**Component Analysis**

**Year:** 2023 **Semester:** Spring **Team:** 10 **Project:** ParkingTrackingSystem

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**Assignment Evaluation:**

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| --- | --- | --- | --- | --- |
| **Item** | **Score (0-5)** | **Weight** | **Points** | **Notes** |
| **Assignment-Specific Items** | | | | |
| **Analysis of Component 1** |  | x2 |  |  |
| **Analysis of Component 2** |  | x2 |  |  |
| **Analysis of Component 3** |  | x2 |  |  |
| **Bill of Materials** |  | x6 |  |  |
| **Writing-Specific Items** | | | | |
| **Spelling and Grammar** |  | x2 |  |  |
| **Formatting and Citations** |  | x1 |  |  |
| **Figures and Graphs** |  | x2 |  |  |
| **Technical Writing Style** |  | x3 |  |  |
| **Total Score** |  | | |  |

**5: Excellent 4: Good     3: Acceptable    2: Poor     1: Very Poor    0: Not attempted**

**General Comments:**

**1.0 Component Analysis:**

The primary hardware components of our design include an LCD screen, WiFi module, 7-segment display, ultrasonic sensor, 12-button keypad, and microcontroller. The LCD screen will be used to display configuration and initial setup instructions. The WiFi modules will be used to communicate between the aggregator module and car detector modules. The 7-segment display will be used to show the current total number of available parking spaces in the garage. The ultrasonic sensor will be used to determine when there is a car entering or leaving the garage. The 12-button keypad will be used in conjunction with the OLED screen to allow the user to enter either the initial number of parking spaces, or the IDs of the car detector modules. The microcontroller will be used in two ways: on the aggregator module to receive data from the car detector modules, configure the system, and drive the 7-segment display, and on the car detector modules to send data to the aggregator module, and read in the ultrasonic sensor data.

**1.1 Analysis of Component 1: LCD Screen**

The LCD screen will be used with the Aggregator Module as a means of displaying instructions and information to the user, mainly for initially configuring the system. When considering what type of display we would need in order to effectively communicate with the user of our device, we thought about the potential messages that would show up on the display during configuration. These include instructions for entering the current number of available spots on reset, adding/removing CDM ID numbers, and displaying simple status signals. Thus, for our design, we do not need a large display with lots of characters; a two-line display will be able to convey all of our messages effectively to the user. After researching multiple two-line displays, we narrowed it down to the three choices found below. Ultimately, they are very similar in function and operation; all of them would fit our needs. Therefore, we decided to go with the WEH001602A COB OLED because all of us had one from ECE 362 and utilizes a 3.3V supply voltage for power and logic communication, which allows for easy prototyping, reduces the need to order them, and simplifies communicating to this device with our microcontroller.

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| **Module** | **WEH001602A COB OLED [1]** | **MC21605A6W-FPTLW [2]** | **MD21605G12W3-BNMLW-VE [3]** |
| **Color** | White / black | Black / white | Blue / white |
| **Display** | 16 x 2 | 16 x 2 | 16 x 2 |
| **Character** | 5 x 8 dots | 5 x 8 dots | 5 x 8 dots |
| **Voltage** | 4.5V ~ 5.5V | 5V | 5V |
| **Max Current** | 25mA | 20mA | 20mA |
| **Price** | $5.99 | $5.00 | $4.77 |

**1.2 Analysis of Component 2: WiFi Module**

This system component contains a WiFi radio and a microcontroller that makes an interface to the radio available through ASCII serial commands and handles a network stack including UDP and TCP. Features of this module include connecting to and creating WiFi networks, initiating UDP and TCP connections, and sending/receiving data over these connections.

Other candidate components included a ZigBee XBee RF module, and a LoRA transceiver. These two components would be able to transmit and receive over a much wider area, but the individual components were much harder to find and more expensive. For our initial demonstration, the larger range was unnecessary, making the price of the components less palatable. We were able to obtain several ESP-01 WiFi modules free of charge from the design laboratory which made our decision easier.

Looking at the capabilities of the three modules, the XBee would be the simplest to use, requiring no connection or pairing process to send data to other modules. The RFM95W radio would be the most complex, requiring a driver to manage configuration of the radio module, including setting transmission frequencies, sync words, power, and more. This would allow the most flexibility, but would require more development and testing effort. The ESP-01 is a good intermediate. The Wifi standard will not only allow modules to communicate with each other in a parking garage, but also it allows the possibility to easily interface with mobile devices for configuration if desired in the future.

In conclusion, we chose the ESP-01 primarily due to its low price and good availability. Its drawback is that its range is two orders of magnitude less than the ZigBee and LoRA alternatives. For larger networks of car detectors, some sort of meshing algorithm may be needed to cover an entire garage structure, but for now, the 60m range should be enough for demonstration on a small, two entrance garage.

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| Module | ESP-01 [4] | XBee [5] | RFM95W [6] |
| Method | WiFi | ZigBee | LoRA |
| Cost | $4.50 | $33.10 | $19.10 |
| Voltage | 3.3V | 3.3v | 3.3V |
| Dimensions | 14.4mm x 24.7 mm | 25mm x 32mm | 29mm x 25mm |
| # of Pins | 8 | 20 | 14 |
| Range | 60m | 1200m | 2000m |
| Communication | UART | UART, SPI | SPI |

**1.3 Analysis of Component 3: 7-segment Display**

The 7-segment display is the component that will be responsible for showing the number of available parking spaces to the user, which will be placed outside of the garage. Due to this, we had to ensure the use of a 7-segment display that would both be large enough for users driving by to see, as well as bright enough. The 7-segment display will be interfaced with the microcontroller as part of the Aggregator Module. From the table shown below, we chose the 6.5” 7-segment display because it requires the least current, as well as is the cheapest option.

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| --- | --- | --- | --- |
| **Component** | **6.5” 7-Segment [7]** | **12” 7-segment [8]** | **9” 7-segment [9]** |
| **Size** | 6.5” tall | 12” tall | 9” |
| **Color** | Red | Black and white | Black and white |
| **Voltage** | 12V | 31.5V | 24V |
| **Max Current** | 20mA per segment / 160mA total | 80mA per segment / 60mA for decimal / 620mA total | 500mA per segment/ 3500mA total |
| **Price** | $20.50 per | $75 per + custom order fee of $75 | Need to custom order |

**1.4 Analysis of Component 4: Ultrasonic Sensor**

The ultrasonic sensor is going to be the hardware that is responsible for detecting a car that is either entering or leaving a parking garage. This sensor implements one of the key functionalities of the Parking Tracking System. The ultrasonic sensor will directly interface with the MCU as part of a Car Detector Module (CDM). When looking into sensors we looked at 2 different kinds: the VCNL4010 Proximity/Light Sensor and the HC-SR04 Ultrasonic Sonar Distance Sensor. Both of these options had some pros and cons, so it took some thought to narrow it down.

VCNL4010 Proximity/Light Sensor (Adafruit)

This sensor is both a proximity and ambient light sensor combined in one. The proximity sensor projects infrared light towards the front of the sensor. The sensor contains a high-sensitivity photodiode that detects the infrared light reflected back at the sensor. The sensor then generates a voltage signal, and sends it back to the pin proportional to the distance the object is away from the sensor. This photodiode also senses the ambient light and sends a proportional voltage in the same way that it does for proximity sensing. The VCNL4010 Proximity/Light Sensor communicates with the MCU using I2C. Some pros of using this sensor include its small form. Since it is so compact, it allows for implementation in any tight spaces. Another pro is that it consumes very little power, and can be used at both three and three tenths volts and five volts. The main con of this sensor is its operating range. The VCNL4010 Proximity/Light Sensor is made for smaller ranges, being accurate up to seven and a half inches. This is a major downside because it is less versatile than a sensor with a bigger range. This sensor’s cost is $7.50.

HC-SR04 Ultrasonic Sonar Distance Sensor (Adafruit)

This sensor is made up of six main components: the transmitter, receiver, timing circuit, trigger circuit, control circuit, and power supply. It utilizes four pins: the power, trigger, echo, and ground. As long as the power pin is connected to a five volt source and the ground pin is grounded, the sensor is ready to work. This is accomplished by sending the trigger pin a five volt logical high from a GPIO pin for at least ten microseconds. Once that is accomplished, the sensor sends out a burst of ultrasonic waves. These waves “echo” back and are sent to the MCU from the echo pin utilizing GPIO. Once you receive the echo, you can calculate the distance by measuring the time in between the waves. As with all of the sensors, there were some pros and some cons to the HC-SR04 Ultrasonic Sonar Distance Sensor. The main con to using this sensor is that it operates at five volts. Although the MCU we plan to implement in the CDM does have a five volt pin, the GPIO can only output/input a three and three tenths voltage. The main pro of this sensor is the range of detection. This sensor’s price is $3.95.

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| --- | --- | --- |
| Sensor | VCNL4010 [11] | HC-SR04 [10] |
| Method | Infrared | Ultrasonic |
| Cost | $7.50 | $3.95 |
| Voltage | 3.3V or 5V | 5V |
| Dimensions | 18 x 16.5 x 3.15 mm | 45.5 x 20 x 15.5 mm |
| Sensing Range | 0 - 200 mm | 2 - 400 cm |
| # of Pins | 6 | 4 |
| Communication | I2C | GPIO |

After careful consideration, we decided to go with the HC-SR04 Ultrasonic Sonar Distance Sensor. While the operating voltage is not ideal, we came to the conclusion that adding a couple level shifters would be a small price to pay for the benefits of the ultrasonic sensor. Not only is it cheaper, but it also requires less pins. What the decision ultimately came down to was the sensing range. The 0 - 200 mm range of the proximity sensor was just too short compared to the ultrasonic range of 2 - 400 cm for the purposes of the Parking Tracking System.

**1.5 Analysis of Component 5: Keypad**

The button keypad is going to be the hardware that is responsible for detecting a keypress that is used as user input during the initial setup of the Parking Tracking System. An example of one of the key functionalities of the button keypad during setup is to enter the total number of parkings spots available before any cars are parked. The button keypad will directly interface with the MCU as part of the Aggregator Module (AM). When looking into button keypads we looked at 2 different kinds: the 16-Button Numeric Keypad Matrix (VUPN7082) and the 12-Button Numeric Keypad Matrix (COM-14662). Both of these options had some pros and cons, so it took some thought to narrow it down.

16-Button Numeric Keypad Matrix (VUPN7082)

This keypad is made up of 16 buttons and provides a convenient way for user input to be given in the form of a simple key press. The 16 buttons include the numbers 0 - 9, the letters A - D, and the special characters \* and #. This keypad needs to be paired with a matrix circuit that allows the MCU to decipher which button was pressed. There are two main pros to this keypad: having 16 keys and already owning some from previous classes. This button keypad costs $7.49.

12-Button Numeric Keypad Matrix (COM-14662)

This keypad is made up of 12 buttons and provides a convenient way for user input to be given in the form of a simple key press. The 12 buttons include the numbers 0 - 9  and the special characters \* and #. This keypad needs to be paired with a matrix circuit that allows the MCU to decipher which button was pressed. There are two main cons to this keypad: only having 12 keys and having to purchase them. This button keypad costs $4.95.

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| --- | --- | --- |
| Keypad | VUPN7082 [12] | COM-14662 [13] |
| # of Keys | 16 | 12 |
| Cost | $7.49 | $4.95 |
| Need to Purchase | No | Yes |
| Matrix Circuit | Required | Required |

After careful consideration, we decided to go with the 16-Button Numeric Keypad Matrix (VUPN7082). While it is a slightly more expensive part, we do not need to purchase it because we already own some from previous classes. Not only this, but it also has 4 more buttons than the 12-Button Numeric Keypad Matrix (COM-14662). Both keypads require a matrix circuit to allow the MCU to decipher which key is being pressed. This decision is definitely the right one for the purposes of the Parking Tracking System.

**1.6 Analysis of Component 6: Microcontroller**

The microcontroller is the main component of our design and handles all of the software processing and hardware interfacing. This involves facilitating the data communication between modules by utilizing the wifi chip, analyzing the sonar sensor data for detection of cars leaving or entering, configuring the overall system based on user inputs, and managing all data and status outputs to each display. From a software perspective, most of the processing is fairly simple and not high-speed, due to cars typically entering and leaving garages slowly (most even have speed bumps) and user configuration happening rarely (only during setup and adding/removing a CDM). From a hardware perspective, the microcontroller will need multiple communication peripherals and I/O pins to manage all the hardware and multiple timers to use for interrupts, as most processing is only needed either after an event has occurred (e.g. a car leaving) or on a regular basis (e.g. checking sensor data). After looking at multiple microcontrollers, we narrowed it down to two choices: the STM32F091 and the ESP32-WROOM-32E.

STM32F091:

This microcontroller was the one used by all the team members during the ECE 362 course. Thus, we all have experience and prior knowledge with this device, especially with using the IDE, owning a development board, and programming various peripherals. Additionally, this chip has 12 timers, two I2C buses, two SPI buses, eight USART pins, and up to 88 fast I/O pins. All of these components within one microcontroller will allow for simple management of the various hardware interfaces within our design and allow for effective interrupt programming. The two major drawbacks for our design are the lack of a built-in wifi module and a max operating frequency of 48 MHz.

ESP32-WROOM-32E:

This microcontroller includes a wifi module, bluetooth module, and an on-board PCB antenna. The bit rate for wifi can go up to 150 Mbps, and the range of operating frequency is 2412 - 2484 MHz. The bluetooth supports two different protocols: Bluetooth V4.2 BR/EDR and Bluetooth LE. This chip can support up to 22 I/O channels, four timers, 240 MHz clock, three UART interfaces, two I2C buses, and three SPI channels. The major advantage of this microcontroller is the built-in wireless communication capabilities, which reduces the complexity of interfacing between the microcontroller and the wifi module. The major drawbacks are the lack of available hardware for prototyping and the learning curve of a new microcontroller, especially the IDE for debugging purposes.

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| Microcontroller | STM32F091 [14] | ESP32-WROOM-32E [15] |
| Max Frequency [MHz] | 48 | 240 |
| Wifi Module Included | No | Yes |
| # Timers | 12 | 4 |
| Max # I/O pins | 88 | 22 |
| # UART Interfaces | 8 | 3 |
| # SPI Buses | 2 | 3 |
| # I2C Buses | 2 | 2 |

After careful consideration, we decided to use the STM32F091 microcontroller for our design. This chip has more peripheral interfaces, timers, and I/O pins available to use, which will be crucial when setting up the communication between our microcontroller and all of our different hardware components and the interrupt procedure involved in our processing. Additionally, our prior experience and abundance of development boards will allow for much easier prototyping and programming, which makes our design efforts more efficient. We decided that figuring out how to interface with an external wifi module would be faster to incorporate within our design than trying to learn a whole new microcontroller and program it with all of our processing needs.

**2.0 Sources Cited:**

[1] “WEH001602A 16X2 COB OLED Character Display 5V WS0010 Chip EH1602A Scandinavian European Cyrillic Russian Font SPI Parallel Port,” *AliExpress*. [Online]. Available:<https://www.aliexpress.com/i/2251832696798206.html?gatewayAdapt=4itemAdapt>. [Accessed: 04-Feb-2023].

[2] “MC21605A6W-FPTLW: Digi-Key Electronics,” *Digi-key*. [Online]. Available: <https://www.digikey.com/en/products/detail/midas-displays/MC21605A6W-FPTLW/13970956?utm_adgroup=Optoelectronics&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_DK%2BSuppliers_Midas+Displays&utm_term=&utm_content=Optoelectronics&gclid=Cj0KCQiAofieBhDXARIsAHTTldqF57hsdxyF9erDqYtcfvz0tZ1JjzTN8VAU0j50ov9aeXngHFXACIYaAmIsEALw_wcB>. [Accessed: 04-Feb-2023].

[3] “MD21605G12W3-BNMLW-VE: Digi-Key Electronics,” *Digi-key*. [Online]. Available: <https://www.digikey.com/en/products/detail/midas-displays/MD21605G12W3-BNMLW-VE/13970969?utm_adgroup=Optoelectronics&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_DK%2BSuppliers_Midas+Displays&utm_term=&utm_content=Optoelectronics&gclid=Cj0KCQiAofieBhDXARIsAHTTldp552yzCB2sY43yv743iBCT-_MTZq6AJRzxzwFzdUlETw8hMBwBWgUaArbqEALw_wcB>. [Accessed: 04-Feb-2023].

[4] “ESP-01/07/12 Series Modules User's Manual V1.3,” *AI Thinker* [Online]. Available: <https://www.universal-solder.ca/downloads/esp8266_series_modules_user_manual_en.pdf>. [Accessed: 02-Feb-2023].

[5] “DIGI XBEE S2C 802.15.4 RF MODULES,” *Mouser* [Online]. Available: <https://www.digi.com/resources/library/data-sheets/ds_xbee-s2c-802-15-4?view=fullscreen>. [Accessed: 02-Feb-2023].

[6] “Adafruit RFM69HCW and RFM9X LoRa Packet Radio Breakouts,” *Adafruit industries blog RSS*. [Online]. Available: <https://learn.adafruit.com/adafruit-rfm69hcw-and-rfm96-rfm95-rfm98-lora-packet-padio-breakouts/downloads>. [Accessed: 02-Feb-2023].

[7] “7-Segment Display - 6.5”, ” *Sparkfun*. [Online]. Available: <https://www.sparkfun.com/products/8530>. [Accessed: 04-Feb-2023].

[8] “Big Digit Seven-Segment LED Displays,” *Evil Mad Scientist*. [Online]. Available:<https://shop.evilmadscientist.com/productsmenu/107>. [Accessed: 04-Feb-2023].

[9] “Large 7-Segment Displays,” *AlfaZeta*. [Online]. Available: <https://flipdots.com/en/products-services/large-7-segment-displays/>. [Accessed: 04-Feb-2023

[10] “HC-SR04 ultrasonic sonar distance sensor + 2 x 10K resistors,” *Adafruit industries blog RSS*. [Online]. Available: <https://www.adafruit.com/product/3942>. [Accessed: 02-Feb-2023].

[11] “VCNL4010 proximity/light sensor,” *Adafruit industries blog RSS*. [Online]. Available: <https://www.adafruit.com/product/466?gclid=CjwKCAiAzp6eBhByEiwA_gGq5K61thGVXMjEY6ByUNyGZPxnj24dCDIgqjD0EzbRCMJ_Yp2c5sJFIBoC7yMQAvD_BwE>. [Accessed: 02-Feb-2023].

[12] “16-button numeric keypad matrix.” *Vetco Electronics* [Online]. Available: <https://vetco.net/products/16-button-numeric-keypad-matrix?gclid=CjwKCAiA_vKeBhAdEiwAFb_nrVasGkInFwHdKdoROXyRSXsBonLIGezR6uVoDnSXt4GQiRptaoc9-BoCXkMQAvD_BwE>. [Accessed: 03-Feb-2023].

[13] “Com-14662: Digi-Key Electronics,” *Digi-key*. [Online]. Available: <https://www.digikey.com/en/products/detail/sparkfun-electronics/COM-14662/8702491?utm_adgroup=Keypad+Switches&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Product_Switches&utm_term=&utm_content=Keypad+Switches&gclid=CjwKCAiA_vKeBhAdEiwAFb_nrX5uWTGia4PCl3rq6qkOOZqwnPOhAvkYeygqVEeUTMNEmwbDXUSwAxoCi7cQAvD_BwE>. [Accessed: 03-Feb-2023].

[14] “STM32F091CBU6,” *STMicroelectronics.* [Online]. Available: <https://estore.st.com/en/stm32f091cbu6-cpn.html>. [Accessed: 04-Feb-2023].

“[15] ESP32-WROOM-32E-N4,” *Digi-key.* [Online]. Available: <https://www.digikey.com/en/products/detail/espressif-systems/ESP32-WROOM-32E-N4/11613125>. [Accessed: 04-Feb-2023].