Preliminary Design Report - DYNO

ECE 492 - Spring 2015

Abstract

This is the preliminary design report for the dynamometer project for the LFEV. Included are the materials required by D000 in the LFEV 2015 statement of work.

Revision 1.1.0

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Summary

This summary should review prior work done on the PDR, as well as a brief overview of the project goals for this semester.

This document in an overview of what is achievable for this project as well as what is required. This document outlines testing strategies, how the different components connect to one another, the various requirements set for by the professors and by the Formula EV association, predicted system states, risk analysis, cost predictions, and a work breakdown schedule for the course of the semester. This document covers these topics in brevity with the intention of increasing accuracy as time progress.

The completed dynamometer test stand will be able to, at minimum, control the motor speed, record detailed information regarding the motor and motor controller. There will also be a safety system in place to protect both the operators and the hardware. The sensors will, at minimum, be able to support the safety systems, and record enough data to generate torque curves and power consumption statistics for use in the TSV Load Controller system.

Acceptance Test Plan

An outline for the acceptance test plan strategy has been developed. This plan outlines the areas of the design that must be tested, including the technical design, the safety design, and the mechanical design. The final draft of this document (D004 - Acceptance Test Plan) will outline the acceptance test parameters for every aspect of the design, including both the positive and negative cases.

Sensors

The sensor systems will be tested by running the dynamometer, and ensuring that the data has been logged correctly in a computer system. Details about the acceptance threshold for these values is discussed in D011 - Calibration and Accuracy.

Test Stand

The test stand is the physical hardware that holds the sensors, the motor controller, and other supporting hardware. This unit will be verified to meet all safety and good practice requirements laid out in GPR005.

Interfaces

The dynamometer system contains interfaces to every other major system in the project. These interfaces are detailed in the D015 - Interface Control Document, and will be tested assuming the receiving ends have been completed as well.

Power Supply

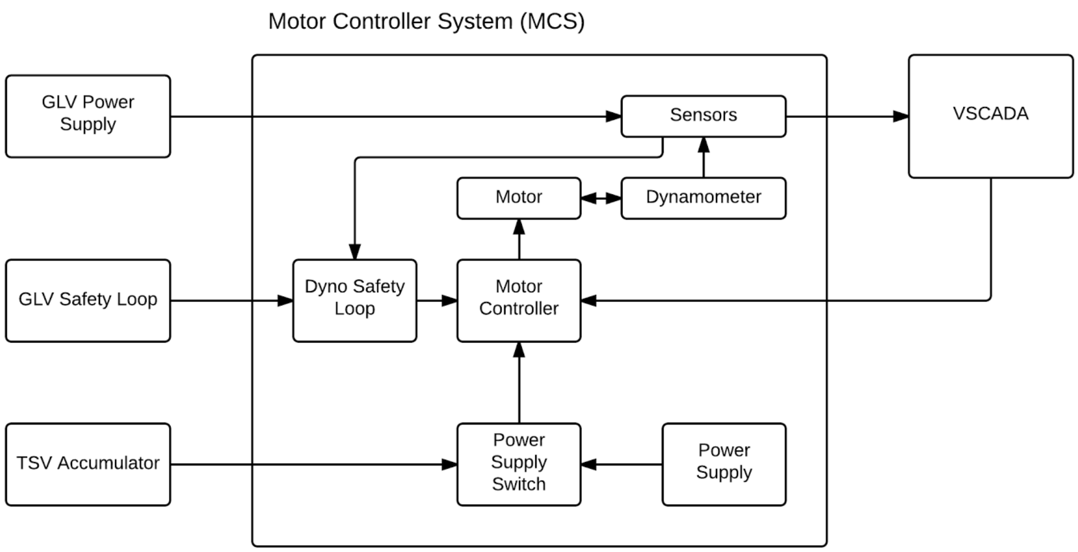
The power supply will supply power to the motor controller, and will be swappable without contact with uninsulated high voltage wires.

Safety

The dynamometer safety system is an independent safety loop that will shut the motor down in the event of any unsafe conditions. These are listed in detail in the D004 - Acceptance Test Plan. This safety loop will also allow the GLV safety loop to shut the system down.

System Design Baseline

This is the preliminary system design for the dynamometer test stand. It is intended to provide a high level overview of the connected systems. This is an early draft and will be updated as time progresses to accurately reflect the future changes to the system.



Requirements Analysis

Requirement	Description	Subsystems	Functional Requirement/Interface
R000	**Formula Hybrid Competition Rules**		**The final LFEV shall meet all requirements given in the Formula Hybrid rules for 2015. The initial goal for competition entry shall be the pure electric vehicle (EV) category.**
EV1.2.1	Motor Parameters	Motor	The maximum permitted operating voltage for Formula Hybrid is 300 V. The EV1.2.1maximum operating voltage is defined as the maximum measured accumulator voltage during normal charging conditions. Note 1: The Tractive System Voltage limit may be exceeded within the motor/controller system as a result of transient inductive effects, but may not be intentionally increased through the use of DC/DC converters, transformers, etc. Note 2: Commercially available motor controllers containing boost converters that have internal voltages greater than 300 VDC may be used provided the unit is approved in advance by the electrical rules committee.
EV1.2.6		Motor Controller	The tractive system motor(s) must be connected to the accumulator through a motor controller. EV1.2.6. Bypassing the control system and connecting the tractive system accumulator directly to the motor(s) is prohibited.
EV1.2.7		Power Supply/ Dyno Safety Loop	The GLV system must be powered up before it is possible to activate the tractive system. Furthermore, a failure causing the GLV system to shut down must immediately deactivate the tractive system as well.
EV2.1.2		Sensors	The foot pedal must return to its original, rearward position when released. The foot pedal must have positive stops at both ends of its travel, preventing its sensors from being damaged or overstressed.
EV2.2.1		Dyno Safety Loop	All analog acceleration control signals (between accelerator pedal and motor controller) must have EV2.2.1 error checking which can detect open circuit, short to ground and short to sensor power and will shut down the torque production in less than one (1) second if a fault is detected.
EV4.5.1		Cabling	All parts, especially live wires, contacts, etc. of the tractive system need to be isolated by non-EV4.5.1conductive material or covers to be protected from being touched. In order to achieve this, it must not be possible to touch any tractive system connections with a 10 cm long, 0.6 cm diameter insulated test probe when the tractive system enclosures are in place.

EV4.5.2	Cabling	Non-conductive covers must prevent inadvertent human contact with any tractive system circuit. EV4.5.2This must include crew members working on or inside the vehicle. Covers must be secure and adequately rigid. Body panels that must be removed to access other components, etc. are not a substitute for enclosing tractive system connections.
EV4.5.6	Cabling	All wires and terminals and other conductors used in the tractive system must be sized appropriately EV4.5.6for the continuous rating of the fuse which protects them. Wires must be marked with wire gauge, temperature rating and insulation voltage rating. Alternatively a manufacturers part number printed on the wire is sufficient if this can be referenced to a manufacturers data sheet. The minimum acceptable temperature rating for TSV cables is 90°C. Note: Many high current fuses can allow significant overcurrent conditions which may be adequate to cover the peak power requirements and allow sizing of fusing and wiring according to continuous or RMS needs.
EV4.5.7	Cabling	All tractive system wiring must be done to professional standards with appropriately sized EV4.5.7conductors and terminals and with adequate strain relief and protection from loosening due to vibration etc. Conductors and terminals cannot be modified from their original size/shape and must be appropriate for the connection being made.
EV4.6.1	Safety	Every housing or enclosure containing parts of the tractive system except motor housings must be EV4.6.1labeled with sticker(s) (minimum 4 x 4 cm) with a red or black lightning bolt on yellow background or red lightning bolt on white background. The sticker must also contain the text “High Voltage” or something similar if the voltage is more than 30 VDC or 25 VAC.

R002	**VSCADA**	**The VSCADA must be connected to all sensors**
R002-0	Sensors	Must interface sensors so that VSCADA can monitor the following sensors; ● Tractive System DC current and motor phase currents ● Temperature of the motor system ● Data available from the motor controller ● Data available from the Dyno Test Stand, including torque and RPM
R002-1	Sensors	The LFEV system shall use a commercial motor controller with a computer interface already installed. VSCADA shall use this interface to access, record, and display all available motor controller data in a form that is integrated with the overall LFEV data display.

R002-2	Sensors/ Dynamometer	The LFEV system shall use a commercial dynamometer with a data acquisition sensor hardware already installed. VSCADA shall use the data acquisition hardware interface to access, record, and display all available dynamometer data in a form that is integrated with the overall LFEV data display.
R002-3	Motor Controller	VSCADA shall be capable of closed loop control and "scripting" of Motor Controller System (MCS) Test Stand operation. Specifically, it shall be possible to set motor RPM and torque through closed loop control as a function of time.

R005	**Motor Controller, and Dynamometer Test Stand**	
R005-0	All	A motor, controller, and dynamometer shall be assembled together along with all necessary mechanical parts, couplings, plumbing, fasteners, TSV and GLV cabling, cooling equipment, sensors, interlocks, safety shields, and cable dress per GPR005, and any other necessary item to create an integrated Motor Controller System (MCS) Test Stand.
R005-1	Dyno Safety Loop	The MCS Test Stand shall permit the safe testing and demonstration of motor and controller performance over the operational parameters (RPM and torque profiles, both forward and reverse) implied by the IEEE Formula EV competition.
R005-2	Motor	The Motor to be used is the HPEVS AC 50.
R005-3	Motor Controller	The Controller to be used is the Curtis 1238R – 7601.
R005-4	Dynamometer	The dynamometer to be used is the Huff HTH-100.
R005-5	Sensors	The MCS Test Stand shall incorporate all necessary sensors and other interfaces necessary for the measurement and data acquisition (DAQ) of all relevant MCS operating parameters, including torque, RPM, motor phase voltage and current, controller input voltage and current, and system temperature at critical locations.
R005-6	Sensors	The MCS Test Stand shall be interfaced to the VSCADA system, GLV Power, TSV Load Controller, Safety Loop Controller, as required to permit full operation of these auxiliary systems.

R005-7		Power Supply	TSV power shall be provided either by the TSV Accumulator battery packs, or by a commercial power supply. A Magna-Power TS Series IV power supply is available for use with this project and is suitable as a source of TSV power.
R005-8		Power Supply Switch	It must be possible to switch between the power supply and battery packs as the source of TSV power without exposure to uninsulated TSV conductors or terminals.
R005-9		Dyno Safety Loop	The MCS Test Stand shall be interfaced to an independent safety loop system that meets formula EV safety requirements to force safe system shutdown should an unsafe condition occur including ground fault, overtemp, overspin, over torque, or operator actuation of prominently mounted Emergency Stop switches.
R005-10		Dyno Safety Loop	Safety plan must be created and approved by course instructions and the Director of Engineering before work can be done on the system

R007	**Safety Loop**		**Review the existing safety loop design and revised to improve electrical and mechanical performance, reliability, and maintainability.**
R007-0		Cabling	The cabling requirements for car installation shall be analyzed and a set of safety cables suitable for use on the car shall be designed, fabricated, and tested. In addition, cables required to support the MCS Test Stand shall be designed, fabricated, and tested.

R008	**TSV Load Controller**		**Review and revise existing design to improve electrical and mechanical performance, reliability, and maintainability**
R008-0	Cabling	Cabling	The cabling requirements for load controller shall be designed, fabricated, and tested to be required to support the MCS Test Stand

System State Analysis

There are two main system states for the motor control system: On and off. The motor control system enters the “on” state when the user starts the car and the car is in “ready to drive” mode. In this state, forward or reverse acceleration can be achieved depending on whether the direction switch is in the forward or reverse position, respectively.

The system primarily enters the “off” state when the user turns the car off. However, the system will also enter this state depending on certain safety conditions. If there is a ground fault, overtemp, overspin, overtorque, or the emergency stop button is pressed, the system will enter this state. In the “off” state, the system is idle.

The motor control system will interface heavily with VSCADA. The state of the motor control system factors into the VSCADA’s own system states and will be controlled by VSCADA.

Risk Assessment

The biggest risk to our project is team members falling behind schedule. If this occurs we will evaluate the given situation as a group in order to determine the appropriate course of action to fix the problem. First, we will discuss how significant the given task is. If the task is minor or does not affect the progression of the project, then this may be corrected with simply a few extra hours of work in the following week. If this is a major fallback and will impede the progression of the project, then we will need to determine if additional manpower is needed to help get back on schedule. If extra help isn’t the appropriate solution, then we might have to alter our schedule to work on other tasks while we wait for the problem to be resolved.

The following sections contains possible risks or delays to the Dyno team’s project that may result in late deliverables, and also potential solutions to these problems:

Late Delivery of Huff HTH-100 Manual

The manual is supposed to be delivered soon, but if not this will cause significant delays to simulating and experimenting with the dynamometer. The manual contains explanations of the dynamometer system in detail, which is needed to properly model it. The manual also has several parameters and constants needed to set up equations regarding the motor. If the manual is late, we will need to either work on other parts of the system like the data acquisition from the sensor or developing the safety loop. We could also attempt to model the motor based on a similar one we could research online, or we could consult the mechanical engineers and their professor on the most accurate model of a hydraulic engine to provide some dummy data to work on the sensors and other parts of the system.

Late Delivery Remaining Sensors

There is still a strain gage sensor, an optical encoder, and a special cable for feedback data regarding information about the valve inside the motor controlling the flow rate of the oil. The strain gage sensor is needed to provide information about the torque. The optical encoder is needed to provide information about the motor RPM, and specialized data cable providing information about the motor valve is needed to provide feedback data in our motor model and system. If these are too late we can order an additional strain gage sensor and optical encoder, but since the data cable does not use a standard connection, there is not much we can do except call the manufacturer and wait for its delivery.

Late Deliverables from the TSV system

This could result in delays regarding modeling the motor with the car's battery pack. If this occurs, we will not be able to simulate the motor perfectly but we would instead simulate the car with a made up DC power source, or we could test the car experimentally using a DC power supply.

Late Deliverables from the GLV Safety Loop system

We need to integrate the GLV safety loop with the one from the dynamometer. If GLV cannot finish their safety loop on time, we will work on our safety loop with all the correct interfacing specs according to the ICD. We could assume that the GLV safety loop doesn't trigger when working on our implementation. When this is fully functional, we can mimic the signal coming from GLV to work on implementing the fully integrated system when GLV is ready.

Late Simulation of the Motor Model

Late model simulation of the motor would cause significant delays. We are required to have a working simulation before we can move onto experimental trials of the dynamometer. If this deliverable is late, we will need to shift all available resources to finishing this as soon as possible to avoid bottlenecking the project. The extra time used to finish the model will have to be taken from the testing and debugging period. We have allotted ample time for this phase to ensure everything is 100% operational, even if we run into several delays.

Cost Analysis

A cost analysis and detailed program budget that demonstrates compliance with financial constraints. This estimate is preliminary, and subject to change based on estimates for other systems and more complete research:

Item	Quantity	Price	Total
0 AWG (gage) wire - 50ft	1	$75.00	$75.00
Wire connector package	1	$50.00	$50.00
Temp sensor - DS18S20+CT-ND	5	$4.95	$24.75
Strain gage sensor - 1033-1004-ND	1	$60.00	$60.00
optical encoder - 102-1923-ND	1	$20.00	$20.00
A2D converter	5	$4.00	$20.00
		Total:	$249.75

A possible non budget item for the Dyno team is a rack and cable management system for the power supply, motor controller, and accompanying computer.

Work Breakdown Structure

Week 2

Group	Finish PDR and Present	☐
Steve	Hierarchical Subsystem breakdown and semester task breakdown	☐
Alex	Complete ATP	☐
John	Risk Assessment and Cost Analysis	☐
Brendan	Requirement Analysis	☐
Nate	System State Diagram	☐

Week 3

Group	Motor Controller Research and AEC 401 Prep	☐
Steve	Safety Plan and ICD Draft	☐
Alex	ATP and C&A Draft - 13th	☐
John	Put AEC 401 together and Test stand research/design	☐
Brendan	Power Supply and Connector Research	☐
Nate	Motor controller research	☐

Week 4

Group	Motor modeled and sensors system designed	☐
Steve	Data acquisition and transmission	☐
Alex	Sensor System Design	☐
John	Requirements Analysis	☐
Brendan	Interface Control Design/Specification	☐
Nate	Motor controller cooling research	☐

Week 5			
	Group	Finish ATP, C&A, and ICD	☐
	Steve	ICD Final Version and TSV/Power Supply Switch Design	☐
	Alex	ATP and C&A Final Version - 26th	☐
	John	Detailed Subsystem Specification	☐
	Brendan	Model the motor in software	☐
	Nate	Learn to program/control the motor controller	☐

Week 6			
	Group	Program the Motor Controller	☐
	Steve	Revised Task Breakdown Schedule	☐
	Alex	Updated System Design Draft	☐
	John	Fabrication Specification and Purchasing List draft	☐
	Brendan	Model the motor in software	☐
	Nate	Learn to program/control the motor controller	☐

Week 7			
	Group	Present CDR, Submit Hardware Purchase Proposal	☐
	Steve	Safety Plan Final Report	☐
	Alex	Interface Demonstration	☐
	John	Program Budget Final amd ICD Final	☐
	Brendan	Communication Link Demonstration	☐
	Nate	Updated System Design Final	☐

Week 8

Group	Review feedback and develop corrective plan from feedback	☐
Steve	Review CDR feedback and develop corrective plan	☐
Alex	Review safety plan feedback and develop corrective plan	☐
John	Review demonstration feedback and develop corrective plan	☐
Brendan	Review communication feedback and develop corrective plan	☐
Nate	Review system design feedback and develop corrective plan	☐

Week 9

Group	Put MSC Together	☐
Steve	Attach Cables and Cable Management	☐
Alex	Sensor Setup	☐
John	Setup the Dyno and learn how to use it	☐
Brendan	Cooling System Setup	☐
Nate	Physical assemble motor and motor controller interfaced and working	☐

Week 10

Group	Verify MCS component functionality	☐
Steve	Independently verify subsystem functionality	☐
Alex	Cooling system testing	☐
John	Setup the Dyno and learn how to use it	☐
Brendan	Simulate the Motor model in various real world settings	☐
Nate	Independently verify motor controller functionality	☐

Week 11

Group	Test and setup the Sensors	☐
Steve	Test and setup temperature sensors	☐
Alex	Test and setup Phase Current and Voltage sensors	☐
John	Test and setup torque and RPM sensors	☐
Brendan	Test and setup Controller Input Voltage and Current sensors	☐
Nate	Q&A test the sensors	☐

Week 12

Group	Testing the Safety Loop	☐
Steve	Safety Loop Integrates with GLV	☐
Alex	Safety Loop shuts down via GLV Safety Loop	☐
John	Safety Loop shuts down via Dyno sensors	☐
Brendan	Test the shut down in various "real world" conditions	☐
Nate	Q&A test the safety loop	☐

Week 13

Group	Test the motor	☐
Steve	Tune Motor Parameters	☐
Alex	Verify motor characteristics	☐
John	Verify safe RPM and Torque range	☐
Brendan	Verify operation of modes	☐
Nate	Q&A test the motor	☐

Week 14

Group	Miscellaneous Testing	☐
Steve	Fixing errors discovered in testing	☐
Alex	Fixing errors discovered in testing	☐
John	Fixing errors discovered in testing	☐
Brendan	Fixing errors discovered in testing	☐
Nate	Fixing errors discovered in testing	☐

Week 15

Group	Demonstrate	☐
Steve	Demo Sensors	☐
Alex	Demo Motor and models	☐
John	Demo Motor Controller	☐
Brendan	Demo Safety Loop	☐
Nate	Demonstrate communication	☐