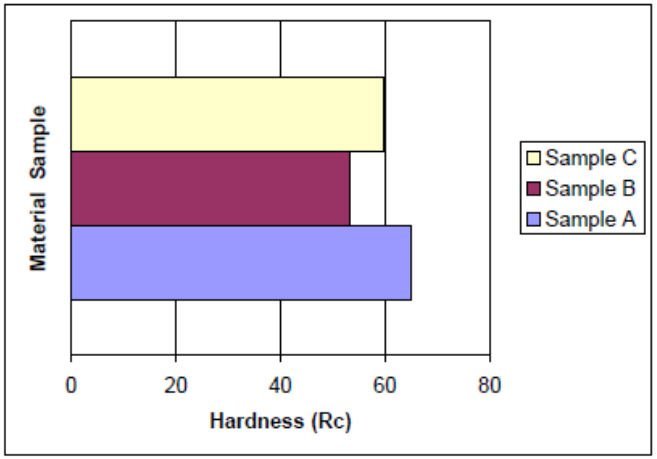
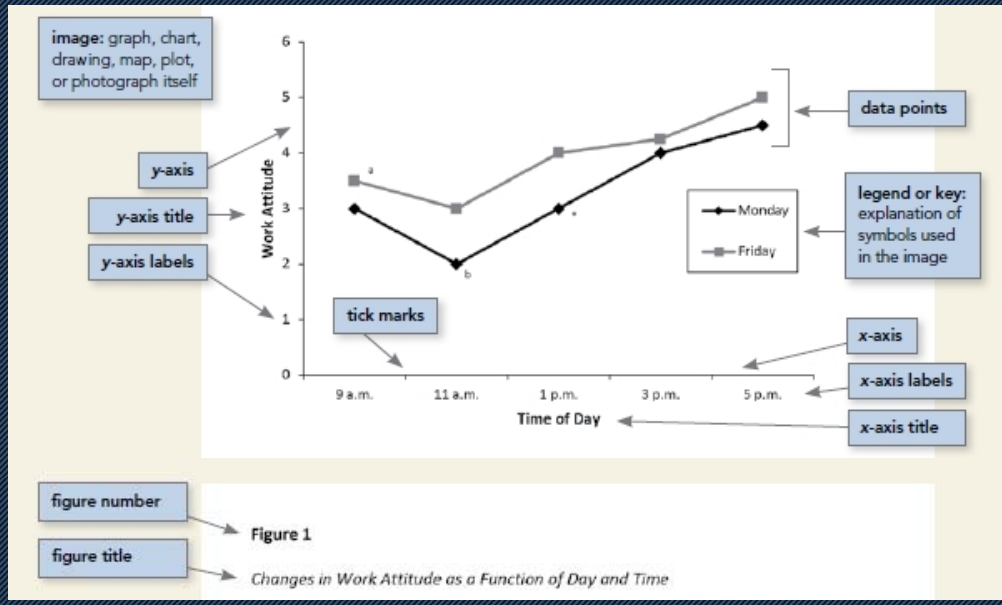


Figure 1: Comparison of the average Hardness (Rc) of the three material samples.



Guidelines for Lab Memos

- The purpose of the memo format is to demonstrate the proper manner for reporting to a supervisor who is not interested in the details of the experiment, but just the outcome. Thus, the memo needs to be a CLEAR and CONCISE account of the experiment
  - What was done
  - What are the results
  - A discussion of the meaning of the results.
- Memos should include:
  - Memo To: , Memo From: , Date , Subject
  - Three paragraphs that make up main text.
    - Objective and Procedure
    - Summary of Results
    - Discussion
- What to avoid:
  - Headings
  - Equipment List
  - Exceeding 1 page of text, more than 3 pages total

Grading TA

MEMO TO: Steve Jones

FROM: John Smith *John Smith*

Student Signature

DATE: January 12, 2003

Objective and Procedure

SUBJECT: Lab #9: Linear Variable Differential Transformers for Displacement Measurements

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Summary of results

On January 5th, Jane Miller and I conducted an experiment to determine the operating characteristics of a linear variable differential transformer (LVDT). In Part A of the experiment, power was supplied to the LVDT by using a 50 mV (RMS) sine wave at 5,000 Hz produced by a function generator. A micrometer connected to the LVDT core was adjusted from 0.0 to 1.0 inches, thus moving the LVDT core through its full range. The RMS output voltage from the LVDT was measured using a multimeter. In Part B of the experiment, the frequency of the power supply was varied from 100 Hz to 150,000 Hz in order to observe the change (if any) in the behavior of the LVDT response.

The LVDT output voltage, recorded as a function of the axial displacement, is listed in Table 1. The data was then plotted to determine the linear operating range of the LVDT. As shown in Figure 1, the shape of the curve indicates that the approximate linear range of the LVDT is from 0.21 inches to 0.83 inches of the axial displacement. The sensitivity of the LVDT is defined as the slope of the LVDT response in the linear range. Using Equation 1, the sensitivity was determined to be 2.12 mV per 0.001 inches of core displacement per 1V of the excitation signal.

The null point of an LVDT is defined as the point in the displacement where the output voltage from the LVDT is zero. As shown in the recorded data from Table 1, the output signal from the LVDT does not actually reach zero volts. This is primarily due to the size of the increment chosen for adjusting the axial displacement. A different increment, smaller than the 0.001 inches used, is needed to find the exact location of the null point. However, based on the recorded data, the null point occurs somewhere in the range of 0.535 to 0.540 inches of axial displacement.

The linear range is the range of the displacements over which the output voltage from the LVDT changes at a constant rate called the sensitivity. From Fig. 1, this range is found to be approximately +/- 0.300 inches from the null point. Beckwith et. al. [1995] provide specifications for LVDT's that indicate typical values for the sensitivity to be in the range of 0.05 to 4.0 mV/0.001 in. / V excitation and for the linear range to be +/- 0.005 inches to +/- 5.0 inches. The observed values for the sensitivity and linear range of the LVDT examined in this experiment fall approximately in the middle of the ranges for the operating characteristics of typical LVDTs.

In Part B of the experiment, the frequency of the excitation signal powering the LVDT was varied for a fixed core position. The RMS output voltage remained constant for frequencies between 950 Hz and 11,000 Hz. For frequencies outside that range, it was observed that the output voltage decreased. Finally, the power supply frequency was set to 100 Hz and the micrometer was adjusted over its full range. The RMS output voltage from the LVDT was significantly lower than that observed in Part A. These two observations confirm that the LVDT is not designed to operate for input frequencies outside the range of 1000 Hz to 10,000 Hz.

Reference to textbook

Discussion

Descriptive caption

Note the use of headings and units

Table 1: Recorded data – LVDT output voltage as a function of the axial displacement.

Displacement (inches)	V out (mV)	Displacement (inches)	V out (mV)	Displacement (inches)	V out (mV)
0.000	53.573	0.485	6.013	0.590	5.666
0.025	51.800	0.490	5.463	0.595	6.216
0.050	49.996	0.495	4.913	0.600	6.772
0.075	48.089	0.500	4.361	0.625	9.524
0.100	46.054	0.505	3.833	0.650	12.260
0.125	43.864	0.510	3.303	0.675	14.983
0.150	41.518	0.515	2.785	0.700	17.723
0.175	39.046	0.520	2.263	0.725	20.447
0.200	36.479	0.525	1.748	0.750	23.141
0.225	33.902	0.530	1.302	0.775	25.830
0.250	31.305	0.535	0.886	0.800	28.515
0.275	28.670	0.540	0.744	0.825	31.192
0.300	26.028	0.545	1.004	0.850	33.845
0.325	23.371	0.550	1.454	0.875	36.481
0.350	20.687	0.555	1.945	0.900	39.075
0.375	17.993	0.560	2.460	0.925	41.508
0.400	15.279	0.565	2.966	0.950	43.913
0.425	12.561	0.570	3.500	0.975	46.056
0.450	9.828	0.575	4.039	1.000	48.068
0.475	7.087	0.580	4.571		
0.480	6.568	0.585	5.118		

Use significant digits when reporting data

Equation for calculating sensitivity:

Sensitivity = ΔOutput signal of LVDT (mV) / 0.001 in (core displ.) / Excitation Signal (V) (1)

= [41.508- 2.460] mV / [0.925-0.560] in / 0.050 V

= 2.14 mV / 0.001 in / 1 V

Equation number

Always include units in calculations

Descriptive caption

Note the use of headings and units

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0.250	31.305	0.535	0.886	0.800	28.515
0.275	28.670	0.540	0.744	0.825	31.192
0.300	26.028	0.545	1.004	0.850	33.845
0.325	23.371	0.550	1.454	0.875	36.481
0.350	20.687	0.555	1.945	0.900	39.075
0.375	17.993	0.560	2.460	0.925	41.508
0.400	15.279	0.565	2.966	0.950	43.913
0.425	12.561	0.570	3.500	0.975	46.056
0.450	9.828	0.575	4.039	1.000	48.068
0.475	7.087	0.580	4.571		
0.480	6.568	0.585	5.118		

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= [41.508- 2.460] mV / [0.925-0.560] in / 0.050 V

= 2.14 mV / 0.001 in / 1 V

Equation number

Always include units in calculations

Note the labeling of important features

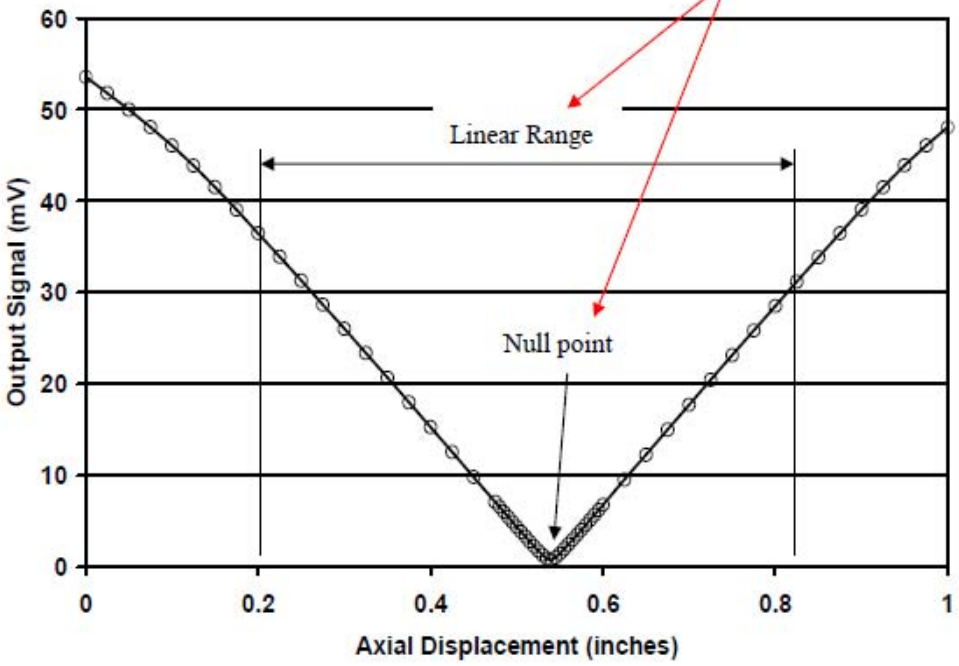

Figure 1: Plot of LVDT output voltage vs. axial displacement.

Reference:

Beckwith, Marangoni, and Lienhard, *Mechanical Measurements*, 5th edition, Addison Wesley, 1995.

Report Grading

The grading of the memos will be based on the following point distribution:

Objective & Procedure	25%
Summary of Results	25%
Discussion	25%
Schematics, Format & Writing	25%
Total	100%

Reporting Format	Percent of Lab Report Grade
Memos (10)	40%
Lab report (1)	40%

Guidelines for Lab Reports

The purpose of the full report format is to describe not only the set-up and the results of the experiment, but also the theoretical background which is the basis for designing and conducting the experiment. Thus, the full report needs to be a DETAILED and COMPLETE account of the experiment.

- Title
- Abstract or Objective
- Introduction or Theory
- Procedure of Methodology
- Summary of Results
- Discussion
- Conclusion
- References
- Appendix

The grading of the full reports will be based on the following point distribution:

Objective	5%
Theory	20%
Procedure	15%
Summary of Results	15%
Discussion	25%
Format and Writing	10%
Schematics and Graphs	10%
Total	100%