Team 8 - Conceptual Design and Planning

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I. INTRODUCTION

A. Problem Definition

Tennessee Tech currently has a driving simulator using Logitech controllers in the basement of Brown Hall. This simulator was built and designed by a mechanical engineering (ME) capstone team a few years ago. While the simulator was sufficient for providing the university with a generic driving simulation, the electrical and computer engineering (ECE) department has decided to team up with the ME department to further improve this old project. The ECE team is tasked with converting a 2014 Nissan Leaf that resides in Lewis Hall into a real-time accurate driving simulation that uses Nissan hardware as opposed to game controllers. This Nissan Leaf is cut in half, removing the rest of the car behind the driver's seat.

Team 8 intends to replace the controllers that interface with the simulation to the Nissan Leaf's hardware which includes, but is not limited to the steering wheel, pedals, and shifter. The use of this hardware will still provide real-time and accurate inputs into the simulation to provide the most realistic driving experience possible to its user. In order to achieve this goal, the car must be powered and tested for the data outputs from the Controller Area Network (CAN) bus, Nissan sensors already inside the vehicle, and external sensors installed by the team . The CAN bus is the highway for all data being communicated between different systems of a vehicle. Thus, the CAN bus contains useful information about steering angles, throttle position, gear position, and brake status. The team will not pull data from the CAN bus because data will not be able to be decrypted, but the team will still read its outputs. The Nissan sensors and external sensors will be the target for data acquisition. To extract data from the sensors and interpret their outputs, the team shall connect the outputs of each sensor to a microcontroller via General-Purpose Input/Output (GPIO) ports. Due to the real-time constraint, this microcontroller will have a clock frequency of no less than 16 MHz to read and write data quickly. Sending data to the simulation is beyond the scope of this project, but the data will still be collected and stored for future capstone teams in an excel spreadsheet.

B. Constraints

The main constraints the team will face during the design and construction of the system includes real-time accuracy, power limitations, Nissan hardware usage, and timeframe of the project. To achieve real-time behavior, all data collection and transfer shall occur in no more than 20 milliseconds. This will be done by using a 16 MHz microprocessor to read inputs from the sensors and write outputs to the personal computer (PC). The power supply shall be a 12V DC power supply and will supply each component of the system. To step down the voltage for the sensors that require less than 12V, the team will design and install a voltage de-amplifying circuit. Nissan hardware including the accelerator, brake pedal, steering wheel, and shifter shall be used to make the driving simulation Nissan Leaf specific. Data will be collected from these hardware components via angle and position sensors installed by the team on the sensor's corresponding component. To finish the entire proposed solution in the timeline of the fall semester of 2022 to the end of the spring semester of 2023, the team will work efficiently on each subsystem of the project and define a realistic goal.

II. BACKGROUND

A. Conceptual Design

To complete the final project, the team must iterate through many design phases to ensure that the final product meets all customer and supervisor requirements. The initial conceptual design is the first step toward achieving the final streamline design of the entire project. This design is broken into several different subsystems and then details each individual subsystem's inputs and outputs. The conceptual design does not lay out every detail of the final product, however, it allows the team to visualize the foundation of the system.

B. Design Background

The objective of the Capstone project is to test and collect all data from the four targets of the driving simulation inputs. The Nissan hardware shall use real-time inputs and outputs, allowing the simulation to look and feel like being inside a Nissan Leaf. The team shall use the Nissan Leaf's original hardware to maintain its look and feel. The processor speed of 16 MHz equates to each instruction on the processor being executed in 6.25e-8 seconds. This is significantly faster than the speed of 20 milliseconds, which is the goal for the real-time constraint. Given some additional latency will be caused by the algorithms written to the processor and from transmission delay from the sensors, the team is confident real-time can still be achieved if a processor of 16 MHz is used. Once the team gets the Nissan shifter gear, the On-Board Diagnostic (OBD) will read the information from the Nissan Leaf vehicle and give information on each of the working sensors.

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III. ETHICAL CONSIDERATIONS

The Nissan Leaf Driving Simulation does not involve many ethical concerns. There is minimal risk of endangerment for users of the simulation or bystanders. One primary concern arises with the pivoting of the front wheels when the steering is turned. To eliminate this risk, the team will install a barricade between the front of the vehicle and bystanders to prevent contact between them and the wheels. Both the ME team and the ECE team will experience the most risk while working with the vehicle. Primarily, it is of utmost importance to take all precautions necessary when dealing with potentially hazardous electrical equipment such as the power supply as outlined in the Institute of Electrical and Electronics Engineers (IEEE) National Electrical Safety Code [1].

Future work on this project can lead to a fully implemented driving simulation using all the available peripherals of the Nissan Leaf. A driving simulation of this type is highly reminiscent of an actual on-the-road experience. Therefore, it could significantly assist the training process for new drivers before they ever operate a real vehicle. In doing so, fatalities behind the wheel and other minor car accidents may see a large decline [2]. The current team's work will leave the next several capstone groups with useful data to pull from the sensors from the vehicle. The goal is to leave future capstone groups with organized and readily available data to transfer into the simulation to complete the customer's request.

IV. Sub-System Design

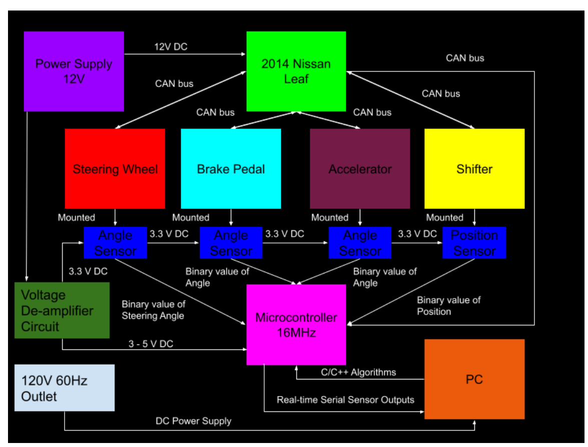

Fig. 1. Block Diagram

A. Power Systems

The internal control systems of the car were originally powered by a 12 V dc battery. With the conversion of this car to being an input device for the simulator, the battery will not be recharged from normal car usage and needs to be replaced with a continuous power supply. So, the beginning design of the power system for the car is transferring the 12 V terminals from a battery to a continuous power supply that will connect to the wall. This will require safety shielding on the power supply connections to the car to ensure that it complies with ISO 8092 standards [3].

Testing of the current from the battery that is initially used by the car will need to be measured to ensure that the car does not overload current limits when connected to the power supply or 120 V wall outlet. This testing will also determine the ripple voltage of the battery and what criteria the power supply will need to fall within. These results will also yield the framework of the circuitry that will be needed to power any non-OEM sensors.

The non-OEM sensors that will be added will require power that should fall within 3 V to 5 V. An additional circuit will be created to convert the 12 V supplied to the car down to a safe level for the sensors. This circuit replaces the need for another power supply and should be more cost effective. The base circuit for this voltage drop will be based around an operational-amplifier. From this circuit, the lower voltage sensors will draw the power they need.

To verify all of the design specifications of the power system, different voltages will be measured across components and recorded in datasheets. This includes the 120 V alternating current source from the wall, the 12 V direct current output from the power supply, current drawn from the wall, and the output values of the DC converter to the lower voltages. The power in the car is DC, however, an oscilloscope will be used to view the ripples of the voltages to determine if they are within the allowed ranges.

B. Gear Shifter

The CAN bus will be used to read the outputs from the gear shifter. These outputs will be collected and sent to the microcontroller. Also, a position sensor will be mounted on the knob of the shifter with the analog outputs being sent to the microcontroller. The sensor will be powered with a 12 V power supply and will be stepped down using an amplifier circuit. This will be used to ensure that the sensor is receiving the appropriate amount of voltage. C code will be created to compensate for the gear shifter's three second time delay to put the Nissan Leaf in neutral. Without this, the sensor could be reading that the car is in neutral when it could be in park. These two methods will be used for redundancy so the car's gear is always matching with what is being stored in the microcontroller. The sensor and CAN bus will operate at 100% accuracy due to the high importance of knowing what gear the car is in.

The main constraint of this subsystem is if the gear displayed on the microcontroller is accurate. If the signal being sent to the microcontroller is not accurate when compared with the actual gear of the car, it could cause the accelerator pedal to not work properly due to the car being in park even though the sensors read that it is in drive. To measure the accuracy of the censors and CAN bus, the team will continuously check to see if the signal being sent to the microcontroller matches what gear the car is in. Since the Arduino board has an analog to digital converter, the analog output signal will be readable. To verify that the sensor is receiving the appropriate amount of power, a multimeter will be used to measure the power being sent to the sensor.

C. Steering Wheel

The steering wheel subsystem in the block diagram is a system to measure the degree angle and the rate of rotation.

A constraint arises due to the steering wheel having 2⅔ rotations from the limit to the left and right (980 degrees). The other limitation is keeping the accuracy within 0 to 10 degrees with the rate of rotation by the user. A small constraint is to find a sensor that is not too sensitive to movement, which will result in high error rates.

The output encoding shall be given with 0 to -480 degrees representing the position from the center to the right limit in the clockwise direction, and the output will be 0 to 480 degrees from the center to the left limit in the counterclockwise direction. The output will send code to the microcontroller with a close degree angle from the steering wheel. It is critical to note that the rate of steering wheel rotation shall send a general idea about what the driver is doing with the steering wheel to the microcontroller.

The information sent to the microcontroller from both sensors shall produce a close realistic steering wheel. An example of this will be when the user turns a positive 45 degrees on the left and moves to steer fast. The first sensor shall detect the speed and give an idea to the microcontroller before the user turns the steering wheel completely. Also, The second sensor will send how much the steering wheel rotated.

The purpose of unit tests and integrated test units is to ensure constraints are met analytically before using them. The unit test will check the rotation is positioned correctly and send verification to a display that is ready to use. However, the integrated test unit will detect if the sensor is working efficiently and send a confirmation to display each sensor working.

D. Accelerator and Brake Pedal

The accelerator and the brake pedal are two separate subsystems but have the same solution. The brake pedal is originally a binary output saying it is being pressed or not being pressed. The gas pedal is not connected to the CAN bus. Therefore, the solution will be an angle sensor that uses a potentiometer to determine the position of the pedal. There will be one sensor on each pedal and the sensor will output into the microcontroller. The sensors will be powered by the 12V power supply converted down to the correct voltage required. The constraints of this subsystem are: output signal must be readable by an Arduino UNO REV3 board, the gear shifter sensor must be working correctly, input voltage must be within device range, the output angle must be accurate to 10%, can be installed into the Nissan Leaf. To measure if the sensors are working properly we will connect them straight to a computer and toggle the pedal at different angles and see if it matches what the computer says the angle is at.

E. Microcontroller

For the microcontroller and the algorithms subsystem, an Arduino UNO REV3 will be used to read and process the outputs of the sensors via general purpose input/output pins (GPIO) [4]. This Arduino device requires 5V DC power to operate. The power supplied to the microcontroller will be either from a laptop for programming or the voltage amplifier circuit that connects to the main 12V DC power supply used for the other subsystems. To maintain the minimal time complexity, the code will be written in C language using low time complexity methods. Alongside the C algorithms, the Arduino Integrated Development Environment (IDE) will be used to aid the programming process. This way, plenty of time can be saved when writing code to the board to read and write data and configure GPIO. This system will begin design after the appropriate sensors have been ordered, and will begin installation when the sensors have been acquired. The microcontroller will have up to four inputs from sensors and will have a single serial output into the PC via a universal serial bus (USB) port. The PC will display the data that is collected from the GPIO ports of the microcontroller for storage in an excel spreadsheet. This way, the outputs for each sensor can be well documented for future implementation into the driving simulator.

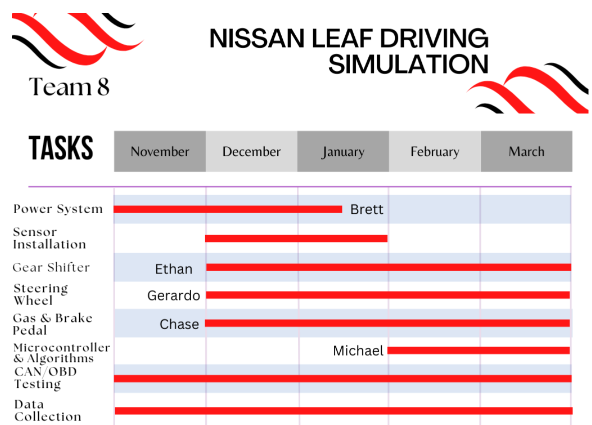

Fig. 2. Tentative Timeline

V. REFERENCES

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