# Electric Motorcycle Testing Conceptual Design

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## I. Introduction

Electric Vehicles (EVs) are evolving and exhibiting a presence in all areas of the world. With this development, there is difficulty in complying with the various charging requirements to support worldwide usage. To address these challenges, Proton Power is developing a battery that will demonstrate significantly faster charging and expanded range. In response, this project will display the utilization of an integrated data acquisition system (DAQ) into a constructed chassis dynamometer to obtain important data to enhance and prove this battery's capabilities. Correctly choosing and integrating sensors into the system is a predominant factor in receiving accurate input and delivering the optimal output. Therefore, extensive testing will take place throughout the design. In addition to ensuring product effectiveness, the device must comply with necessary standards and engineering ethics to validate overall safety. In the following sections, this conceptual design will precisely outline the overall system but allow fluctuation in decisions considering certain hardware and software selections.

### *A. Formulated Problem Statement*

This dynamometer system is expected to capture the data necessary to develop a software model of the motorcycle. This model will mathematically predict the differences and impacts of changing the battery types that supply power to the motorcycle. The function constraints and expectations of the dynamometer are listed below. The dynamometer shall:

1) Be transferable and not permanently fixed to one location.
   a. This constraint comes from Proton's request to ship the apparatus to various locations.
2) Be able to safely operate the motorcycle up to 85 km/h.
   a. This constraint comes from the specification sheet of the Bob motorcycle, which states a max speed of 85 km/h (see appendix Figure 6).
   b. The stand should be able to support safe operation up to speeds of at least 85 km/h.
3) Capture and display relevant testing data in real-time and be transferable.
   a. This is a requirement from Proton to monitor and operate the motorcycle effectively and efficiently.
   b. Having transferable data allows Proton to share the motorcycle's capabilities with other parties.
4) Be able to be fully operated remotely.
   a. This constraint was created for safety and approved by the customer.
   b. This allows the stand to test a motorcycle with minimum safety risk to operators.
5) Comply with all relevant codes and standards listed in *II. Ethical, Professional, and Standard Considerations,* Section B below.
   a. This is required to ensure safe operation and compliance with all relevant regulations.
6) Contain a standalone harness with sensors that can be temporarily fixed to the bike to verify the dyno data.
   a. This requirement comes from Proton to verify the accuracy of the measurement from the dyno stand.
   b. This constraint also incorporates redundancy, which will identify sensors on the dyno or harness that distribute inconsistent data.
7) Support incline/decline testing up to 8% road grade.
   a. This constraint comes from Proton wanting to verify the motorcycle's ability to handle different road grades (hills).
   b. This requirement contributes towards developing a model of the motorcycle's dynamics.
8) Support repeatedly testing the bike from 0km/h to 50km/h and then back down to 0km/h.
   a. This constraint is a direct request from Proton.
   b. These are specified values required to build a Hamiltonian model of the motorcycle.
9) Be able to adjust operating speed in 1km/h increments and measure response time.
   a. This constraint is a direct request from Proton.
10) Display values on a single PC using pre-existing dyno software.
    a. The PC display is a customer requirement to see the data being gathered.
    b. The customer advised using existing dyno software to prevent too much time spent developing software.
    c. This could prevent the project from being completed within the capstone duration.
    d. The customer agreed the team should find something available to purchase.
11) Support weights up to 400kg on the motorcycle.
    a. This constraint is a testing requirement given by Proton.

b. The customer wants to test the motorcycle with various weights up to 400kg.

12) Be tested with motorcycle batteries having a charge of at least 50% capacity.
    a. This is a constraint from Proton.
    b. The motorcycle should not be tested with batteries with less than a 50% charge.
13) Be able to simulate the braking system of the motorcycle.
    a. The customer has specifically requested the ability to conduct brake testing from 50 km/h to 30 km/h.
14) Support the motorcycle being powered and operated with the original 72V-20A batteries until the prototype batteries are available.
    a. The customer plans to have new battery technology available for testing in the Fall of 2024.
15) Alert users of risk and ensure they are following correct procedures.
    a. Prompt user on the user interface with: "Operating a vehicle on a dyno can be dangerous and cause great harm or death if operated incorrectly. Ensure the bike is securely fastened to the dyno and no loose objects are hanging near the bike. Push accept if you have ensured the bike is safe and secure for operation."

## II. Ethical, Professional, and Standard Considerations

With this project, there are numerous ethical, professional, and safety considerations that must be considered. This stand will be tested with extremely heavy and fast-moving loads along with dangers that must always be considered when working with electricity. To make sure that safety is the top priority there will be several codes and standards followed as well as safety measures put into place. Therefore, there must be a detailed review of the broader implications that this project produces to ensure that all safety considerations have been accounted for.

### A. *Ethical*

With this project, a primary ethical consideration lies in ensuring complete transparency and accountability with all direct stakeholders involved. This entails providing comprehensive information about testing procedures, the obtained results, and any significant limitations or challenges encountered throughout the project. By prioritizing transparency, trust can be fostered between the project team and stakeholders, ensuring that customers always have access to accurate information.

Furthermore, safeguarding the safety and security of any private data utilized is paramount. IEEE 7002-2022 serves as an ethical code governing data privacy and security, and it will be diligently implemented to prevent unauthorized access or misuse of data [5].

Proton Power and Bob's mission is to develop affordable and efficient electric motorcycles that can be widely distributed, particularly in third-world countries. As part of this project's ethical considerations, it is crucial to uphold this mission. This will be achieved through exhaustive testing of the motorcycles, providing Proton Power with valuable insights for making future improvements. By doing so, the project ensures accessibility to all members of society, irrespective of their socioeconomic status or geographic location.

### B. *Standards*

Within the different sets of codes and standards, different ones apply directly to the testing stand the team is designing/building. These must be complied with. The following apply:

*1) NFPA 70&79* [1][2]: NFPA 70 is the National Electric Code (NEC) that holds all standards for electrical installations including wiring, installing, and safety regarding electrical aspects. NFPA 79 is the standard for electrical machinery which a testing stand would fall under.

*2) IEC* [3]: The International Electrotechnical Commission provides guidelines and protocols that will be necessary to follow for this project.

*3) OSHA* [4]: Standards from OSHA ensure workplace safety and work to protect all employees from harm, which is essential for this project due to its risk to humans.

*4) IEEE* [5]: IEEE provides a set of ethical guidelines essential to a project.

### C. *Broader Impacts*

The impact of this project extends beyond its immediate goals, encompassing broader implications within the realm of electric vehicles (EV) and societal advancement.

The primary broader implication of this project lies in its contribution to the advancement of electric vehicle technology by providing Proton with the necessary information to develop a battery with a vastly extended range. This contribution facilitates the ongoing advancement of EV technology. The integration of the data acquisition system (DAQ) into the EV bike stand enables comprehensive testing, thereby optimizing battery performance and efficiency. This technological advancement not only benefits Proton Power and Bob's mission to produce affordable and efficient electric motorcycles but also propels the entire EV industry forward.

Furthermore, by aiding in the development of the EV industry and facilitating the adoption of EVs in third-world countries, this project significantly reduces carbon emissions and mitigates the environmental impact of transportation. Prioritizing the development of sustainable and accessible transportation solutions, this project aligns with global efforts to combat climate change and promote environmental sustainability.

Also, this project contributes to Proton Power and Bob's goal of making affordable and efficient electric motorcycles accessible worldwide. A broader implication of this project is providing communities with efficient transportation solutions.

### D. *Constraints Derived From Broader Impacts:*

A fully functioning chassis dynamometer can pose many different risks to the work environment and the workers in it. Moving mechanical parts is extremely dangerous, and testing equipment. The standards section addresses some of these risks and how to prevent them.

The team has decided to take each of these risks into account and enact constraint number 15 to help users ensure maximum safety and correct procedures are followed.

## III. Block Diagrams

To fully capture the design and functionality of the test stand, 3 main subsystems have been developed and are portrayed in Fig. 1. Within these, branch a combination of 6 more subsystems. The following sections describe each subsystem in more detail and how they will meet previously stated requirements and constraints.

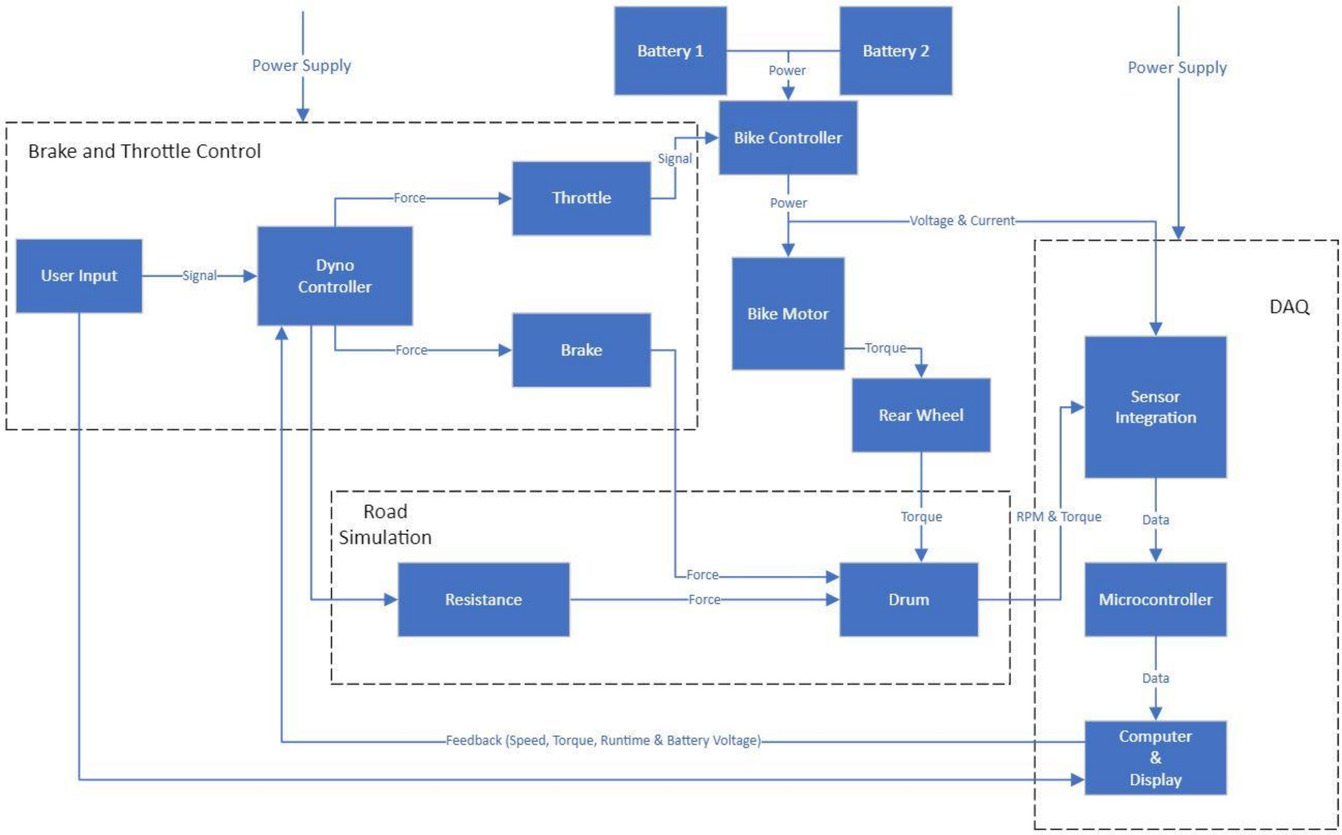


Fig. 1. Overarching Block Diagram

### A. *Data Acquisition (DAQ)*

The data acquisition (DAQ) subsystem exhibits indispensable attributes that elevate its importance above the other subsystems. Although the dyno would not be operable without the combination of the following subsystems, they would not correctly function, if able to at all, without the implementation of the DAQ. The importance of this subsystem can be gathered through it presenting a solution to the most important constraint: capturing and displaying relevant testing data in real-time. The DAQ resolves this constraint through a process containing signal conditioners, signal converters, a controller, and software. Through the execution of correctly applying these systems, accurate, real-time data will be derived to support the generation of a model.

<u>Input:</u> Sensor signals

<u>Output:</u> Analyzable digital data

<u>Applicable Constraints:</u> **3, 10**

<u>Design Verification:</u> Verification of the DAQ's functionality will entail various tests to ensure its ability to accurately distribute usable, displayable data to other subsystems. Upon observing each system receiving correct data, it can be gathered that the DAQ successfully resolves constraint **3**.

*1) Signal Conditioning:* Signal conditioners that are implemented into the design will be responsible for modifying signals from the sensors to generate a usable input for the DAQ. This conditioning may include amplification, filtering, etc. With this, the DAQ will then be able to accurately and sufficiently capture and process data from all implemented sensors.

<u>Input:</u> Raw sensor signals

<u>Output:</u> Conditioned electrical signals

<u>Applicable Constraints:</u> **3**

<u>Design Verification:</u> To test the accuracy and precision of the signal conditioner, various tests comparing the conditioned signal with the physical value will be run. This will determine the amplification needed to get an accurate value. Additionally, testing that the signal is within the

expected tolerance will also occur. This verification will ensure the resolution of constraint **3**.

*2) Signal Conversion:* For a sensor to be processed through the microcontroller, it must be presented as a digital signal. This is generated from the analog signal, that is provided by the sensors. This is where the use of an ADC, or Analog to Digital Converter, comes in to use. The ADC takes the signal that is being conditioned, through amplification or filtering, and converts this signal to digital form. This allows the signal to be analyzed and used in the microcontroller.

Input: Amplified or Filtered Analog Signals

Output: Digital Representation of Input Signal

Applicable Constraints: **3**

Design Verification: To correctly verify that the Signal Conversion is correct, a design involving known values will be tested. Doing this will involve an input with a verified output and using the input to compare with what the output will give.

*3) Controller:* The controller plays a significant role in the data acquisition system. It will acquire the information given from the signal conversion and sensors, and generate information and proper signals for the software to display.

Input: Digital Representation of Signals from Sensors

Output: Processed Digital Data

Applicable Constraints: **3**

Design Verification: To ensure that the values being received are correctly handled, various testing will be conducted. This testing includes comparing the values given in the microcontroller datasheet with measured data. Additionally, ensuring that proper signals are being sent and giving an accurate output will give assurance that the controller is being properly used.

*4) Software:* Along with the controller, there will be a requirement to have dyno-specific software that will be able to read from the sensors and microcontroller. This software will have the ability to faciliate all aspects of the data received from the sensors. With this, the ability to define parameters and visualize data come to life. This software may include, but not limited to, LabVIEW, MATLAB, Python, etc. With the proper application of this, the ability to retrieve and display real-time data is achieved.

Input: Processed Digital Data

Output: Displayed Analyzable Data

Applicable Constraints: **3 and 10**

Design Verification: To verify the accuracy of the information being displayed, mathematical equations will be used to derive the expected output and then compared with measurables to assure that the data displayed is accurate. Conducting these tests on all used applications is important to rid of misconnections or faulty code.

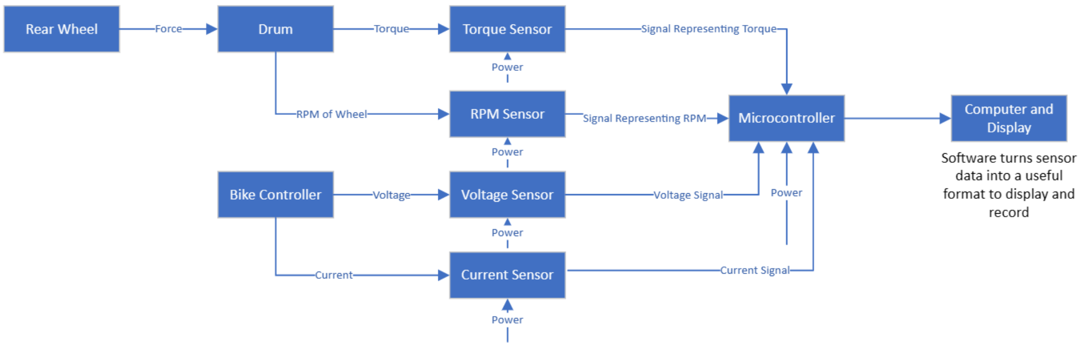


Fig 2. DAQ Block Diagram

## *B. Sensor Integration*

The sensor integration subset of the DAQ subsystem shall provide measurements of metrics critical for monitoring the dynamometer's condition and the motorcycle's performance output.

Input: Each sensor transmitting to the microcontroller

Output: Displaying the metrics measured and outputting to the dyno controller.

Relevant Constraints: **3, 6, 8 and 10**

Analytical Verification: All sensors are successfully supplied with power sufficient to operate as designed and transmit data compatible with the DAQ microcontroller. The sensors should be accurate enough to produce consistent measurements with identical repeated testing procedures.

*1) Voltage:* Voltage is measured to assess the condition of the DC power supplied by the batteries, which will directly affect the bike's performance. Measuring the voltage over time will also reveal the batteries' discharge lifespan.

Input: Bike controller powering the drive motor.

Output: Voltage supplied to the drive motor.

Relevant Constraints: **3, 6, 10 and 14**

*2) Current:* Current is measured to assess the amount of DC power consumed by the bike's drive motor during operation. Measuring the current drawn over time will also reveal any change in amperage over the batteries' discharge lifespan.

Input: Current drawn from the drive motor.

Output: Power consumed by the drive motor in wattage.

Relevant Constraint: **3, 6, 10 and 14**

*3) Torque:* Torque is measured as the force exerted by the bike's rear wheel onto the drum using a load cell or similar force measurement device that is part of the drum roller assembly. The load cell measures the force as the bike's wheel tries to rotate the drum against resistance. Torque data with RPMs will be used to calculate the bike's horsepower.

Input: Load transducer on the drum

Output: Bike torque applied to the drum.

Relevant Constraints: **3 and 10**

*4) RPM:* RPM is measured using a sensor to detect the rotational speed of a component, in this case, a drum roller. These sensors can be optical, magnetic, or based on other principles that allow them to count the number of rotations within a given period. RPM and torque data will be used to calculate the bike's horsepower.

Input: Sensor measuring the rotational speed of the drum.

Output: Rotational speed of the drum.

Relevant Constraint: **3 and 10**

*5) Acceleration:* Acceleration is measured by recording the change in speed or velocity over time. It is calculated by the rate of change of RPMs over time elapsed.

Input: RPM and Runtime input to DAQ.

Output: With software, calculate acceleration of the bike.

Relevant Constraint: **3 and 10**

### *C. User Interface*

The purpose of the user interface sub-system is to allow the user as much ease in testing/data receiving as possible. This system will allow full remote access to control the bike and the test stand equipment, and it will utilize PC/laptop software tools for easy control. Along with this, it will display and capture the data received through testing. As a result, this subsystem will work very closely with the DAQ system. The user interface is an essential part of the system because it will control every part of testing from beginning to end, specifically using parts 1-3 listed below.

Input: various signals (see 1-3)

Output: various signals (see 1-3)

Applicable Constraints: **3, 4, 8, and 10**

Design Verification: To verify the team's design of a computer user interface, the completed computer design will have to successfully be able to send out communication signals. This can be tested by changing the parameters of the UI and watching the output change (using a simple LED circuit to test.) The UI will also have to be able to display input display input data. This can be tested by sending it different magnitude signals and having it plot/display them as if it were the DAQ data (could use a simple microcontroller).

*1) Test Setup Configuration:* The system will allow for user-loaded parameters for the bike's operation on the test stand. Examples of some changeable parameters will include desired speed, desired motor throttle, resistance (for road grade testing), and resistance (for braking applications.) The user interface will also allow for the design of a specific test to be run automatically without hands-on control. Instead of a user hand-changing each parameter in real time (unless preferred), they have the option to preset a test to complete different tasks and respond to different actions. For example, a customer would like to test from 0-50 km/h in a span of 30 seconds. This will be able to be pre-configured and tested automatically.

Input: User-specified testing parameters

Output: Signals for communication with test equipment

*2) System Feedback:* The system will deliver precise data back to the user for optimal analysis and changes to be made. This feedback will include metrics such as motor RPM, wheel speed, wheel acceleration, drum resistance, and torque. This will allow the bike control system to know if it needs to throttle up/down or if the dyno control system needs to apply less/more resistance.

Input: Data (signals) from DAQ

Output: Signals for communication with test equipment and visual/numerical representation of received DAQ data (for user)

*3) Data Visualization:* This system will allow for real-time performance metrics to be displayed in a visually appealing format. This includes motor RPM, bike acceleration, bike speed, slope (if being tested), torque, time, motor voltage, and motor current. This data will be displayed numerically as well as graphically on the same PC/laptop that is controlling the test parameters (requested by the customer in constraint 10. It will also allow the user to save the test data to a file if preferred.

Input: Data (signals) from DAQ

Output: Visual/numerical representation of received DAQ data (for user)

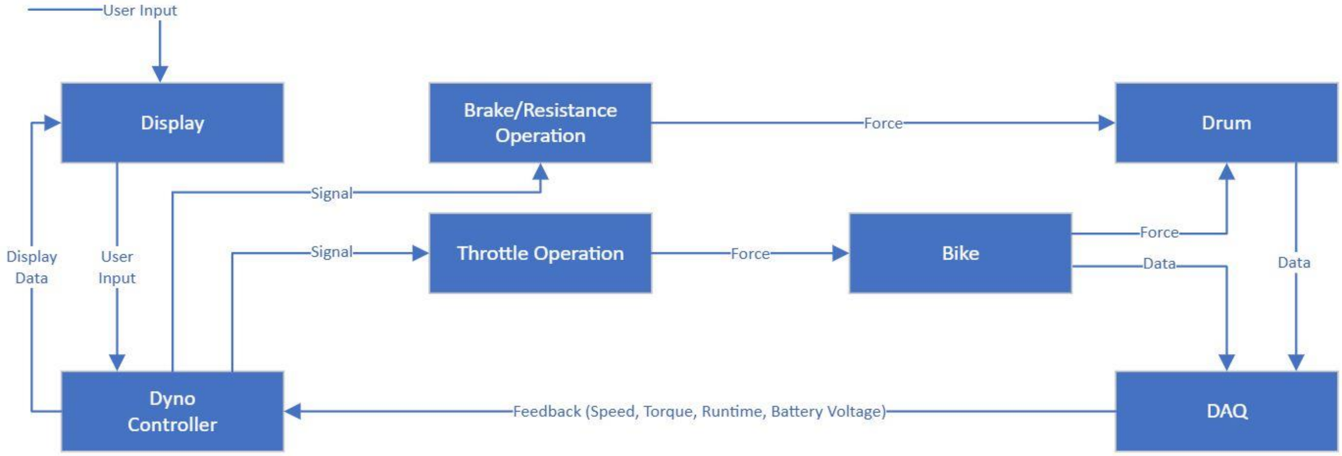


Fig 3. User Interface Block Diagram

## D. Throttle Control:

Due to constraints **4**,**8**, and **9**, the test subject must have external throttle control that will ideally be operable from the display location. This will allow the speed of the bike to be controlled from a safe distance. This will also allow the user to test the bike under specific testing parameters determined by the user.

Input: Desired bike speed

Output: Controlled throttle actuation

Applicable Constraints: **4**, **8**, and **9**

Design Verification: To verify the design of the throttle control system the output speed of the bike must be viewed in accordance with the input from the user. This system will be considered a success if the input speed and test parameters set by the users match not only the output speed given by the bike but also the speed determined by the sensors. This will verify constraint number **4** by confirming the system is remotely operatable. To confirm constraint **8** the remote throttle system must also be able to accelerate the bike up to 50 km/h and then back down to 0. The output speed determined by the sensors can confirm this constraint. The last constraint that needs to be verified is constraint **9** which is incrementing the bike by 1km/h increments. This can also be confirmed by analyzing the output speed of the bike and confirming that the calculations performed by the controller sent to the actuator precisely control the throttle of the bike.

*1) Actuator:* This system will have the ability to physically turn the throttle of the bike remotely. This system will require a force strong enough to fully rotate the throttle handle of the EV bike. This system must be able to be operated by a controller so that it can rotate the throttle handle up to 180 degrees at specific measurements defined by the user.

Input: Speed calculations for the motor.

Output: RPM of the bike.

*2) Controller:* This will be a closed-loop control system having the ability for feedback typically to a controller. This system will take inputs from the user and the speed of the bike and send a signal to the actuator that can control the throttle. This system will allow the user to set test parameters that way the bike can go through test runs and achieve specific speeds at increments that the user wants. This system must be able to be programmed and perform calculations based on real-time data to determine the adjustments that need to be made to the throttle of the bike to match the user input.

Input: User interface Input.

Output: calculated signal to adjust RPM.

## E. Brake Control

The braking subsystem portrays characteristics that increase its complexity above the other subsystems. Although complex, the correct and accurate design of this system exhibits extreme importance as it satisfies one of the main requirements: the ability to test at different, variable speeds. Without the ability to slow the bike from different speeds, tests on the deceleration would prove extremely difficult. This subsystem will allow for resistance to be applied to the drum/roller to reduce speed to a desired rate. To generate this design efficiently and effectively, an electric motor, a resistance load, and a control system, as seen in Fig. 5, will be implemented.

Input: Vehicle speed and load data.

Output: Resistance on drum.

Applicable Constraints: **2, 4, 5, 8, and 13**

Design Verification: To confirm the functionality of the braking system, various tests, within the customer's desired parameters, will be conducted. These tests will include constraints **2**, **8** and **13.** Successful verification will be reached upon observance of accurate speeds during and after braking. In addition to testing, adherence to constraint **4** will be confirmed through the ability to externally operate the system from the user interface station.

*1) Electric Motor:* The electric motor will be responsible for acting as a generator to produce electrical energy. From this generation, it then will be responsible for providing a resistive torque to simulate a braking force on the drum. Various tests on the produced torque and drum speed will be conducted. These metrics will then be compared to expected values derived from mathematical operation and the manufacturer's specification sheet.

Input: Electrical energy from resistance load.

Output: Resistive torque.

The electric motor chosen must be able to adhere to constraints **8** and **13**. This provides that the motor must simulate the bike's brake to allow testing over various speed decelerations. Specifically, the customer has requested that tests from 0km/h to 50km/h and then back down to 0km/h be attainable. Additionally, a test from 50km/h to 30km/h must also be within the dyno's functionality. For these constraints to be met, the accurate, precise operation of the electric motor is critical. Without this operation, the ability to provide a resistance to simulate braking is lost.

*2) Resistance Load:* The resistance load will be responsible for dissipating the electrical energy generated from the electrical motor. This dissipation converts the electrical energy into heat which controls the motor's outputted braking force. To verify the functionality of this load, the releasing of heat must be confirmed as well as testing that the brake force is the correct value to slow the bike to the desired, inputted speed.

Input: Controlled electrical energy value.

Output: Heat dissipation.

Upon selection of a resistance load, constraints **2**, **8,** and **13** need to be complied with. As stated, constraints 8 and 13 encompass that the system can run tests at variable speeds through acceleration and deceleration. Constraint **2** states that the bike can be operated safely up to maximum speed (85km/h). These constraints, without a resistance load, would be unattainable. For, without this, the speed of the drum would be uncontrollable, so the bike's brakes could not be simulated and damage to the electric motor may also occur due to overload. Therefore, the resistance load plays a crucial role in delivering a functioning brake system and ensuring safety.

*3) Control System:* The control system will be responsible for regulating the amount of electrical energy sent to the resistance load. This regulation will allow for precise, dynamic control over the force applied to the drum. To verify the functionality, tests on the increase and decrease of electrical energy from various inputs will be run. This will exhibit taking metrics speed and torque, and observing whether the braking force provides the expected output speed.

Input: Sensor data and testing parameters.

Output: Braking force control signal

The design of the control system will aid in meeting all listed applicable constraints for the braking subsystem. It will allow for the electrical energy dissipated to be controlled by the user and system feedback. Constraint **4**, not previously discussed in previous sections, is met through compatibility with the user interface. Due to this design, the user will be able to simulate the bike braking without having to manually squeeze the brakes. This helps to ensure maximum safety. In addition to safety, constraints 2, 8, and 13 are met as the subsystem can simulate dynamic braking over variable accelerations and decelerations. Without this system, the ability to regulate electrical energy flow would be lost. This would present another major safety factor as the system would exhibit uncontrolled braking. Additionally, without the control system, the ability to slow the bike's speed through input would not be possible. As a result, the control system is vital to ensuring its safety, reliability, and effectiveness.

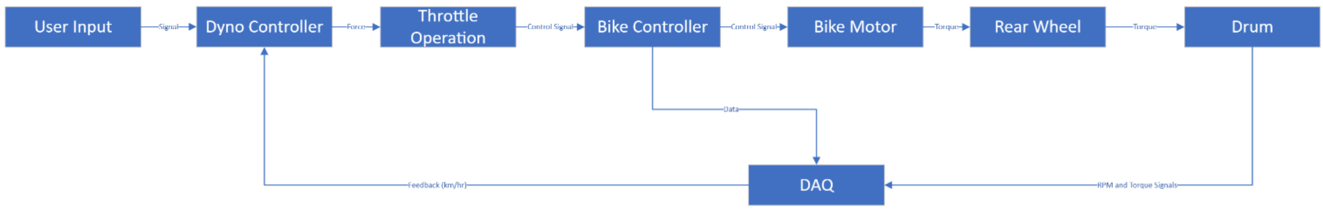


Fig 4. Throttle Operation Block Diagram

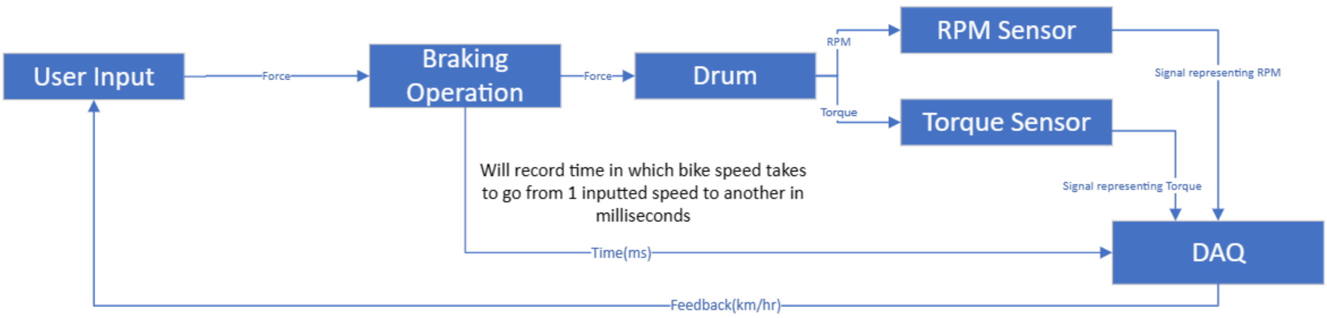


Fig 5. Braking Operation Block Diagram

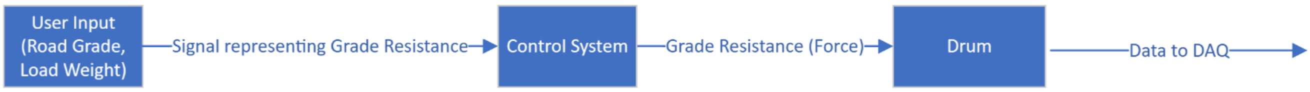


Fig 6. Road Grade Simulation Block Diagram

### *F. Road Grade Simulation*

The road simulation system is intended to actively work to simulate different road grades (slopes).
*Drum/Roller Resistance:* The stand must be able to simulate an 8 percent road grade, equal to 4.5739 degrees, from constraint **7**. The team will need to apply resistance to the drum to either increase or decrease demand on the motor. The grade resistance is a force in newtons that can be found by multiplying the mass of the vehicle by the acceleration due to gravity by the sine of the road grade angle [6]. When the vehicle is going uphill the grade resistance is positive and when going downhill the grade resistance is negative. The weight of the bike is 120 kg and the customer wants the bike to be tested at 150, 200, and 400 kg, from constraint **11**. This means that the max grade resistance that must be added to the drum will be 211.220N, 250.335N, and 406.794N of force respectively. This is equivalent to 21.538kg, 25.527kg, and 41.481kg of force.

The user will input a road grade from -8 to 8% and the weight of the load. Then the amount of grade resistance will be calculated and will be applied to the drum to cause less or more demand on the bike motor as needed. The amount of force outputted to the drum is measured for verification and can be used as feedback to a control system so that the outputted force onto the drum matches the desired force.

Input: Road Grade and Load Weight

Output: Grade Resistance

Applicable Constraints: **7 and 11**

Design Verification: The subsystem will be considered verified when the amount of force applied to the drum is equal to the calculated value. The force applied can be measured using a load cell and the measured value will be compared to the desired value. The resistance can also be measured by measuring the torque produced by the actuator affecting the drum and converting it to total resistance.

## IV. Timeline

Located in the appendix, Fig. 8 shows the Gantt chart that outlines the tasks and specific deadlines for the detailed design. The general tasks and deadlines are generated from the different subsystems, task due dates, and holidays or breaks that are in the university calendar. Each task is either designated to a specific individual in the group or is assigned to the entire team. Each member of the group is assigned a subsystem based on their knowledge and background in electrical and computer engineering. The member assigned to a specific subsystem is responsible for the design, setup, and testing of that subsystem. The chart is designed to show a general timeline of when tasks are being worked on and planned to be completed, but, if necessary, they can be changed.

## V. Conclusion

Creating a user-friendly, accurate, and dynamic electric motorcycle dynamometer to satisfy customer desires is the overarching goal of this project. By implementing the previously listed subsystems, this design will provide Proton Power with the ability to efficiently test their batteries. The overarching goal of this project is to create a user-friendly, accurate, and dynamic electric motorcycle dynamometer to satisfy customer desires. The precise outline of this conceptual design will allow third-party users to generate the same system with different applications without trouble. As the project progresses, the detailed design of each subsystem will be formed following the timeline and breakdown presented within this document.

# VI. WORKS CITED

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[6] X. Li, J. Ma, X. Zhao and L. Wang, "Intelligent Two-Step Estimation Approach for Vehicle Mass and Road Grade," in *IEEE Access*, vol. 8, pp. 218853-218862, 2020, doi: 10.1109/ACCESS.2020.3042656.

## VII. Appendix

| Item | | Content | Note |
|---|---|---|---|
| Length | | 1975 ng/2050mm | Without shelves/with shelves |
| Width | | 710mm | / |
| High | | 1050mm | / |
| Wheelbase | | 1300mm | / |
| Weight | | 120kg | Battery pack included (Contain the battery pack) |
| Seat height | | 815mm | Driver/crew |
| minimum ground clearance (Minimum ground clearance) | | 160mm | / |
| Maximum climbing angle (Maximum Angle of climb) | | 19° | / |
| Motor | Motor type (The motor type) | Wheel huh motor | / |
| | Rated output power (RP) | 3500w | / |
| | The rated voltage | 65V | / |
| Battery(Power Battery) | | 65V30Ah/unit | Lithium iron phosphate battery ( Lithium Iron Phosphate lithium battery) |
| Battery pack quantity (Number of battery packs) | | 2(One) | Removable |
| Maximum speed (MAX-Speed) | | 60km/h (ECO)<br>75km/h (SPORT) | A single |
| Constant speed range | | 110KM | 40km/h (ECO), single (A single) battery remaining 10% 10% battery remaining) |
| Working condition endurance | | 90km | GB14622-2016-RS1+RS1 (SPORT), A single, 20% battery remaining |
| Tire Size | | 2.75-17 | front wheel |
| | | 110/70-16 | rear wheel |
| instrument | | LCD instrument | / |
| Braking System | | Front, rear disc, CBS | / |
| Reverse Gear | | √ | / |
| Driving Mode | | ECO、SPORT | / |
| communication method (Communication Isolation) | | CANBUS | Instrument, battery, controller |
| Charger | | 650w (65V10A) | |
| Loading Quantity | | SKD 105pcs | 40HQ |

Figure 7: Bob Motorcycle Technical Document

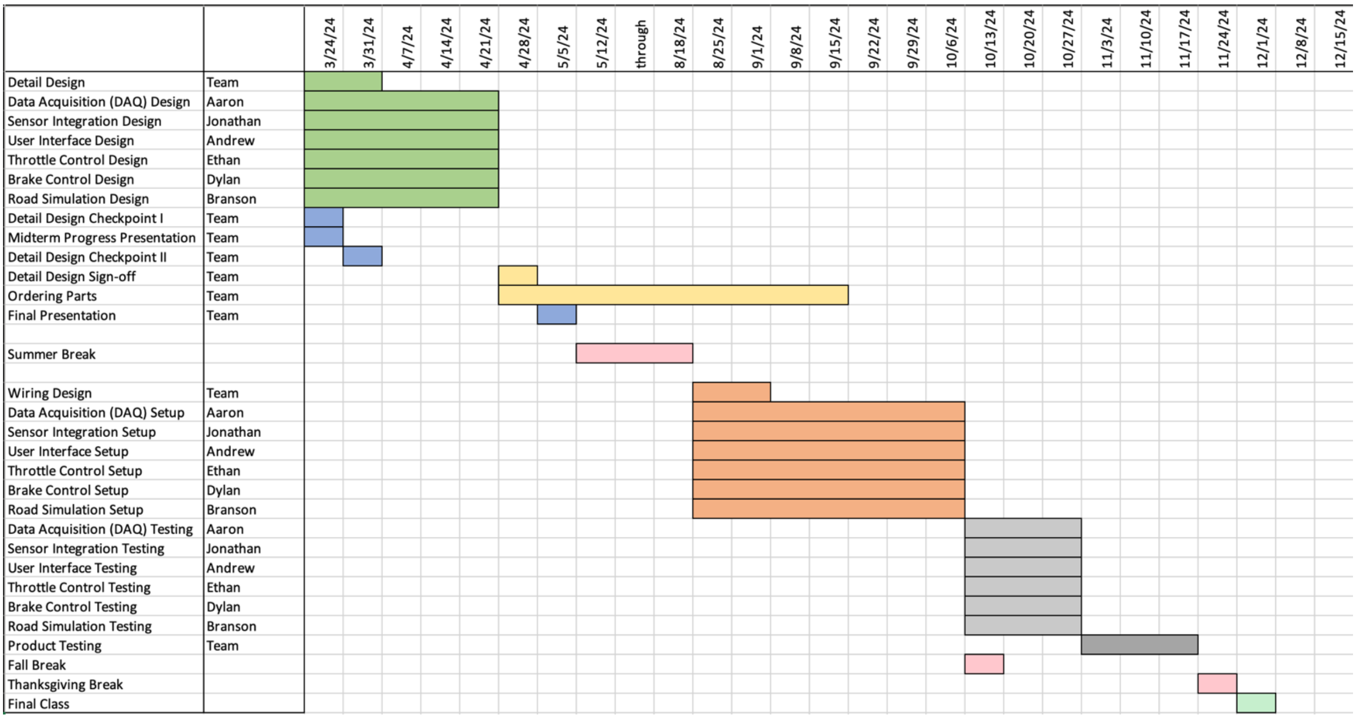


Figure 8: Gantt Chart