ME 1049 Final Project – Summer 2023

This project is to be done by teams.

Objective: To build and demonstrate a microcontroller-based system that addresses a need for a specific user. Each team must define the need that their system will address and then proceed to design, build, test, and demonstrate that system.

Schedule and Checklist (see details in sections below):

Task	Due Date	Points	
Team Formation	**May 26** (submit names of your preferred teammates)		Use this Spreadsheet
Proposal	**June 8** (submit a PDF file to Canvas)	100	Canvas assignment
Check-in 1	**June 20** (remote meeting -- review project plan and submit initial parts request, including motor analysis)	150	Canvas assignment
Check-in 2	**July 7** (remote meeting -- demonstrate fully functioning code and hardware for your motor and two other major elements)	150	Canvas assignment
Final Demonstration	**July 27** (in-person -- submit review form and demonstrate your project)	500	Canvas assignment
Final Documentation	**August 10** (submit files of your final documentation to Canvas)	200	Canvas assignment
Team Evaluation	**August 10** (submit to Canvas)	50	Canvas assignment
Workspace Cleanup and Parts Return	**August 10** (in-person -- return all project parts and lab kit)	100	
		1250 total points	

Grading

Project grades will be based on the following rubric:

project grade = (*scale factor*) X (*total project points*)

Grading Scale Factor

This project is about adding value to a system or task through mechatronics. There are two sides to that proposition – the first is the value added; the second is the effort needed to create that value. The entrepreneur's dilemma is about being able to provide sufficient value to a beneficiary (and reap the rewards for doing so) without expending too much cost (time and funding) that would make the process infeasible. In fact, the goal is to make the reward/cost ratio as great as possible. Your team's possible grade for this project will consider both sides of this dilemma, as described below.

Value Creation vs Effort in Your Mechatronics Project

Mechatronic elements do not offer inherent value. That is, a motor that moves nothing, or a sensor that measures a quantity that no one cares about, is of no value. Mechatronics is used to solve a problem or to add a beneficial feature to a product or task. However, these features don't come for free. It takes time and money to develop a subsystem that moves an object, not to mention the cost of parts, and the more controlled the movement, the greater the cost.

In this project, your team must think of a system or task that can benefit from the use of mechatronics, and you will compile a list of features (mechatronic elements) that will produce that value. Because this is a class project, you will be expected to expend a certain effort to demonstrate that you've met learning objectives. Your maximum project grade will be based on a scale factor, determined by the following steps:

1. List all the features that add value to your proposed system.
2. Define the corresponding mechatronics element(s) (sensor, actuator, etc) that will be used to realize each feature.
3. Using the classes standardized effort estimation (shown below) define the relative effort to implement each mechatronics feature in your system.
4. The scale factor for your grade will be the sum of all effort points.:

   scale factor = Σ(*effort points*)/10

   Scale factors will be capped at 1.0 to achieve a maximum possible grade on the project.

Your feature and element list will be evaluated to ensure that all components add value to the system. The help validate that, you need to calculate the value/effort ratio for each feature as follows:

1. Apply 10 points worth of value to your system, dividing those point among all features (this will ensure that each part does add value).
2. For each feature, divide the value by the effort. The highest ratios are the features that add the most value for the least effort.

Effort Estimations for Mechatronics Projects

Below is a list of baseline requirements plus additional mechatronic features that you may consider adding. For each feature, the relative effort that each would require for implementation in a proof-of-concept protype of the sort that you will create.

- **Baseline** (the baseline for each project is that you will build a physical proof-of-concept prototype system that demonstrates the proposed features by way of an embedded microcontroller, like the ATmega328P; use of Arduinos or similar microcontrollers may not be used to meet baseline requirements).
- **Motor** (*at least one stepper motor or permanent magnet dc motor is required for each project; hobby servo motors are not allowed*) | effort = 2 for turning to one or more desired positions or controlling at one or more specific (non-maximum) speeds
  - effort = 1 for simply running at max speed (this is simply an on/off device)
  - effort for each subsequent similar motor use is 0.5 less

- **Other similar output devices or actuators** (e.g. solenoid, heater, etc.) | effort = 2 for controlling to one or more (non-maximum) operating points
    - effort = 1 for simply operating as on-off device
    - effort for each subsequent similar actuator use is 0.5 less
- **LCD, 7-segment, or similar display** | 2 points
    - effort for each subsequent similar LCD device is 0.5 less
    - effort for each addition 7-segment display = 1 less
- **Binary outputs** (e.g. LEDs) | effort = 0.5
    - up to 3 of any one type may be used to accumulate effort points
- **Power electronics** utilizing PWM or wave-control (H-bridge, amplifier, etc.) | effort = 1 each
    - effort = 0.5 for relays or other on/off power electronics
- **Voltage regulator** | effort = 1
- **Analog measurement** | effort = 1
    - effort = 0.5 for each subsequent analog measurement
- **Binary input** (e.g. switches) | effort = 0.5
    - up to 3 of any one type may be used to accumulate effort point
- **Microcontroller functions** not already included in other features (e.g. interrupts, delays, serial communication, etc.) | effort = 0.5 each
- **Battery power** | effort = 1
- For other features or components not listed above (e.g. wireless communication, etc.), your team may make a case for the effort required

An example table of value and effort for a project is shown below.

#	Feature	Description	Mechatronics Element	Effort	Feature Value	Value/Effort Ratio
		Example: This [element] does [action on a person or thing] to [accomplish something of value in the system].				
1	Goalie automatically moves to ball	This motor moves the soccer goalie to block the ball.	Stepper Motor	2	6	**1.2**
1		This H-bridge provides power to the stepper motor.	H-bridge	1		
1		These sensors are arranged in “zones” to detect where the ball has been kicked so that they system can properly move the goalie to block the shot.	IR Break Beam Sensors (5)	1.5		
1		Serial communication is used to communicate between one microcontroller that detects the ball and one that controls the motor.	Asynchronous Serial	0.5		
2	Automatic scoring and display	This display shows a count of successful goals.	7-segment display	2	3	**0.5**
2		This display shows a count of shots blocked by the goalie.	7-segment display	1		
2		This sensor detects when a shot has been blocked.	Vibration Switch	0.5		
2		This interrupt is triggered by the vibration sensor to record a blocked shot.	Interrupt	0.5		
2		This switch is used to detect when the ball has entered the goal.	Push-button Switch	0.5		
2		This interrupt is triggered by the switch to record a goal.	Interrupt	0.5		
2		A delay is used to prevent switch bounce of the goal sensor.	Delay	0.5		
3	Ready Status Displayed to User	This LED indicates that the goalie is ready for a new shot after resetting to its home position.	LED	0.5	1	**2**
			Total	11		
			Scale Factor	**1.1**		

Schedule of Tasks:

Any submissions for this project are to be done via Canvas links unless otherwise specified. Only one submission is needed per group (except for the teammate evaluation, which is to be done individually).

Team Formation

If you wish to form your own full team (three students) or partial team (two students), use the [spreadsheet link posted on Canvas]() and enter the names of your team on a free row. All students will be placed on teams after this date.

Proposal

Each team must submit a proposal for the system of their choice. You are required to describe the problem to be solved by your automated system and in a table (as in the example above) list the mechatronic elements to be included, what role the element plays in the system, its value added, and the relative effort required to implement it. Calculate the scale factor to be applied to your project.

Grading Rubric for proposal:

1. (50%) Write a short story (half page or less) that describes the need to be addressed by your proposed system. The story must clearly define who will benefit from the system and there must be sufficient detail to understand the important features of the system that add value (mark these with superscripts to match those in your table of effort and value). Note that this is not to be a list of mechatronics elements and technical jargon – describe your system in nontechnical language.

   For example, instead of saying, "We will build an automatic door opener that includes a sensor to detect a person in the door and a motor to move the door. The sensor will be a model XR28…," describe the system through a story, like, "As usual, Mary was juggling multiple tasks as she approached the lab door, one arm full of packages that she had just picked up that contained supplies for the next round of experiments to be run, and the other holding her life-saving coffee. As she neared the door, she had to decide which load to put on the floor as she dug out her ID card to swipe and unlock the door and then open it. How wonderful, she thought for the millionth time, if the door could just see me coming[2] and automatically open[1]…even better if it could somehow recognize me so that I didn't even have to take out my ID card[3]…. The proposed system will solve the problem in this story by…"

2. (50%) Provide a table that includes:
   - a list features of your proposed system that solve the problem posed in the story
   - the corresponding mechatronics element(s)
   - the relative measure of effort to implement each element (from the list above)
   - a tabulation of the grading scale factor for your project
   - a tabulation of value/effort ratio for each feature.

   Use the example table provided above as a template.

Within approximately one week the proposals will be reviewed, and feedback will be provided so that you can begin working on the project with an idea of the final projected grade.

Project Proposal

Team # ________

Names: _________________, __________________, _________________

1. A short story (half page or less) that describes the need to be addressed by your proposed system. In the description, use superscript numbering for each feature that list of features in the table below.

2. Table of mechatronic elements of your system. Use the example above as a template.

Ordering Parts, Fabrication, and Testing

Once you've defined your system, you may begin collecting parts and building the system.

Parts: In building your mechanism, groups may make use of any parts and materials that you provide on your own, and any of the wide variety of power electronics, sensors, motors, and valves already in the lab. The TAs can help to determine if materials exist for your specific project needs. Materials are also available in the Makerspaces for general fabrication and prototyping. In addition to these parts, groups may request up to $100 in materials for their projects from qualified vendors. More information about hardware purchases will be provided. For parts that need to be purchased, you must consider the following vendors:

Adafruit (diy electronics, sensors, robotics)
Digi-Key (electronics)
Grainger (general industrial tools and parts)
Home Depot (only for fabrication materials)
Jameco (electronics – good source for power supplies, batteries, connectors)
Lowes (only for fabrication materials)
McMaster-Carr (general materials and mechanical parts)
MSC Industrial Supply (general industrial tools and parts)
Mouser (electronics)
Newark (electronics and instruments)
Open Builds (framing and linear motion stages)
Pololu (diy electronics, sensors, robotics, our preferred site for motors)
ServoCity (diy electronics, sensors, robotics)
Sparkfun (diy electronics, sensors, robotics)

Parts will be ordered weekly. Submit your part requests using the Parts Order Form spreadsheet linked on Canvas. Any parts on the list by 5pm on Friday will be ordered that weekend. Once you've placed an order, monitor the sheet so that you know when to pick up the parts from a TA. Note that all parts must be returned at the end of the semester.

Fabrication: You will likely need to fabricate parts for your projects. You are encouraged to use the Makerspaces for fabrication since the processes available there are well-suited for the level of prototyping needed in these projects. ***You may not use SCPI without prior approval of Dr. Clark.***

Testing: Testing of your systems may be done in the SB27 lab, the Makerspaces, or any other available space in Benedum.

Check-in 1: This Check-in will be done by Zoom at designated times (a sign-up link will be available) and must be completed by end of due date.

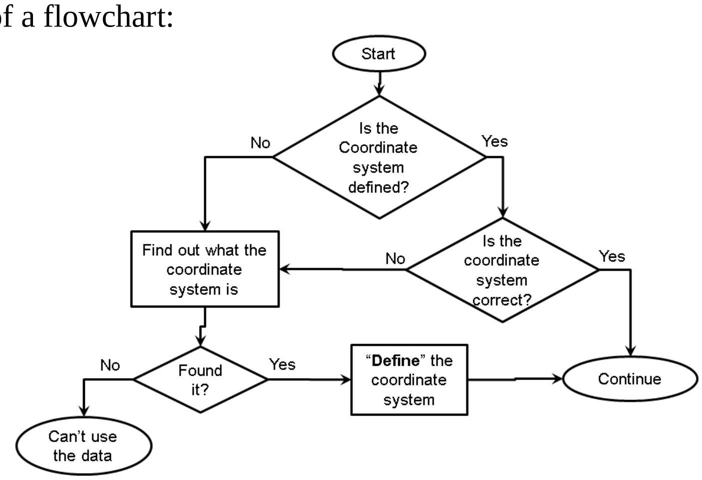
Prior to the Check-in, submit *a single* PDF document to Canvas with all required documentation listed below *in the order listed*. The document will be reviewed during the check-in.

During Check-in, all team members are to meet with the instructor or TA to review the project plan and initial parts request.

Any initial parts placed on the Parts Order Form by the time of this check-in will be reviewed.

Before Check-in 1, teams must submit a single document for review including:

1. Updated story from your proposal (track changes if there are any, otherwise just submit the previous version)
2. A sketch or basic CAD model of the system so that it can be described during the Check-in.
3. Updated list of mechatronics elements from your proposal (track any changes or submit the previous version if unchanged).
4. A flowchart or operation diagram that describes the operation of your system (think of this as the basis for pseudo-code and then real code for your system)
   Example of a flowchart:



5. A list of which team members will be responsible for what parts of the system. The best way to do this may be with a Gantt chart (e.g. Teamgantt). Address all aspects of the project, from start to finish, including:
    - Each feature
        - Physical hardware development
        - Software development
        - Testing
        - Integration with full system
6. Show an analysis of how at least one motor and power electronics were selected for the project:
    a. Explain which motor is being analyzed (where is it in your system, what it does, show a schematic of the portion of the system being moved by the motor)
    b. show estimates for required speed and torque and explain how those estimates were made. *A free body diagram and full force/torque analysis of your system must be shown.* Show the derivation for required torque and speed in variable form and then show the final calculations in numeric form. Do not attempt to show this by way of Matlab code or a spreadsheet.
    c. Show how motor voltage and current requirements were determined for your motor, and how these numbers correspond to the selected power electronics to be used in the system. Specify the chosen motor and power electronics parts to be used. Note that this information is necessary before any motors or power electronics will be purchased.
7. An explanation of what three mechatronic elements will be demonstrated during Check-in 2 (the demonstration must include fully functioning code and a physical demonstration). In the interest of making significant progress, these should be the elements of highest effort in your table. Highlight these in your table for Item 3.

Check-in 2: This Check-in will be done by Zoom at designated times (a sign-up link will be available) and must be completed by the end of the due date.

Submit ***a single PDF document*** to Canvas with all required documentation listed below ***in the order listed***. The document will be reviewed during the check-in.

All team members are to meet with the instructor or TA to review the project plan and demonstrate progress to date.

Any initial parts placed on the Parts Order Form by the time of this check-in will be reviewed.

Before Check-in 2, teams are expected to submit for review updates to parts 1-6 from the Check-in 1 document. Track any changes. For any parts that are unchanged, just resubmit the earlier version.

During Check-in 2, teams must demonstrate three major mechatronics elements.

Final Demonstration (in-person)

The system must be demonstrated to the instructor. All team members must be present during the demonstration. A sign-up form for scheduling your demonstration will be made available.

For demonstration, fill out the Final Grading Form shown below ***prior to demonstrating your project*** (one per team).

MEMS 1049 Final Project Grading Form
Group #: _____ Names:
Proposed Project (this is the project plan that received a projected grade)
Project Story (What problem does it solve? How? Expand this box as needed.):
List of elements of your mechatronic system
Actual Final Project (list any differences from the approved proposal)
Project Story (show changes from proposed project)
List of elements of your mechatronic system (show changes from proposed project)

Final Documentation

Final documentation consists of three parts: documentation file, video, code.

Documentation File: Submit final documentation in a PDF file to Canvas. Include final versions of items 1-6 from Check-ins 1 and 2, plus item 7 shown below. Do not show any tracked changes in your final documentation.

1. Description: the updated story of your system, including photos, sketches, or diagrams.
2. Model: a high-quality sketch or basic CAD model of the system (CAD does not need to be of enough fidelity to fabricate the system but must convey the operational concepts).
3. Updated list of mechatronics elements in your system.
4. A flowchart or operation diagram that describes the operation of your system.
5. A list of which team members were responsible for what parts of the system.
6. Your most updated motor analysis.
7. Schematic(s) of the electrical circuit(s) used in your system.

Video: Provide a short video of the operation of the mechanism/system. Start the video with a brief explanation of the story and the need that your system addresses, then show it in operation. Selected videos and/or documentation may be shared with future classes.

Code: Submit the C code for your project to Canvas.

Grading Rubric of Final Documentation: Final document is 50%, video is 35%, code file(s) are 15%.

Team Evaluation

Each team member must complete and submit a teammate evaluation (a Canvas link will be provided).

Team Evaluation for MEMS 1049 Projects

Group # ______

This information will be kept confidential (I will not share it with your teammates), and it *will* be considered in determining your project grade.

Your Name: ______________________________

Your Teammates' Names: ____________________________________,

____________________________________,

____

What tasks did you do in completing your MEMS 1049 final project?

What tasks did your teammates do in completing your MEMS 1049 project?

Of the total effort and knowledge applied toward achieving the final grade on your project, how much is attributable to you and how much is attributable to your teammates?

My Contribution = _______%

__________________________'s Contribution = _______%

__________________________'s Contribution = _______%

__________________________'s Contribution = _______%

Total Contribution = 100 %

Workspace Cleanup and Parts Return

Each group must clean all of their project materials from the lab and return all hardware to its proper place in the lab. At this time the TA will confirm that your workspace and materials are sufficiently restored to their proper conditions.

Examples of Previous Projects (see Canvas for example past projects)

- Maze solvers (and combined fire extinguishers or metal detectors)
- Baseball pitching machine controller
- Digital umpire
- Automated Zamboni
- Automated golf ball loader (for driving range)
- Automated mixing valve for water
- Vehicle that tracks a path
- Pin-ball machine
- Player drum set (like player piano, but learns from listening)
- Robotic dog
- Automatic fish tank cleaner
- Automated coffee maker
- Player piano
- 3-axis milling machine
- Miniature car wash
- Conveyor belt system
- Draw bridge
- Automated assembly line
- Package sorting system
- Putt-Putt golf game
- Automated saw mill
- Model sustainable house
- Automated river lock system
- Automated drag race track
- Slot car race track
- Electronic etch-a-sketch
- Automated trainyard
- Front door message system
- Formula SAE projects:

3. Electronic shifter
4. Traction control