Conceptual Design for Parking Lot Monitoring System

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I. Introduction

This document aims to provide a high-level look at the design of the parking lot monitoring system. The fully formulated problem will be restated and explained in detail to make clear what problem the system will attempt to solve. The conceptual design of the system is detailed in a block diagram. The block diagram consists of the various subsystems of the parking lot monitoring system. An overview of each subsystem's components and overall function is given to help explain how the system's various parts will work individually and with each other. The information being passed from each subsystem to the next is shown in the block diagram to give a better idea of how the subsystems work together. This document will also dispel any ambiguity in the specifications and constraints section on how the system will be designed and the reason for the specific design. The timeline for the project is included in this document as well.

A. Fully Formulated Problem

Finding a parking spot on campus can be stressful for many students. It is a common belief that this problem stems from a simple lack of adequate parking for students who commute to campus. However, a few lots often have spots available. Due to human nature, students want to park as close as possible to where their classes are. This results in students wasting time looking for spots in the most high-demand lots instead of parking where spots are readily available and walking the rest of the way or taking the shuttle. If students had a way of knowing ahead of time whether it would be worth looking for a spot in a given parking lot, then that could save them both time and stress.

This is the problem that the past capstone team who worked on the parking lot monitoring system also set out to solve. However, the current team believes the past team's solution to be flawed. The cameras the previous team relied on to detect cars entering and exiting lots are vulnerable to any condition affecting visibility. This could mean rain, snow, a bad glare, or even just the darkness of night would reduce the system's accuracy, for example. Therefore, the current team has proposed a new solution to avoid these potential weaknesses. Ground sensors such as inductive loops would remain accurate in these limited visibility situations. This would result in the system having considerably lower downtime and remaining accurate around the clock. Combine this with a backup power system; you have virtually no downtime in most scenarios.

The system will be subject to certain specifications and constraints. These specifications and constraints, as well as their origin, are:

1) The existing solutions inherited from the previous project, the camera and sign, shall be maintained at their current capability.
   - As a continuation project, it is expected that the existing systems are to be maintained at current capability.
2) The system shall have a backup power system for the sensor in case the main power supply fails.
   - To ensure that the correct count of vehicles in a parking lot is kept during power outages, a backup power system is required.
3) The system shall keep a local count of vehicles that enter or exit a parking lot.
   - If communication to the server is severed, a local count will be kept to update the server after a connection is re-established.
4) The system shall detect vehicles entering and exiting a parking lot.
   - The parking lot monitoring system relies on this in order to determine the number of open spots. This is how the system will count cars.
5) The data collected by the sensor shall be communicated to the central computer wirelessly.
   - Wireless communication is the most logical form of communication because of the distance between the ground-based sensor and the central computer.
6) The system shall function at all times of the day.
   - To keep an accurate count of vehicles in a parking lot, entering and exiting vehicles must be counted during all hours of the day.
7) The sensor shall function between 20 kHz and 100 kHz frequencies
   - Derived from the broader considerations. This constraint is intended to minimize the likelihood of

damage to sensitive electronics such as hearing aids or pacemakers.

8) The sensor shall be moisture and sunlight-impervious
    - NEC Articles 310.10.C and 310.10.D. In order for the system to be reliable over time, it must be resistant to common weather conditions.

II. Ethical, Professional, and Standards Considerations

A. Ethical and Broader Impacts

The ethical consideration for this system is to prevent any damage to sidewalks or roads during experimentation or sensor testing. Furthermore, seeking approval from the campus facility management before conducting any experiments is essential to ensure that the system's testing does not interfere with the campus environment. Another ethical consideration involves not utilizing the campus Wi-Fi network to connect the wireless sensor system to the server created by the previous capstone team [1]. This decision prevents any potential disruption or burden on the campus network. Instead, alternative wireless connectivity will ensure the system's data transmission to the server without impeding the campus's network resources.

B. Standards

National Electric Code Articles 310.10.C and 310.10.D provide guidelines for insulated conductors and cables used in wet locations and locations exposed to direct sunlight [2]. The ground sensor will be located outside the parking lots, meaning rain and direct sunlight will be present over its lifespan. The sensor must be moisture-impervious, metal-sheathed, and covered with insulated material that is rated to be listed for use in wet locations and also sunlight impervious.

C. Broader Considerations

The use of powerful inductive loops can negatively impact devices that are sensitive to strong electromagnetic fields. Communication systems such as Wi-Fi routers, cellular networks, and even hearing aids are examples of such systems. To combat this, the inductive loops will be designed to operate between 20 kHz and 100 kHz frequencies. While operating in this frequency range, the inductive loops cannot generate a strong enough electromagnetic field to harm other devices. Another broader consideration with this system is that there are advantages and disadvantages to using inductive loops to detect vehicles for monitoring purposes over using cameras for this task. A significant advantage of using inductive loops for the campus of Tennessee Tech is that they only have to be placed at designated entrances and exits, requiring fewer units to be deployed versus using numerous cameras to cover a single lot. With far fewer units being distributed across campus, maintenance personnel only have to go to the entrance/exit of a lot to repair the loop, whereas having to find the specific camera that is not functioning correctly, retrieving the appropriate equipment to reach the camera and resolve the issue with the camera. A disadvantage to the inductive loop system is that the system is designed to detect a large amount of metal from a vehicle. This system may not be capable of detecting motorcycles entering and leaving a parking lot due to the size of the motorcycle compared to a vehicle. This issue has been noticed by many highway departments and other organizations that implement inductive loops as a method to count the number of vehicles passing over a section of road in a specified area.

III. Block Diagram

The system has been broken down into four main systems and nine subsystems designed to be as modular as possible. The four main systems are the power system, ground-based sensor system, data interpretation and transmission system, and upkeep of the past team's system for the CSC team. The nine subsystems are the ground-based sensor, signal processing, data interpretation, data transmission, data storage, power, backup power, power controller between main power and backup power, and housing for the ground-based sensor system. The sensor subsection is responsible for acquiring data for the signal processing subsystem. The signal processing is in charge of removing noise from the sensor signal before converting it to a digital signal for the MCU. The main power supplies the necessary power requirements for all systems to function correctly. The backup power is responsible for providing power during power outages so the system can still function until power is restored. When not in use, this subsystem will be charged until it is needed for future use.

A. Subsystem 1: Ground Based Sensor

This subsystem will be how vehicles are detected at the designated entrances/exits. The output of this system will be monitored by the next subsystem, so this subsystem's focus is to detect vehicle movement over the sensor.

1) Inductive Loop Sensors: The inductive loop has been used primarily as a permanent method to count the number of cars that use the specific road by making cuts into the asphalt and installing numerous loops of wire into the asphalt. Making these cuts protects the wire from being run over by numerous cars while detecting the number of vehicles on the road. Instead of continuously increasing the count of vehicles passing over the inductive loop, this system will use two inductive loops, one to signal an increase in the number of cars and a second one to signal a decrease in the number of cars, on a smaller scale that will be simple to install on top of the asphalt while also having the ability to be portable to move from one location to another location.

Input: Vehicle movement over inductive loop

Output: Analog voltage signal

The input power will be 9-12 V DC to power the function generator for the inductive loop. The function generator will create a sine wave with a specific frequency to send through the inductive loop. The frequency range will follow the given range of 20 kHz - 100 kHz that is found in the Fully Formulated Problem section. According to the Federal Highway

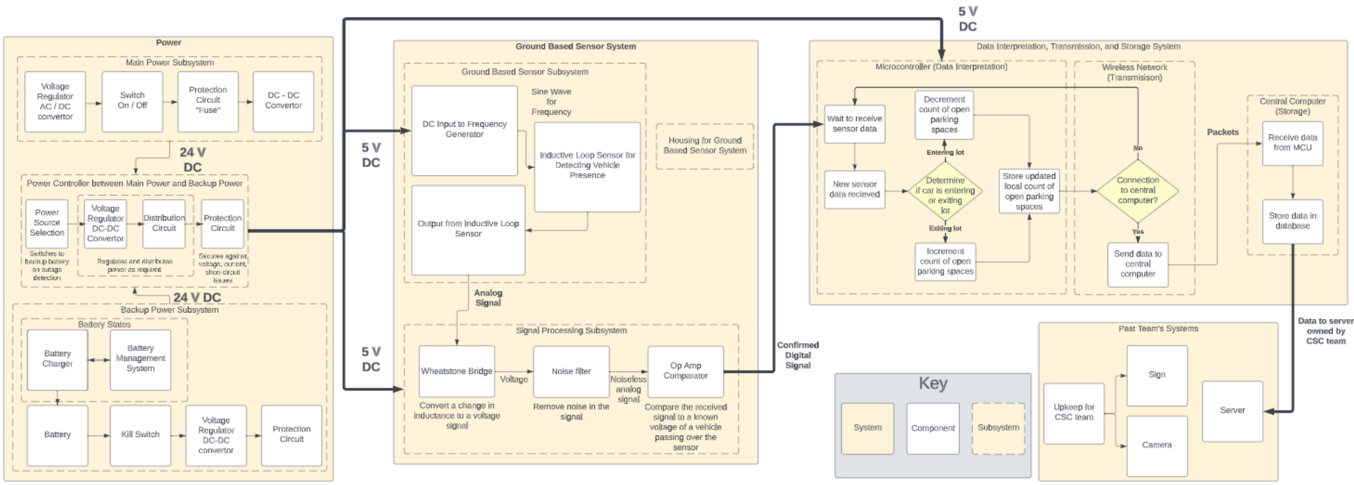


Fig. 1. Block Diagram of Parking Lot Monitoring System

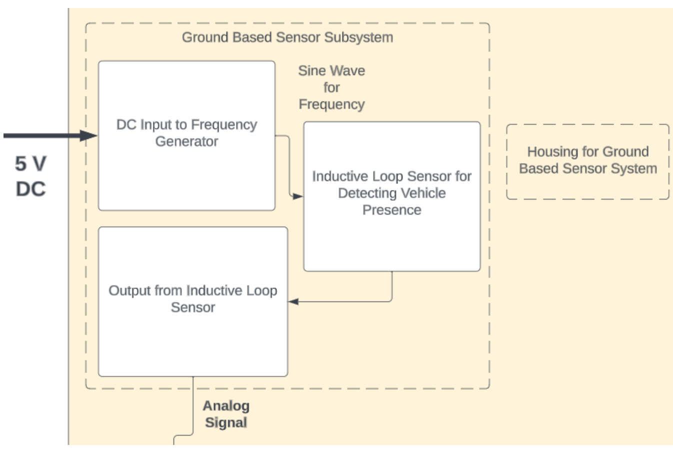


Fig. 2. Ground Based Sensor Subsystem

Administration (FHWA) on inductive loops, the electronics unit transmits energy into the loops at frequencies between 10 kHz to 200 kHz, depending on the model [3]. To verify that our system will stay in the range mentioned by the FWHA, this system will narrow the range to keep it within limits used by other inductive loops. A signal generator with DC input will be used to validate that the system will stay within the specified frequency range. It will be tested extensively before implementing it into the circuit that the frequency that the signal generator is set to is the actual frequency that is being transmitted through the loop.

When the frequency is changed due to a vehicle passing over the inductive loop, the inductance of the inductive loop will change due to the change in frequency. With this change in inductance, the voltage across the inductive loop will change as both inductance and voltage are directly proportional to each other in the same manner that voltage and current are directly proportional to each other. The voltage of the inductive loop will be measured with a Wheatstone Bridge circuit in parallel with the inductive loop to detect a change in voltage. This analog voltage signal will be transmitted to the Signal Processing Subsystem for further evaluation.

B. Subsystem 2: Signal Processing

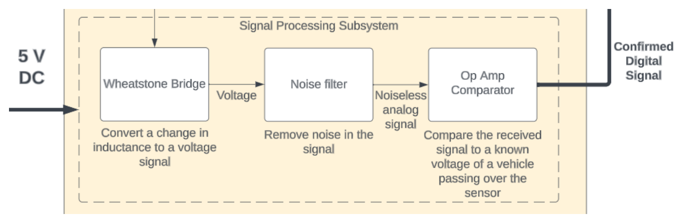


Fig. 3. Signal Processing Subsystem

The signal processing system will detect a change in voltage across the inductive loop and output a digital signal that represents a confirmed detection of a vehicle. The order of operations for processing the signal goes as follows:

1) Convert the signal measured from the inductive loop into a voltage signal using a Wheatstone bridge
2) Filter out noise from the converted voltage.
3) Compare amplified voltage to the known reference voltage of a vehicle passing through an inductive loop using an operational amplifier comparator.

The output voltage should be as close to 3.3 V as possible, as that is a common voltage that can be interpreted as a high signal by most microcontrollers. At 3.6 V, damage is possible for many small microcontrollers, which is why the output voltage will not exceed 3.6 V. The operational amplifier comparator will be designed to either output a 3.3 V signal or a 0 V signal depending on what has been received. Capping the output voltage to 3.3 V will prevent the microcontroller from being damaged due to a high voltage.

C. Subsystem 3: Data Interpretation, Transmission, and Storage

The Data Interpretation subsystem, Transmission subsystem, and Storage subsystem are responsible for understanding

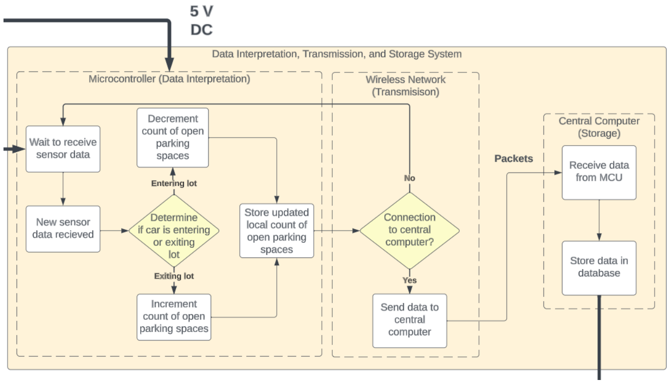


Fig. 4. Data Interpretation Subsystem

the data sent from the Signal Processing subsystem, making decisions based on this data, transmitting data over a wireless network, and storing the data in a database. The data interpretation takes place in software loaded to a microcontroller contained in a housing next to the ground sensors. The transmission subsystem consists of a wireless connection between the microcontroller and the central computer. The storage subsystem takes place in the central computer.

In greater detail and in order of operation, the Data Interpretation, Transmission, and Storage subsystems:

1) Receives a high logic level digital signal when a sensor detects a vehicle. The microcontroller will associate a timestamp with the signal when it is received in order to decide the direction of traffic.
2) Decides based on the data received whether a vehicle is entering or exiting the lot. This will be a comparison of the timestamps associated with the signals received.
3) Increments the number of parking spots available in the lot if the car is exiting or decrements the number of parking spots available in the lot if the car is entering.
4) Stores the updated number of parking spots available in the lot locally.
5) Check whether the microcontroller can reach the central computer over the wireless network.
6) Sends data to the central computer if the microcontroller can reach the central computer over the wireless network. If there is no connection to the central computer, the microcontroller will return to its initial state, which is waiting for a new signal. If there is no connection, then the following steps will not be executed this time around.
7) Receives the data sent over the wireless network from the microcontroller to the central computer.
8) Stores the data in a database on the central computer. This data is available for the computer science team to use for their purposes.

Constraints on the subsystems: This subsystem will communicate over its own wireless network, not the campus network. This is so the system does not cause excess network traffic that could affect those using the campus network. Compliance will be validated by checking the connection status on the system's wireless router.

D. Subsystem 4: Backup Battery

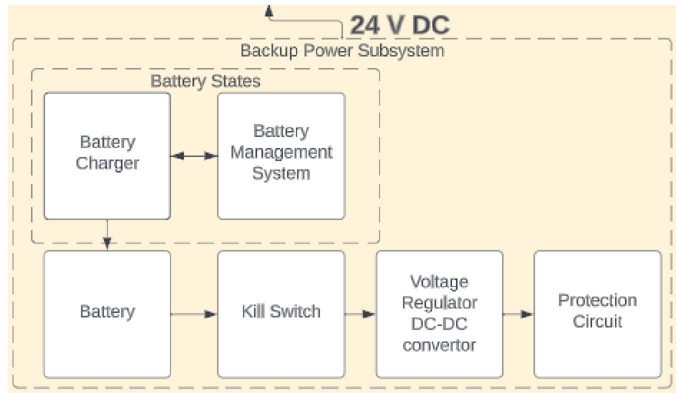


Fig. 5. Backup Power Subsystem

This subsystem powers other needed subsystems while the primary power source is off. The subsystem includes a battery, which can charge while the primary power source and the server are online. Also, it will have a battery management system that will allow the user to know the battery's status. That battery will have a kill switch to shut down the backup battery in emergencies. Moreover, a voltage regulator DC to DC will feed the power controller with a constant 24 V / DC by stepping down the voltage from the battery to the needed voltage from the power controller subsystem. Lastly, a protection circuit will incorporate safety features to protect against overvoltage, overcurrent, short circuits, and other potential issues.

E. Subsystem 5: Power

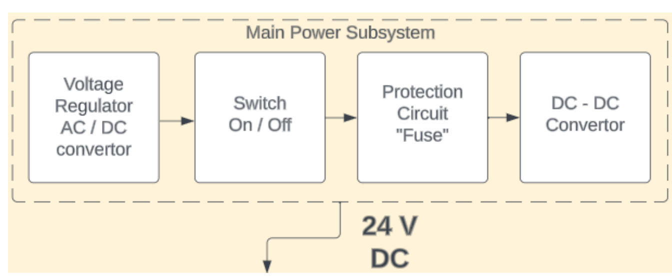


Fig. 6. Main Power Subsystem

An AC/DC converter with a voltage regulator is crucial to electrical systems. It converts from alternating current (AC) to direct current (DC) or vice versa. This conversion is essential to power various electrical equipment requiring a particular voltage type. To control the power supply, the subsystem also has a switch for turning the converter on and off. A protection circuit, frequently done using a fuse, is included in the subsystem to guarantee the system's safety. The fuse serves as a safety measure, protecting the converter and connected equipment from being harmed by an excessive current. A DC-DC converter may also be incorporated into this subsystem, allowing for additional voltage management and modification to match the needs of particular devices. This component is essential for giving electronic devices secure and consistent electricity. However, a few essential components are crucial for operating the power controller subsystem, which controls and directs. Electricity inside the system. Power source selection is a critical feature that enables the system to alternate between several power sources, assuring redundancy and dependability.

F. Subsystem 6: Power Controller

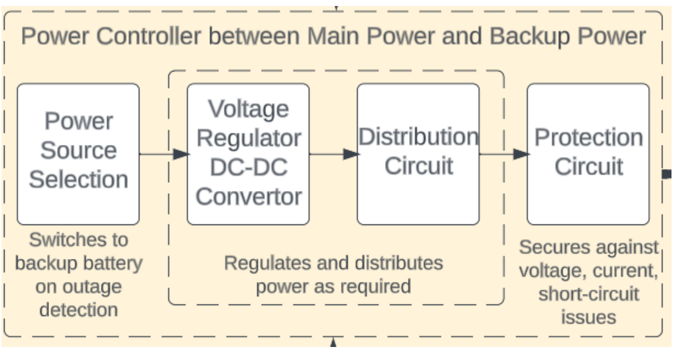


Fig. 7. Power Controller Subsystem

The received voltages from the main power source and the backup battery will be managed by selecting the appropriate power source (main power or backup battery) and ensuring that the appropriate voltage levels are supplied to the connected subsystems.

The power controller continuously monitors the status of the main power source. If an outage occurs or disruption is detected, the power controller switches to the backup battery as the power source.

Moreover, the power controller has voltage regulation and distribution circuits that can step down or adjust the voltages as needed to supply each subsystem with the required voltages.

Also, protection against overvoltage, overcurrent, short circuits, and other potential issues is needed to ensure the safety of the other subsystems.

G. Subsystem 7: Housing for Ground Based Sensor System

With any part of a project operating outside, the group needs to consider how to protect the electrical components that are exposed to the weather. To protect the components, a housing subsystem is necessary. This will involve obtaining the measurements of all PCB boards, the number of inputs and outputs, and any other necessary equipment that must be placed inside a protection unit. Another part that is necessary for the housing is security to avoid theft, vandalism, or other events that could negatively impact the components. To solve this issue, the housing will have a locking mechanism that will prevent and/or deter anyone from causing harm to the components inside the housing for the system. To guarantee that only the correct personnel will have access to the housing

Fig. 8. Housing Subsystem

system to access the components, the necessary information or equipment will be provided by the team to whoever will be responsible for maintaining the system after the project is complete.

IV. Timeline

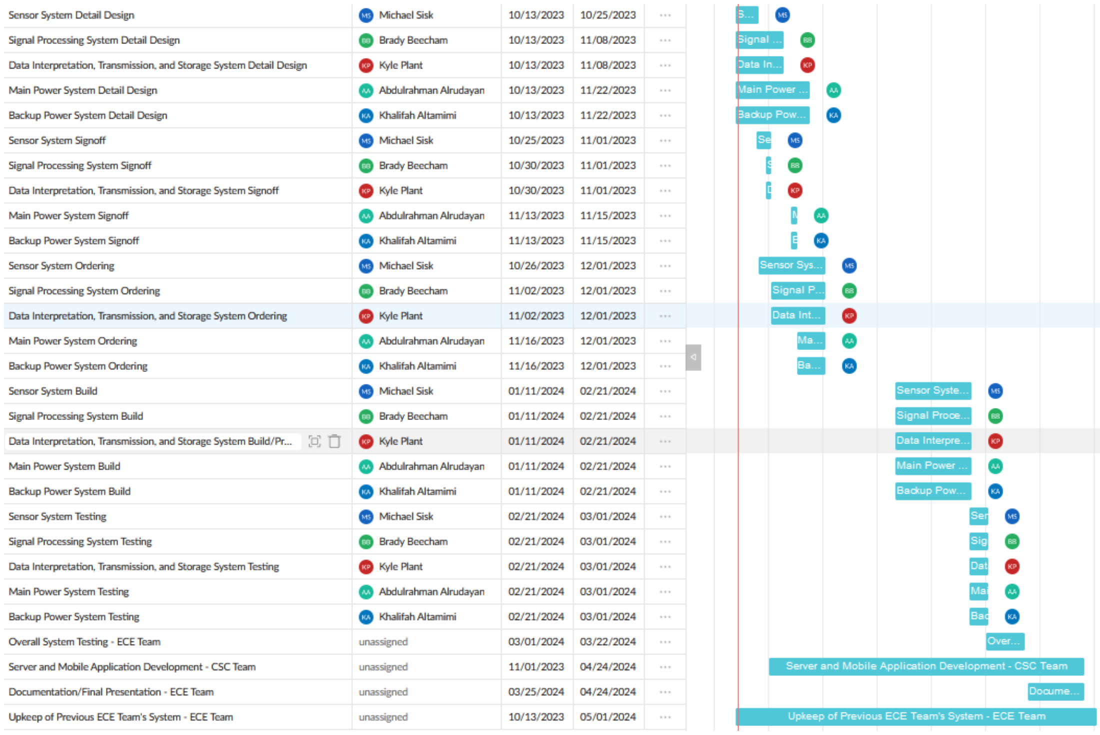
When viewing Fig. 1. Block Diagram for Conceptual Design, it is worth noting that there are four main systems and eight subsystems for a team with five members. The system labeled ”Past Team’s Systems” will be a minor system as the team plans to upkeep the electrical aspect of the system. Hence, the CSC team that will be working on artificial intelligence (AI) software has cameras that will work for them. The sign will also be maintained as displaying the number of available parking spots within a given parking lot will be necessary.

When viewing Fig. 9. Timeline for Conceptual Design, each team member is responsible for a specific subsystem based on their knowledge, skills, and interests in electrical and computer engineering. Each team member is listed in the following paragraphs with an explanation about their main subsystem and the importance of the subsystem.

Michael Sisk will be responsible for the Ground-Based Sensor Subsystem. This subsystem has been deemed the highest priority subsystem as the team must be able to detect the presence of a vehicle, and the entire project will be complete with it. This team member will also be responsible for the Housing Subsystem for the Ground Based Sensor System. This subsystem has low priority compared to the others, but it is necessary to complete. Once the Ground-Based Sensor Subsystem has been designed and approved and parts have been ordered, this subsystem will start for the project.

Brady Beecham will be responsible for the Signal Processing Subsystem. This subsystem is necessary as the signal that comes from the output of the Ground-Based Sensor System will need to be edited to an extent without losing essential parts of the signal so the signal can be transmitted to the next subsystem.

Kyle Plant will be responsible for the Data Interpretation, Transmission, and Storage Subsystem. This subsystem will have high importance as it will take the edited signal from the Signal Processing System and process it so it can be



Sensor System Detail Design	Michael Sisk	10/13/2023	10/25/2023
Signal Processing System Detail Design	Brady Beecham	10/13/2023	11/08/2023
Data Interpretation, Transmission, and Storage System Detail Design	Kyle Plant	10/13/2023	11/08/2023
Main Power System Detail Design	Abdulrahman Alrudayan	10/13/2023	11/22/2023
Backup Power System Detail Design	Khalifah Altamimi	10/13/2023	11/22/2023
Sensor System Signoff	Michael Sisk	10/25/2023	11/01/2023
Signal Processing System Signoff	Brady Beecham	10/30/2023	11/01/2023
Data Interpretation, Transmission, and Storage System Signoff	Kyle Plant	10/30/2023	11/01/2023
Main Power System Signoff	Abdulrahman Alrudayan	11/13/2023	11/15/2023
Backup Power System Signoff	Khalifah Altamimi	11/13/2023	11/15/2023
Sensor System Ordering	Michael Sisk	10/26/2023	12/01/2023
Signal Processing System Ordering	Brady Beecham	11/02/2023	12/01/2023
Data Interpretation, Transmission, and Storage System Ordering	Kyle Plant	11/02/2023	12/01/2023
Main Power System Ordering	Abdulrahman Alrudayan	11/16/2023	12/01/2023
Backup Power System Ordering	Khalifah Altamimi	11/16/2023	12/01/2023
Sensor System Build	Michael Sisk	01/11/2024	02/21/2024
Signal Processing System Build	Brady Beecham	01/11/2024	02/21/2024
Data Interpretation, Transmission, and Storage System Build/Pr...	Kyle Plant	01/11/2024	02/21/2024
Main Power System Build	Abdulrahman Alrudayan	01/11/2024	02/21/2024
Backup Power System Build	Khalifah Altamimi	01/11/2024	02/21/2024
Sensor System Testing	Michael Sisk	02/21/2024	03/01/2024
Signal Processing System Testing	Brady Beecham	02/21/2024	03/01/2024
Data Interpretation, Transmission, and Storage System Testing	Kyle Plant	02/21/2024	03/01/2024
Main Power System Testing	Abdulrahman Alrudayan	02/21/2024	03/01/2024
Backup Power System Testing	Khalifah Altamimi	02/21/2024	03/01/2024
Overall System Testing - ECE Team	unassigned	03/01/2024	03/22/2024
Server and Mobile Application Development - CSC Team	unassigned	11/01/2023	04/24/2024
Documentation/Final Presentation - ECE Team	unassigned	03/25/2024	04/24/2024
Upkeep of Previous ECE Team's System - ECE Team	unassigned	10/13/2023	05/01/2024

Fig. 9. Timeline for Conceptual Design

determined if a vehicle is entering or leaving a parking lot and update the count. The count will be sent to the server to update the sign. This system will also be able to store the data locally in the case of a power outage and the server is down, but the system is still working correctly due to the backup power system.

Abdulrahman Alrudayan will be responsible for the Main Power Subsystem. This subsystem will be needed to convert a standard 120 VAC wall outlet plug input source into the necessary DC values to operate the previously mentioned systems' components correctly. Suppose the output values from the voltage regulator need to be corrected. In that case, the system will not function properly, and it also introduces the possible risk of damaging the system and its components.

Khalifah Altamimi will be responsible for the Backup Power Storage Subsystem. This subsystem will be very useful to the entire system as the system will have the ability to keep a local count during power outages. When a power outage occurs, the Backup Power Storage Subsystem will energize and provide short-term power to continue functioning until the main power is restarted. This will allow students to continue knowing which parking lots are available while power is out on campus. When the main power is on, the backup power will be charged and stay charged until it is again needed.

The CSC team mentioned will be responsible for implementing AI software into the camera system built by the previous ECE team. Implementing AI software into the camera system while creating a ground-based system to monitor parking availability in parking lots will allow the system to be used across all campus parking lots. With the two different methods being implemented on campus, parking lots that do not have the capabilities to install cameras can be monitored accordingly through the ground-based system, and the cameras can cover the lots that cannot implement the ground-based solution due to constraints.

V. Conclusion

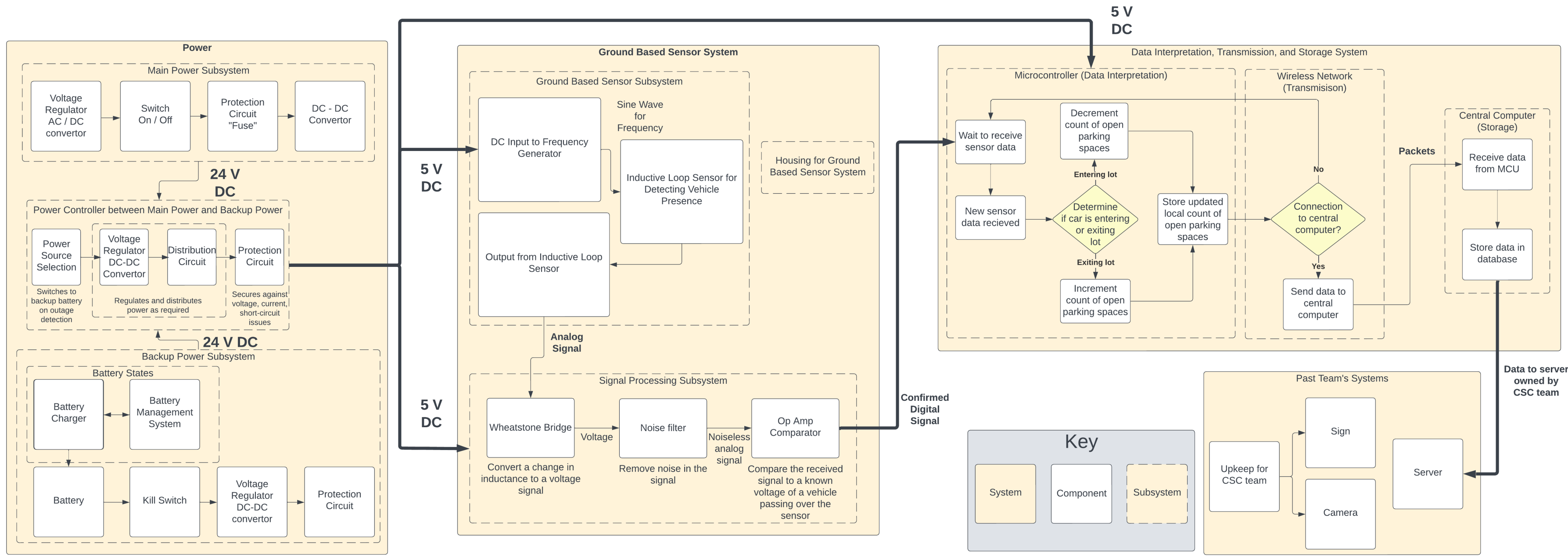
The parking lot monitoring system's design has been outlined in this document, along with a breakdown of its key elements and features. Finding a parking spot on campus could be more efficient and manageable, which is the main issue that our method tries to solve. To guarantee accuracy and minimize time off, the current team has suggested a novel strategy using ground-based sensors. The system is broken down into four main systems and nine modular subsystems in the document. The main systems are Power, Ground Based Sensor System, Data Interpretation and Transmission and Storage, and Upkeep of the Past Team's Systems for the CSC team. The subsystems are the Ground Sensor, Signal Processing, Data Interpretation, Data Transmission, Data Storage, Power, Backup Power, Power Controller for Main Power and Backup Power, and Housing for the Ground Based Sensor System. The accurate and continuous operation of the parking lot monitoring system depends on each subsystem. To sum up, by giving students access to real-time information on parking availability and improving overall campus parking management, the parking lot monitoring system is intended to ease parking woes. This project wants to develop a trustworthy and effective solution for college students focusing on ethics, standards, and modular subsystems.

REFERENCES

[1] Kesternucum, “KESTERNUCUM/ECE-capstone-team3: Parking lot monitoring system,” GitHub, https://github.com/kesternucum/ECE-Capstone-Team3/tree/main (accessed Sep. 13, 2023).

[2] ”Article 310” thenecwiki,https://thenecwiki.com/2021/02/article-310/ (accessed Oct. 14, 2023).

[3] “Chapter 2, Traffic Detector Handbook: Third edition-volume I,” FHWA, https://www.fhwa.dot.gov/publications/research/operations/its/06108/02.cfm (accessed Oct. 14, 2023).



Power
Main Power Subsystem
Voltage Regulator AC / DC convertor
Switch On / Off
Protection Circuit "Fuse"
DC - DC Convertor
24 V DC
Power Controller between Main Power and Backup Power
Power Source Selection
Switches to backup battery on outage detection
Voltage Regulator DC-DC Convertor
Distribution Circuit
Regulates and distributes power as required
Protection Circuit
Secures against voltage, current, short-circuit issues
24 V DC
Backup Power Subsystem
Battery States
Battery Charger
Battery Management System
Battery
Kill Switch
Voltage Regulator DC-DC convertor
Protection Circuit
5 V DC
5 V DC
5 V DC
Ground Based Sensor System
Ground Based Sensor Subsystem
DC Input to Frequency Generator
Sine Wave for Frequency
Inductive Loop Sensor for Detecting Vehicle Presence
Output from Inductive Loop Sensor
Housing for Ground Based Sensor System
Analog Signal
Signal Processing Subsystem
Wheatstone Bridge
Convert a change in inductance to a voltage signal
Voltage
Noise filter
Remove noise in the signal
Noiseless analog signal
Op Amp Comparator
Compare the received signal to a known voltage of a vehicle passing over the sensor
Confirmed Digital Signal
Data Interpretation, Transmission, and Storage System
Microcontroller (Data Interpretation)
Wait to receive sensor data
New sensor data recieved
Determine if car is entering or exiting lot
Entering lot
Exiting lot
Decrement count of open parking spaces
Increment count of open parking spaces
Store updated local count of open parking spaces
Wireless Network (Transmisison)
Connection to central computer?
No
Yes
Send data to central computer
Packets
Central Computer (Storage)
Receive data from MCU
Store data in database
Data to server owned by CSC team
Key
System
Component
Subsystem
Past Team's Systems
Upkeep for CSC team
Sign
Camera
Server