Motor Assisted Cooler (M.A.C)

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***Abstract* — The goal of this project is to research and design a working motorized cooler with cooling and self charging capabilities while keeping the elderly on top of mind. This process involved three main subsystems which include the motorized cooler, a refrigeration unit and solar charging to keep it running for longer duration. This project was selected for its electrical and computer engineering aspects to put our skills to the test and deliver a cheaper alternative to products that already exist in the market.**

Index Terms — Motors, Peltier effect and Solar Charging

I. INTRODUCTION

Florida is known for many things, Disney, beaches, and of course the elderly. It has become commonplace in movies and television shows when Florida is brought up, they are almost always talking about retirement. With that being said, these people enjoying their twilight years should be able to enjoy the beautiful beaches that this state has to offer without having to rely on anyone else to not impede on their independence. For this reason, our Senior Design team wanted to focus on the older generation and their ability to enjoy the great outdoors like everyone else.

For this reason, MAC (Motor assisted cooler) came into being. The MAC comprises three main parts, our motor design, refrigeration unit, and it's solar charging capabilities. The mobility of this project will solely rely on the two motors that will be attached to a flatbed cart with a handle to help the user move the load with relative ease. The cart itself will have all terrain wheels to help the elder traverse any terrain to reach their destination. We added a way to cool the inside of the cooler to not add any unnecessary weight for the user to haul around. We have gone with thermoelectric refrigeration for this purpose for its lightweight and power consumption. The refrigeration unit will be installed inside a cooler to keep whatever is inside nice and cold. These two systems are dependent on a power source which will increase its longevity. This is where our solar charging comes into play. We will be including solar panels in our design to keep the fun in the sun going even longer. All these systems will be powered by microcontrollers which will be hidden from the user for a sleek and functional design.

This report will document the details of the MAC research and subsequent development. It starts with the functionality of the sub components of the project. Then it will go into the specific hardware implementations for each of these modules. Next, we will go into further detail of the software design elements. The hardware and software implementation portions include the block diagrams, flowcharts and schematics. Last, we mention the power supply constraints including the battery and solar panel specifications.

II. PROJECT FUNCTIONALITY

As part of our project description, we have listed some of the core functionalities we planned to implement in our final design. We have chosen these functionalities for two main reasons. The first being the obvious fact that they will give our design the ability to serve the purposes stated in the introduction of this document. The second, not so obvious reason, is because these functionalities are important to our team in terms of skills which we were interested in developing.

This senior design project has given our team not only the chance to design a working product that can be helpful for many people around the world, but also a chance to test our engineering skills by building something which we have never attempted to build before. As a team, we were interested in control systems, alternative energy, and thermo-electric engineering. This project was an almost perfect opportunity to gain experience in these engineering disciplines.

There are three main functionalities of this project: motor-assistance, solar charging, and powered refrigeration. The motor assistance gave our team a chance to gain experience in control systems. The solar charging aspect of the project gave us a great chance to work with alternative energy solutions. Powered refrigeration is a perfect example of a thermoelectric device. With these functionalities the user will be provided with the essentials needed for any outdoor recreational activity and we, as a team, have gained our much-desired experience in these disciplines.

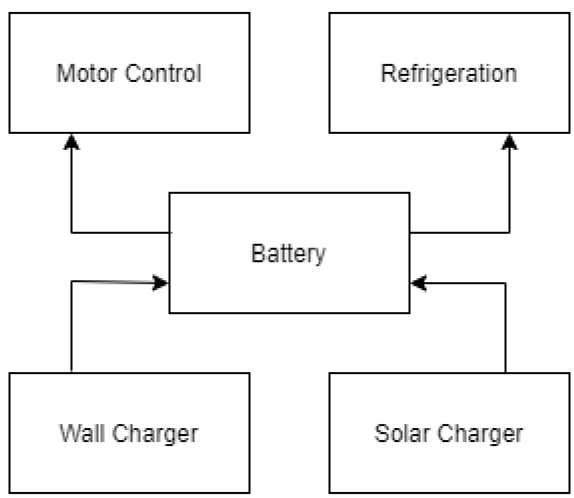


Fig. 1.
Main Block Diagram

The following sections will give a little description of these three functionalities that were just mentioned, focusing more from the user point of view and the impact that these functionalities will have on creating a design that meets the product goals.

A. Motor-Assistance

The motor-controlled movement of this project is very important because it will provide the greatest advantages to its users. This feature added value in the following ways: the cooler will be able to be used by almost anybody in the world, users will have the ability to carry much heavier loads, and the co oler will be able to traverse rougher terrain with this added weight.

B. Powered Refrigeration

Powered refrigeration is not the sole source of refrigeration but can be used to greatly extend the life of the ice within the cooler. This will allow our users to spend more time enjoying the outdoors and less time refilling their cooler with ice. Almost all coolers available today are built to store the contents cool or hot depending on the user's needs. There are many choices out there depending on which price point fits a person's budget. But they all have something in common, they all need another source to keep the contents cool, such as ice, which will eventually melt and start to heat up. In lieu of that we added a refrigeration component to our cooler to bypass this need.

C. Solar Charging

The solar-charging feature is necessary for the entire project to function. This feature added value to the project in the following way: The power will be available for a longer period of time and, as discussed previously, the user will have the chance to stay for a longer period of time without worrying about finding an outlet and having to charge it through a wall charger.

III. HARDWARE IMPLEMENTATION

The following sections will discuss hardware design of each individual part of the project.

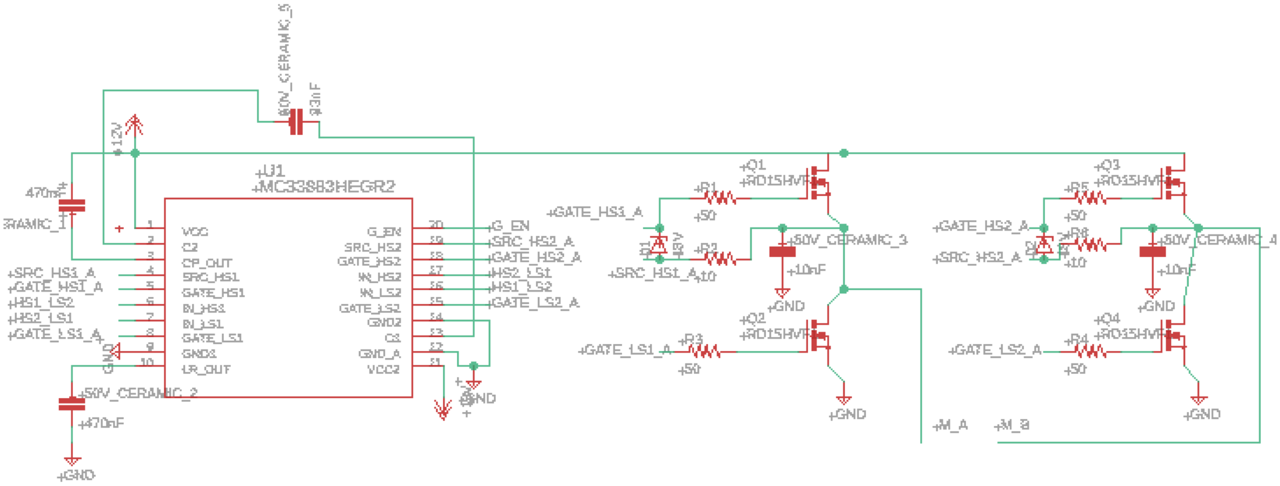


Fig 2. Motor Control Circuit Diagram

A. Motor Control

To implement the motor assist functionality, two 12-volt brushed DC motors were attached to the front wheel mounts of the base of the MAC system. The motors that were chosen contain an internal planetary gear reduction which, according to the manufacturer specification, produced an output torque ratio of 1:5.2 and a maximum output speed of 480 RPM.

A belt drive system was designed and implemented to transfer the torque from motor to wheel. Pulleys were attached to the wheel hubs using two-part epoxy. To do this, the inner bearing had to be removed. A brass sleeve was attached to the inner diameter of the pulley to keep the friction as low as possible between it and the axle. The pulley which was attached to the output shaft of the motor has 20 teeth while the pulley attached to the wheel has 60. This gives a further torque increase with a total output ratio of 1:15.6.

To control the speed of the DC motors, Pulse Width Modulation is used. This is a very well known concept, so it will not be explained fully here. The PWM is generated using a PIC18 microcontroller (PIC18F14Q40). The PWM signal used has a frequency of 60 Hz. This particular frequency was chosen based on internet research into good frequencies to use for DC motors. Because the MAC system will be used primarily outdoors away from home electrical systems, the 60 Hz frequency should not cause issues.

The duty cycle of the PWM used to control speed is controlled by the user's input via a slide potentiometer attached to the custom handle built for the MAC. The custom handle is a 2-part construction with a telescoping action. A spring is used to create a dampening effect on the movement of the handle. As the user begins to pull the cart, the handle extends and the voltage across the slide potentiometer begins to increase. This analog voltage is read by the ADC within the microcontroller.

A switching circuit is needed to apply the 12 volts from the battery at a high enough current to power the motors properly. MOSFET transistors were used to accomplish this. An H-Bridge circuit was implemented because, originally, forward and reverse were going to be functional. Due to time constraints and some PCB issues, only forward functionality was implemented. To power the MOSFETs, the MC33883 gate driver is used. This gate driver ensures that the high and low sides of the H-Bridge are never causing a short circuit between the 12-volt and ground. The H-Bridge circuit with the gate driver can be seen in the above figure.

B. Refrigeration

Currently, there are four main types of Refrigeration Systems, Mechanical-Compression, Evaporative, Absorption, and Thermoelectric. Three out of the four were not feasible for a mobile cooler due to the weight and efficiency of those systems, which left us with the obvious choice of a Thermoelectric system.

This method of cooling relies on the Peltier Effect, which consists of an electrical current going to a junction cooling one side and heating the other. In our case, a Peltier Tile was used which is made up of equal amounts of P-type and N-type semiconductors covered by two ceramic tiles, which provide electrical insulation shown in the figure below.

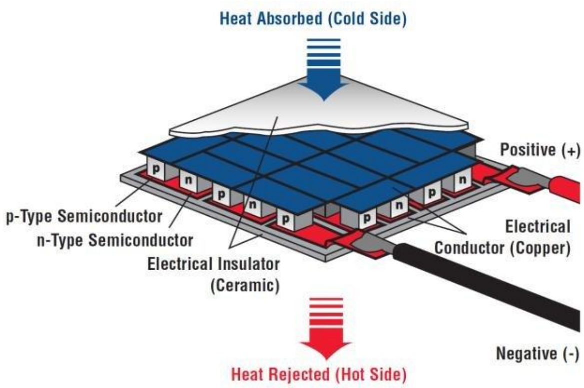


Fig.3
Peltier Module

When a DC current is applied to the circuit, a temperature differential is created across the two different semiconductors which causes the Peltier Effect displayed below.

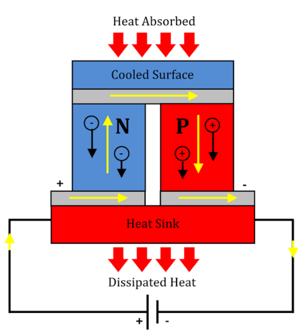


Fig. 4
Peltier Effect

With this taken into consideration, for our design we added two heatsinks and attached them on both sides of the Peltier module to spread the heat more effectively. In addition to the heatsinks, two fans were also installed on our device to cool the aforementioned heatsinks to dissipate the heat more efficiently as well as the cooling capabilities.

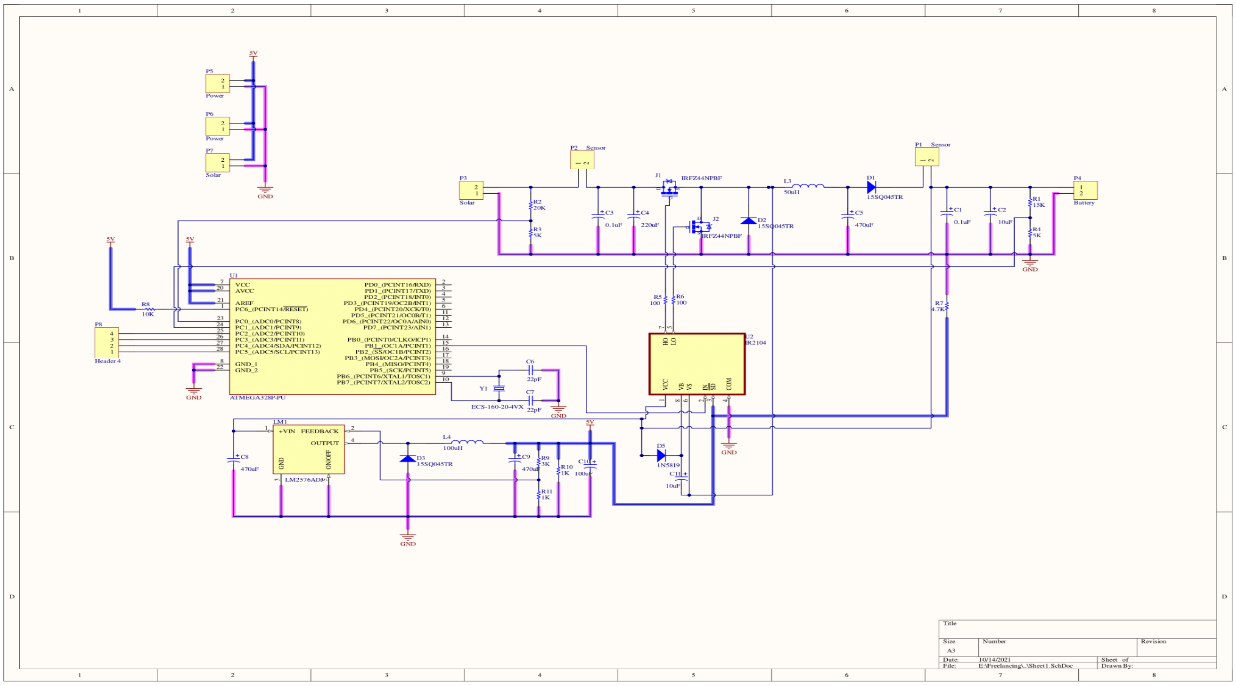
In the original design of our refrigeration system, our device was going to be attached on the inside of a cooler with a partition separating our main components such as the batteries, solar charging circuit and the Peltier unit which would have required us to cut into the side of the cooler thus making it not as efficient to cool. With that in mind, while we were looking for coolers, one of our team found an old cooler which had a Peltier cooling device integrated for use! So instead of cutting into a cooler our team decided as a whole to use this cooler instead, which is called the Igloo Pentikool. After some modifications to our cooler we were able to achieve the cooling capabilities we were looking for.

Features	**Parameter**
Voltage	12V
Current	4.5A
Cooler Dimensions	18”L x 13”W x 11”H
Capacity	24 quarts
Time to Cool to 40°	30 minutes from 80°

Now that we have our cooler and cooling system, our next task was to be able to stop our refrigeration unit from running continuously. Due to some time constraints of our original design, a third party temperature controller was used in our final product. This temperature controller has a built-in relay to shut off the Peltier Device to prolong battery life to the user's set temperature and will turn itself back on once it hits two degrees higher than the desired temperature, which could also be customized.

C. Solar Charger

The actual solar system consists of a 50W solar panel and the power is used to charge two 12V, 9Ah batteries connected together. There are different charging techniques available for the design of the circuit. Our goal was to design a system efficient enough so it gets maximum power from solar power



and charges the connected batteries in less time. To achieve that goal we decided to design a solar system based on maximum power point.

The solar charger is implemented using the ADC and PWM channels of the microcontroller. The PWM signal turns on and off the buck converter to achieve the maximum tracking point and avoid losing much power. The purpose of the microcontroller is to read output voltage and current and calculate the power. Same data will be read on the other hand from the battery side. Based on the reading, the microcontroller controls the buck converter by increasing or decreasing the duty cycle of PWM or even turning it off if needed. To the right is the block diagram and circuit diagram of the charging system can be seen at the top of the page.

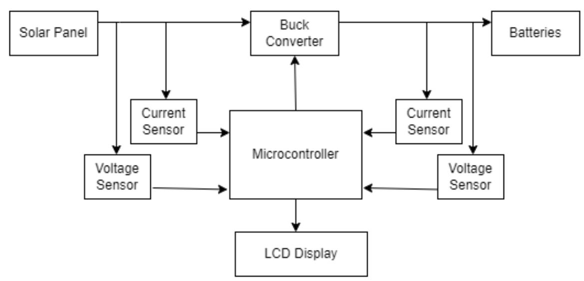


Fig. 5
Solar Charger Block Diagram

The most common converters used in MPPT charge controllers are buck boost or buck converters. Our requirements can be met with only a buck converter so it is decided to implement a charging circuit using buck converter but if the solar charger is used for a big scale like in utility then it is recommended to use buck boost converter. A normal charging circuit only converts 30 to 40 percent energy into electrical and this efficiency can be increased by using mppt and in our case since the cart may be left outside for a longer period of time so we need a fast charging system with higher efficiency.

D. Wall Charger

Due to timing constraints and keeping the budget low, the team has decided to buy a wall charger from the market. The wall charger in this project did not design by the team members

E. Voltage Regulator

The buck switching regulator LM2576 adjustable version is selected to step down 12V from the lead acid batteries to 5V in order to power the motor controller board, the MPPT solar charge controller and the 20x4 LCD display. This regulator has a wide input range (7-40V) and output range (1.23-37V). It is capable of driving loads up to 3A with excellent line and load regulation. In addition to that, it is optimized with minimum external component counts and includes a 52-kHz fixed frequency internal oscillator. It offers high power efficiency up to 80%. The datasheet provides the complete schematic and guides us how to pick the correct values for each component.

The figures below shows the formula of how to regulate the output voltage by adjusting the values of R1 and R2 and the schematic of the voltage regulator:

$$V_{out} = V_{ref}\left(1.0 + \frac{R2}{R1}\right)$$

$$R2 = R1\left(\frac{V_{out}}{V_{ref}} - 1.0\right)$$

Where $V_{ref} = 1.23$ V, R1 between 1.0 k and 5.0 k

Fig. 6
Resistor selections

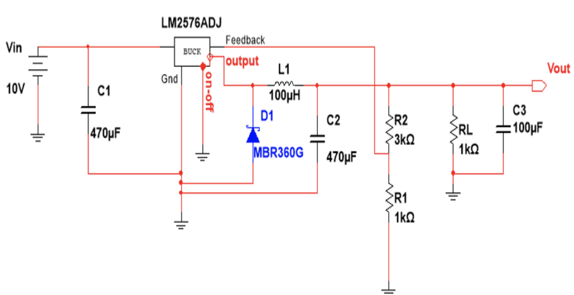


Fig. 7
Voltage Regulator Schematic

IV. SOFTWARE IMPLEMENTATION

A. Motor Control

The motor control code was, originally, going to implement a PID controller to ensure the proper output based on the user's intentions. It was found, however, through testing that the PID control algorithm was an unnecessary complication that added a negligible effect to the output. Thus, the PID algorithm was scrapped and we decided to instead use a simple transfer function to convert the ADC readings into the desired PWM duty cycle. Because the ADC uses a 12-bit value and the PWM duty cycle is stored in a register as a 10-bit value, we simply shifted the ADC result to the right by 2 bits.

```
CCPR1 = average >> 2;
```

Fig. 8
Duty cycle transfer function

It can be seen in the above figure that the duty cycle value which is being stored in register CCPR1 is the average variable value shifted by 2 bits. The average is used to filter noise from the ADC readings. For every duty cycle update, the ADC actually takes 8 readings. For each reading, the result is compared with all zeros signifying a null result. If the result is found to be all zeros, the loop counter is reduced and the loop continues. If the result is not null, the result is shifted to the right 3 bits (divide by 8) and added to the current average. This routine is shown in the following figure.

```
average = 0x0000;
for(i=0; i<8; i++)
{
    ADCON0 |= 0x01;      // start the conversion

    // waiting for ADC conversion to complete
    while ((ADCON0 & 0x01) != 0)
    {}

    // checking for null
    if ((ADRES | 0x0000) == 0x0000)
    {
        i--;
        continue;
    }
    average += (ADRES >> 3);
}
```

Fig. 9
Average Filtering

B. Solar Charger

Perturb and observe method is used to implement the design. According to Maximum Power Transfer technique, the output power of a circuit is maximum when the source impedance matches with the load impedance. In the source side a buck converter is connected to a solar panel in order to enhance the output voltage. By changing the duty cycle of the buck converter appropriately by PWM signal the source impedance is matched with that of the load impedance. The perturb and observe method does have some drawbacks like oscillations and confusion with rapidly changing environment conditions. But it is widely used due to its simplicity and cost effectiveness and our project is using the same technique. The next figure shows the algorithm implemented in the microcontroller for perturb and observe method.

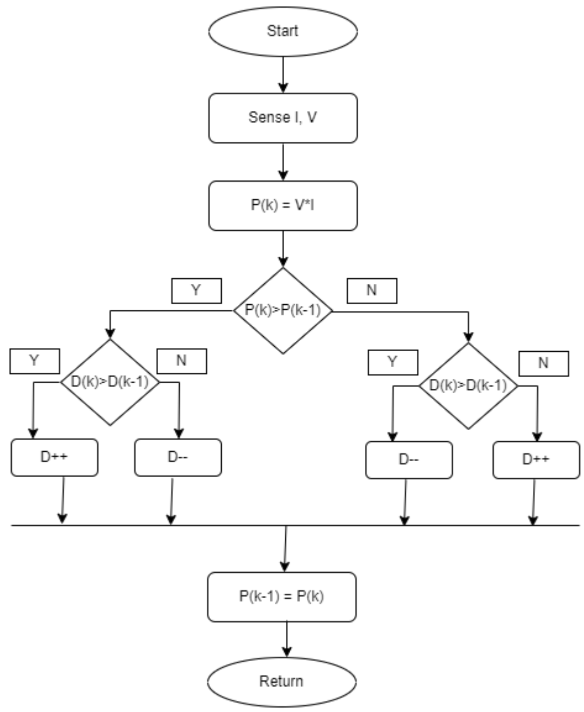


Fig. 10
Maximum Power Point Algorithm Flow Chart

V. POWER SUPPLY

Power is one of the most crucial parts of the project. We have made the decision for the power sources based on the factor of power efficiency and affordable solution. We also try to minimize the excess weight put on the device.

A. Battery

We will be using 2 rechargeable 12V-lead-acid batteries as the primary power supply to run the Peltier cooler, motor controller, solar charging circuit and the LCD display. The battery brand is Raion power RG1290T2 (12V, 9Ah). They are non-spillable, low cost and lightweight. These batteries will be connected in parallel and charged from the solar source. They can be charged with the current less than 2.7A. There is a wall charger beside the solar panels as a backup power supply.

B. Solar Panel

Aiming for a sustainable solution, solar panels are one of the most safe and clean alternative energy. A

50W solar panel is utilized as the main power source for this project. The reason we select this panel is due to the appropriate dimension and cost saving purpose. It is lightweight and fits perfectly on top of the cart. Since the device is used for outdoor activities, the solar panel is beneficial as it can actively provide energy to charge the battery while the device is operating outside.

The table below has shown the technical specifications of the chosen solar panel:

Features	**Parameter**
Max Power	50 W
Open-Circuit Voltage	21.6 V
Optimum Operating Voltage	18 V
Optimum Operating Current	2.78 A
Weight	6.82 pounds
Dimensions	20.15 x 25.8 x 1.18 inches

VI. CONCLUSION

To guarantee that our design is innovative, research was conducted on competitive products in the market of battery powered and "smart" cooler systems. There are, in fact, many products currently that have made improvements to the original design. The problem with the current products on the market is that none of them combine these features into a single machine. The biggest oversight in these smart coolers are the weight added by the refrigeration systems and battery. The current products that are motor-powered do not include any of the other features. Aside from the lack of other features, the controls provided are not intuitive or even very useful. We believe that we have combined the most important features of the powered coolers and added an intuitive motor-assist system that will not only counter the extra weight of the devices but will make the entire system feel weightless to the user. This will allow people of all types to bring this cooler to any location they desire.

VII. MEET THE TEAM

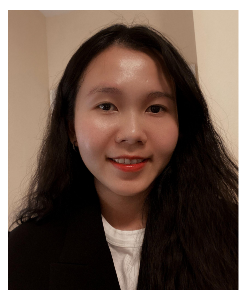
David Crumley

David Crumley is a senior at the University of Central Florida and planning on receiving his bachelors of science degree in computer engineering. He aspires to work on robotic systems in the aerospace industry.

Aqeel Ahmed

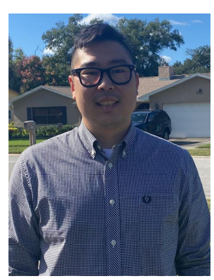
Aqeel Ahmed is a student of Electrical Engineering at University of Central Florida and expected to graduate with a bachelor degree by December 2021. He has interest in the power industry and is willing to focus his future career in Power Electronics.

Phuong Thi Y Duong



Phuong is a graduating Electrical Engineer student from the University of Central Florida. She intends to gain some more work experience before considering pursuing a higher degree. She hopes to find a full-time position in the power field and embedded system after graduation.

Min Park



Min Park is graduating from the University of Central Florida with a bachelor's degree in Computer Science. He will be continuing his education in Computer Sciences to pursue a career in software engineering.