Charge Du Soleil

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***Abstract* — Charge Du Soleil is a solar-powered, light-seeking autonomous rover capable of charging small electronic devices such as a cell phone or tablet. Key features include light sensing photo resistors, MPPT capability, object detection and avoidance, and a photovoltaic array for harnessing solar energy. Once the mobile device begins to run low on power, you can simply plug it into the robot to charge. In conditions of minimal light, Charge Du Soleil will seek areas of greater light intensity. Once a suitable location is reached, the rover will stop, and begin collecting energy and replenishing its power supply. As a result, we have created a fun and efficient way of collecting and using solar energy.**

***Index Terms* — Ultrasonic Proximity Sensor, Switching Voltage Regulator, MPPT, Geared DC Motor, Motor Shield, Arduino Uno, Solar Energy, Photoresistors, and Power Bank.**

I. INTRODUCTION

Charge Du Soleil was inspired by the thought of constant use and abuse of electrical outlets, especially with electronic devices. We wanted to find an alternate way of charging our devices that was away from the wall and not influenced by the power grid. Consequently, we decided to incorporate solar energy.

Three solar panels are used in a predominantly sunny outdoor environment to charge the rover. The output voltage from the panels is then regulated to an optimum value via two separate MPPT microchips. The panels charge the power bank, which contains a battery. The power banks have the pass-through feature, which allows for receiving charge inputted while simultaneously outputting power via USB. Two power banks will be used to power our components, with the larger to charge the four 6V DC motors of the rover and the smaller to charge the microcontrollers.

The HR-SC04 utilizes ultrasonic sensors to detect and avoid obstacles in front of it. These sensors prevent the robot from bumping into obstacles such as people, walls, cabinets, and other objects that can hinder the rover’s path.

Photo resistors serve as the light sensors. If the light intensity on one sensor is larger than the other, Charge Du Soleil will turn in that direction. Once the light intensity is sufficient and the area is optimum for energy collection, the robot will stop moving.

Utilizing the practically infinite abundance of solar energy is the primary motivation and focus of Charge Du Soleil. The main goal of our project is to design and construct an energy efficient, portable, low cost, and interactive robot that is fun and easy to use.

II. CHARGE DU SOLEIL COMPONENTS

Charge Du Soleil is comprised of multiple individual components that are integrated with one another in order to achieve full functionality of the robot. These components include the chassis, DC motors, motor shield, microcontroller, motion sensor, and photo resistors. These important devices are listed below.

A. Chassis

When first designing this robot, we considered developing a robot platform from scratch, but we soon realized that smart car kits were cheap and abundant. The mobile platform kit selected is from DFRobot. We chose this one because of all its desirable features such a compact dimension of 200 mm (7.87 in) by 170 mm (6.69 in) by 105 mm (4.13 in). In addition, the entire chassis is made up of a lightweight aluminum construction resulting in a total weight of 660 g (1.45 lb) [1]. Due to the additional weight of the solar panels and power banks, it is crucial that the chassis be lightweight to retain mobility but also rigid to not distort under stress. The chassis is based on a 4WD design with 4 independent DC motors running the wheels. Four plastic wheels and tires are included as well as space to internally house four geared DC motors and 5 AA batteries (which are replaced by the larger power bank in Charge Du Soleil). Holes to mount the Arduino development board are pre-drilled into the base platform. Standoffs are given to raise the secondary platform and functions as a canopy for the car. An extension piece is included in the package as well to support additional components [1].

B. Motors

DC motors are simple electromagnetic devices that convert direct current (DC) electrical power into mechanical power. This type of motor is used in Charge Du Soleil because motors can be directly powered by sunlight since electricity via the sun is also DC. The four yellow DC motors used here were actually included in the DFRobot kit and operate between 3-12 V [2]. These compact Chinese motors are low-cost and have the ability to move the robot. A useful quality of DC motors is that they can operate in both clockwise and counter clockwise directions. This feature allows for both forwards and backwards rotation. Another helpful attribute is the fact that a 4WD configuration allows each geared DC motor to spin independently, making turning in the left and right directions possible. Varying the input voltage applied alters the rotational speed of the DC motor [2]. Motors used for Charge Du Soleil operate at 6 V and according to Table 1, current draw is 160 mA and rotational speed is roughly 180 RPM.

Yellow DC motors	Specifications
Gear ratio	1:120
No-load speed (6V)	180 RPM
No load current (6V)	160 mA
Locked-rotor current (6V)	2.8 A
Size	55 mm X 48.3 mm X 23 mm
Weight	45 g

Table 1: DC Motor Specifications

C. Motor Shield

The Adafruit V2.3 is used as the motor shield for Charge Du Soleil. This component was chosen primarily due to its compatibility with the Arduino Uno, and that it can run four DC motors on one shield. This is the best way to control DC motors, servos and steppers. The PWM driver in the center handles electronic speed control letting the Arduino control inputs outputs and sensors [3]. Two motor drivers are also included. Each driver has two channels of 1.2 A up to 3 A peak at 12 V. Adafruit claims this is sufficient to handle any kind of stepper or DC motor with no problem. Three (3) large filter capacitors eliminate any noise feedback within the system. For battery power, a terminal block allows an external battery pack to be connected with built-in polarity protection to prevent damage to the module. The five (5) 1.5 V AA batteries originally inside the robot supply a voltage of 7.5 V which successfully powered the motors during testing. In the final design, 6V will be supplied to the motors via solar panel. Each of the two (2) motor control ports can control either two (2) brushed DC motors or one (1) stepper motor. In the case that more motor control ports are desired, the Adafruit V2 design permits shield stacking. Each additional shield adds two motor control ports [3]. Libraries, examples, tutorials, and wiring diagrams are all readily available online.

D. Micro controller

Charge Du Soleil uses the Arduino Uno development board which contains the ATmega328 microprocessor from the Atmel family as the one central microcontroller for controlling the motor shield, ultrasonic proximity sensor, and photoresistor light sensing apparatus. This is the brain of the entire project, and without this, nothing would function at all.

The board comes equipped with both a USB connection and a power jack. The Arduino Uno can be supplied with power either from the DC power jack (7-12 V), the USB connector (5 V), or the VIN pin on the board (7-12 V) [4]. During the programming phase, the board was powered by a laptop via USB connection. Later on, when testing movement of the robot, a 9 V battery powered it using the power jack. During the final design, 5 V 1 A will be supplied to the board from the power bank via the USB connector. The board can operate on an external power supply of 6 to 20 V, however, the recommended value is 7 to 12 V. Less than 7 V may supply less than 5 V to the 5V output pin and cause instability [4]. This can become problematic for the HC-SR04 sensor because it requires the full 5V input to VCC. More than 12 V can overheat the internal voltage regulator and damage the board. As previously stated, because the power bank supplies only 5 V, it will be connected to USB connector. Included is also a 5V pin supplying a regulated 5 V output and a 3V3 pin supplying a regulated 3.3 V output. According to Table 2, the maximum current draw on the 3V3 pin is 50 mA. It is worth noting that these are output pins ONLY and supplying voltage to them bypasses the voltage regulator and is NOT recommended [4].

ATmega328	Specifications
Operating Voltage	5 V
Input Voltage (recommended)	7-12 V
Input Voltage (limits)	6-20 V
Digital I/O pins	14 (of which 6 provide PWM output)
Analog input pins	6
DC Current per I/O pin	40 mA
DC Current for 3.3V pin	50 mA
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 2: ATmega328 Specifications

E. Ultrasonic Proximity Sensor

In order for the robot to navigate safely, object avoidance must be implemented. In order for Charge Du Soleil to sense objects in its path, the HC-SR04 was selected. The HC-SR04 is an ultrasonic sensor that uses sonar to determine the distance to an object similar to the system bats or dolphins are naturally equipped with. This package offers excellent non-contact range detection and stable readings. One major benefit of using this sensor is that its operation is not affected by sunlight. Charge Du Soleil intends to operate mainly in direct sunlight.

The HC-SR04 has four (4) connection pins, VCC (which MUST be supplied by +5V DC according to the specifications in Table 3), Trig (Trigger input), Echo (Echo output), and GND (ground) [5]. According to the timing diagram shown in Figure 1, to start measurement, the Trig pin must receive a pulse of high (5 V) for at least 10 uS.

This will enable the sensor to transmit out 8 cycles of ultrasonic bursts at 40 kHz and wait for the reflected ultrasonic burst. Once the sensor detects this reflected signal, it will set the Echo pin to high (5 V) and delay for a period [5]. The delay period set is proportional to the distance. To obtain this distance, measure the width or delay of the Echo pin. The VCC pin will be paired to the 5V output pin on the Arduino Uno and the GND pin to the GND pin.

HC-SR04	Specifications
Power Supply	+5 V DC
Quiescent Current	<2 mA
Working Current	15 mA
Effectual Angle	<15 degrees
Ranging Distance	2-400 cm
Resolution	0.3 cm
Measuring Angle	30 degrees
Pulse Width	10 uS
Dimensions	45 mm X 20 mm x 15mm

Table 3: HC-SR04 Sensor Specifications

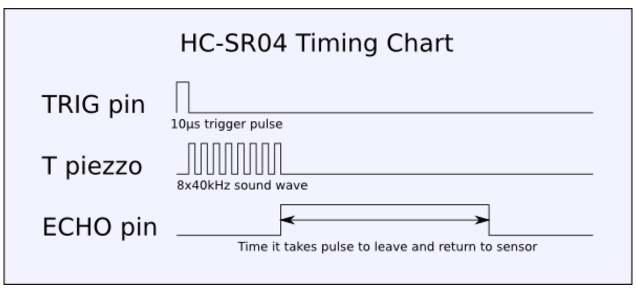

Figure 1: HC-SR04 Timing Chart

F. Photoresistors

Charge Du Soleil is able to seek the best possible light source to improve energy collection. Light sensing is done using photoresistors. A photoresistor is also known as a light dependent resistor (LDR) where resistance across the two prongs inversely varies with the amount of light exposure [6]. In brightly lit conditions, there is less resistance and in dim light there is more resistance. The resistance in a photoresistor can be a few hundred ohms in maximum brightness and a few hundred ohms in the dark. Two photoresistors are used in Charge Du Soleil to sense the light exposure. If the resistance on the sensors is over a certain value, there is not enough light and the robot will continue to search for a better area to charge. Once the resistance on the sensors is below this value, there is sufficient light and the robot will send a signal to the motors to stop running. At this location, Charge Du Soleil is satisfied and will stay. If the difference in resistance values of both sensors is above a certain value, Charge Du Soleil will then turn in the direction of the lower resistance value. If the difference in resistance values of both sensors is less than this value, Charge Du Soleil will continue to travel straight until the sensors receive equal light. It is worth noting the inaccuracy of these devices however. Under the same lighting conditions, resistance in two LDRs can vary [6]. It is important to test the resistance in order to maximize the accuracy of the light seeking algorithms. Lux is the standardized unit for measurement of light intensity or illuminance. As seen in Figure 2, as the lux increases, the resistance across the photoresistor decreases. From the software standpoint, the photoresistor’s change in resistance will be rated from a 0 to 1023 (2 to the tenth power minus 1). The higher the value is read, the more intense the light is at that point.

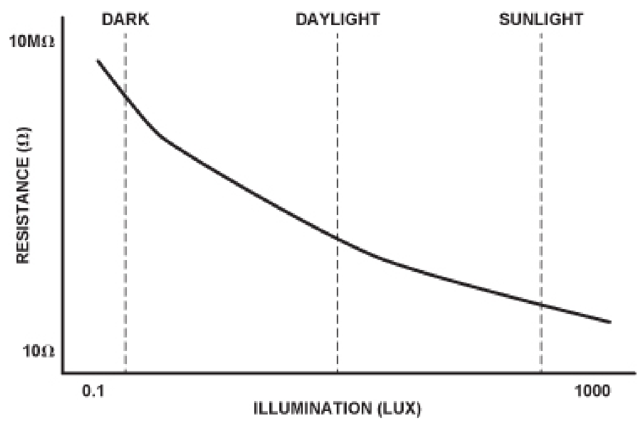

Figure 2: Lux VS Resistance curve

G. Power

The main component of the power system for Charge Du Soleil is the solar panel that is being implemented into it. One of our goals with the power system for Charge Du Soleil is to make the battery rechargeable with a solar panel. This feature allows Charge Du Soleil to function as a mobile device charger indoors and outdoors as it operates during the day. The three solar panels used here are AllPowers 12 V 5 W. Based on the relationship between power, voltage, and current (P=IV), the current generated by each panel is 0.4167 A. For our purposes, we will be using two solar panels in parallel (12V, 0.833A, 10W) supplied into the first charge controller that will power the motors, while the third panel will be fed into a second controller and power the Arduino microcontroller as well as its neighboring components. This method, although somewhat trickier than the typical lithium polymer battery, will have the benefit of us knowing the charge percentage of our power supply as well as a larger pool for energy storage. Both charge controllers have max power transfer microchips that will allow for the highest efficient solar energy to be harnessed, regardless of the weather variations of intensity of light. The MPPT chip (explained later in this section) will track the constantly change photovoltaic curve, and pinpoint the maximum voltage and current values for a given input voltage and current. As a result, very little heat will be lost in the process, achieving on of our goals to have an efficient machine.

Figure 3: Series Configuration

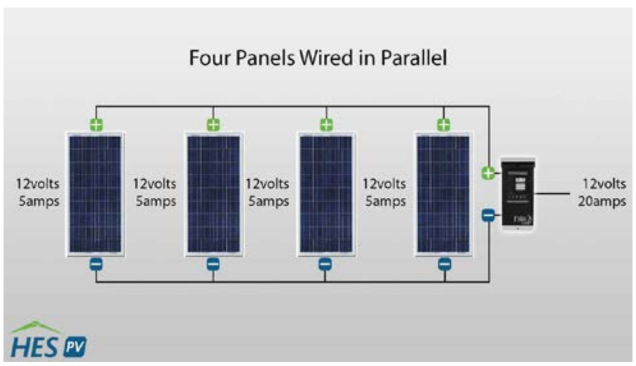

Figure 4: Parallel configuration

According to Figure 4, when the three panels are connected in series, the voltage will triple to 36 V and when in parallel the current will triple to 1.25 A. Regardless of the type of configuration chosen, power will be tripled at 15W. This photovoltaic assembly will produce a current of approximately 1.25 A [7]. The desired voltage to charge the power bank battery is 5 V. To avoid damaging the battery internals, a voltage regulator is necessary. Linear voltage regulators were originally considered due to their low lost and simplicity but rejected due to their low efficiency. The efficiency of a linear voltage regulator increases as the difference between input and output voltage decreases [8]. When the desired output voltage is only slightly below the supplied input voltage, efficiency will approach 95 to 99% efficiency. A main advantage to this over a switching voltage regulator is that there will be a more stable voltage output with minimal noise ripple [8]. The photovoltaic assembly used by Charge Du Soleil has been measured to produce over 20 V in direct sunlight. This means that the voltage regulator used must step down 15 V. In this application, although more expensive and complex, a switching DC/DC converter will be used. In order to charge the batteries efficiently, an MPPT (Maximum Power Point Tracking) system is desired. A MPPT is a special type of charge controller that optimizes the energy yield of a photovoltaic array by controlling the panel operating voltage [9]. It operates by taking DC input from the PV module, converting to AC using a high frequency oscillator and converting back to a different DC voltage and current to exactly match the PV module to the battery. This additional power collected from the modules translates into increased battery charge current which decreases battery charging time [9]. Solar panels produce a current at a certain voltage equal to the voltage of the load attached. If this operating voltage is not set correctly, the system will not reach its full potential. Conventional controllers (non-MPPT) connect the solar modules directly to the battery. This forces the panels to operate at the battery voltage, which is not their ideal operating voltage to produce maximum available power. Alternatively, MPPT charge controllers calculate the optimum voltage for maximum power. Allowing the solar panels to operate at their maximum rated voltage instead of the battery voltage results in quicker recharging [9].

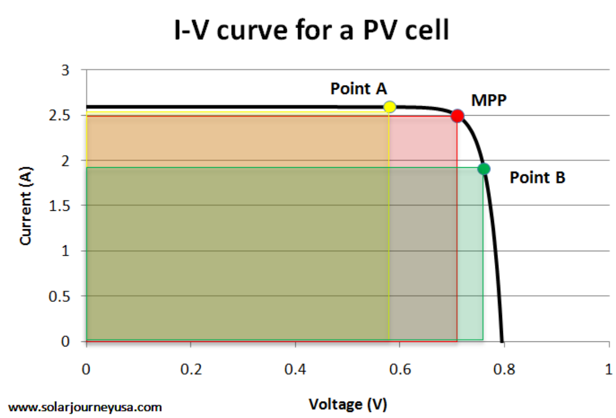

Figure 5: I-V curve for a PV cell

In Figure 5, Point A represents when the operating voltage is set to 0.58 V and the current is 2.6 A. The area of the yellow rectangle represents the total power of the cell at 1.51 W. Point B represents when the operating voltage is set to 0.76 V and the current is 1.9 A. The area of the green rectangle produces slightly less at 1.44 W. At the MPP or maximum power point, the red rectangle under the curve is at its maximum and produces 1.77 W.

Also included in Charge Du Soleil is a boost or step-up converter which will increase the input voltage of the motors from 5 V to 7.5 V via the first larger power bank and simultaneously decrease current to 1.67A. As previously stated, the current draw for one DC motor is 160 mA therefore a minimum of 640 mA (4 motors) must be supplied. The maximum current and voltage that can be supplied to the motors is 3A and 12 V, respectively. The values we plan to use fit well in the middle of the minimum and maximum values of our motor, therefore, we expect the motor to be fully operational.

Power Bank

Charge Du Soleil uses two power banks to serve as an “extra battery” or external charger for mobile devices. The 9000 mAh power bank has an input voltage of 5 V and can be charged via USB port or AC/DC wall adapter. It is equipped with two (2) 5 V USB outputs, one of 1 A, and the other 2.5 A. A smaller 2200 mAH power bank serves as the secondary unit. It has an input of 5 V 1 A, and one output of 5 V 1 A. The solar panels mentioned previously will charge the power banks, and the microprocessor, ultrasonic sensor, motors and mobile device will discharge it. It is very important to use a power bank design which allows pass-through charging. This feature allows the power bank and devices to charge simultaneously. Without the use of pass-through charging, power to the microprocessor, ultrasonic sensor, and motors will be cut once the solar panels charge the power bank. It is ideal for the photovoltaic array to charge the power bank as it is being discharged by the components mentioned previously. Most power banks on the market do not include this feature, so it is often necessary to see it listed under the specifications. The unit of measurement of battery capacity is amp-hour obtained by multiplying current flow in amperes by the time in hours of discharge [10]. The 9000 mAH power bank delivers 9 A for 1 hour or 4.5 A for 2 hours. The 2200 mAH power bank delivers 2.2 A for one hour or 1.1 A for two hours.

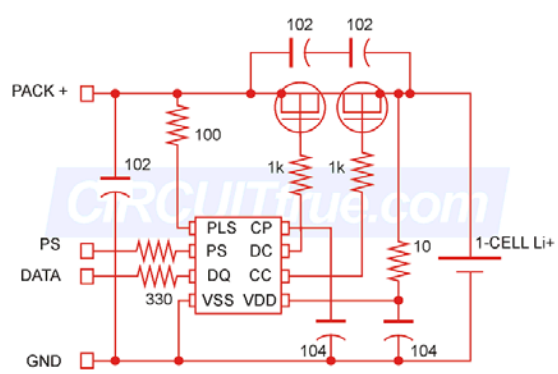

Figure 6: USB Power Bank Circuit Diagram

According to Figure 6, the interior of a USB power bank contains a USB input, voltage regulator chip, resistors, capacitors, diodes and a lithium-ion cell battery. This system is very fragile, and it was beneficial to use a power bank which includes all these necessary components. Lithium-ion is very popular in modern consumer electronics mainly due to its energy density [11]. A large amount of energy can be stored in a relatively small space. In fact, the energy density of lithium-ion is twice that of Nickel Cadmium. Unfortunately, the use of lithium-ion cells requires the use of a protection circuit to maintain safe operation. It limits the peak voltage of each cell during charge and prevents the cell voltage from dropping too low on discharge [11]. In addition, the cell temperature is monitored to prevent temperature extremes. The purpose of the circuit shown above is to decrease the 5 V supplied down to 3.7 to charge the lithium-ion cell. The output is then boosted back up to 5 V to charge mobile devices such as cell phones and tablets.

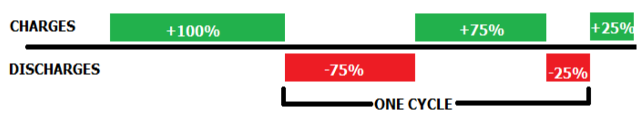

Figure 7: Discharge cycle of Lihium Ion cell

The main advantage of using Li+ batteries is the low maintenance and longevity. There is no memory and no scheduled cycling is required to prolong the battery's life. The capacity of any type of battery will diminish after a certain amount of recharging. With lithium-ion batteries, this capacity diminishes only slightly with each complete charge cycle. One complete charge cycle is when 100% is discharged but not necessarily at one time. In Figure 7, 75% of Charge Du Soleil’s battery capacity may be depleted indoors, then recharged fully outdoors. Once 25% of the battery is depleted, a total of 100% has been discharged. This completes a complete charge cycle.

III. Block Diagram

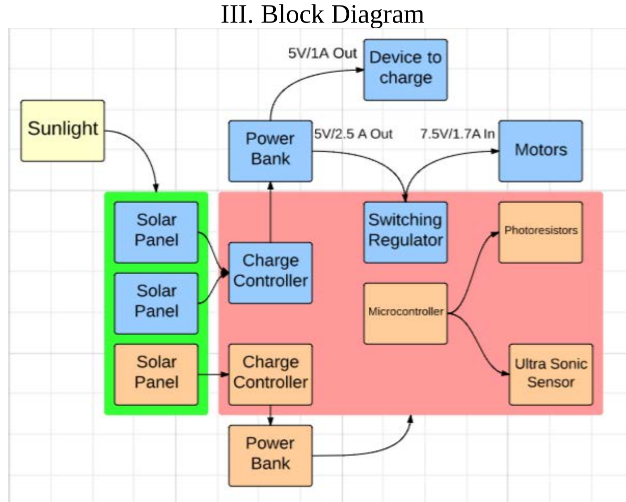

Figure 8: Block Diagram

The block diagram shown above in Figure 8 shows how all of the components listed above will interacted with one another on the robot. The blue labeled boxes represent all of the components that will be used to with powering the motors of the car. The orange colored boxes represent all of the components that will be used to power printed circuit board (PCB).

Of the three solar panels being used, two of which will be dedicated to the motors and the third will be dedicated to the PCB. A charge controller will be used to control the input voltage from the solar panels down to the recommended voltages needed to charge the power banks. The power bank that will be used to power the motors has two outputs (5V/2.5A and 5V/1A) in which the 5V/2.5A output will be used to power the motors and the other output will be used to charge the USB powered device connected. The second power bank will be used to power the PCB. As shown on in the diagram, everything that is within the red block will be on the PCB. The PCB will need 5V to power it and the output on the second power bank is 5V. The photoresistors will be used to measure the amount of light that is in the area and the ultrasonic sensor will be used to measure the current distance an object is from the robot itself. Both will feedback the information it receives back to the microcontroller which will then determine which way the robot should move.

IV. Code

Charge Du Soilei was developed with an intended purpose of being fully autonomous robot with the ability to seek the strongest source of light and being able to avoid objects at the same time. The coding for this project was all done in Arduino CC coding language. Within the code, there's two main functions; light seeking and object avoidance.

The light seeking portion of the code starts by reading in the value of light from a left and right photoresistor and then compares the values. The maximum reading from each resistor can be 1023 and minimum is 0. If the reading from the left photoresistor is stronger than that from the right photoresistor and the difference is greater than 75, the robot moves slightly to the left. If the reading from the right photoresistor is stronger than that from the left photoresistor and the difference is greater than 75, the robot moves slightly to the right. If the difference between the two is less than 75, the robot continues to move forward. The robot will stop when the reading on either of the photoresistors is above 900 (which would be the reading needed outside to charge the solar panels).

With the object avoidance portion of the code, the ultrasonic sensor is used to measure the distance of an object in front of it. A trigger distance of 30cm was set and if the robot moves to towards and object and the distance becomes less than 30cm, a trigger will then flag to robot to find its way around the object. The robot will come to a complete stop, turn a couple of centimeters to the right, measure the distance from the right and return to its initial position. The same process will then happen measuring the distance from the left side. A comparison function will then compare the distance readings to determine whether to turn left, turn right or to do a complete 180° turnaround. A higher distance reading from the left leads to the robot turning left (by 90°) and a higher distance reading from the right leads to the robot turning right (by 90°). If the distance reading is the same for both, the robot will reverse to the right at 90° and then will turn left at 90° to complete the 180° turnaround.

V. Printed Circuit Board

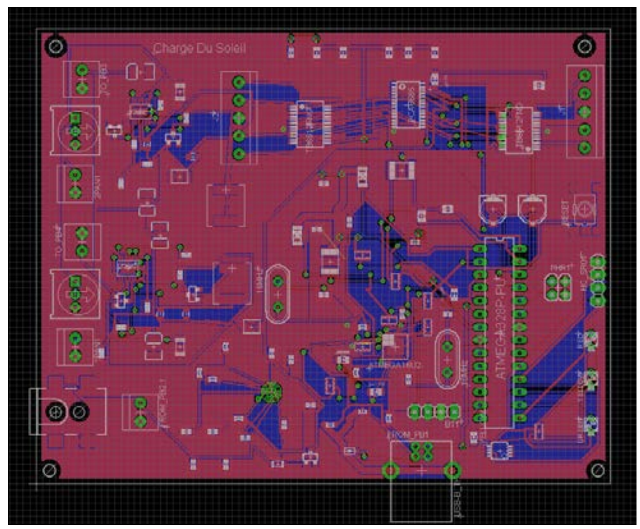

Figure 9: Printed Circuit Board Layout

Using CadSoft Eagle Professional Edition 6.5, Charge du Soleil constructed a two layer printed circuit. This board shown above in Figure 9, incorporates the Arduino Uno ATMega328 to run the coding environment and the ATMega16U2 to send and receive information via USB port. These sections can be found on the bottom right of Figure 7. In addition, on the far right edge of the board, just alongside the ATMega328 lies the locations for mounting the photoresistors and the motion sensor. This locations were strategically placed due to the fact that the motion sensor needed be in the front of the chassis in order to properly detect for obstacles directly in front of the rover. Also, both the photoresistors and motion sensor were situated near the center of their locations in order to give the most precise readings for light from both sides from the resistors, and to see directly ahead of itself for the motion sensor's case. Rigid extension cables are to be placed in the photo resistor junctions to be extended a few inches in the air. This will avoid interference in light sensoring when the LEDs on the board turn on. Some additional parts to mention along this same area are the Bluetooth junction and the USB-B port.

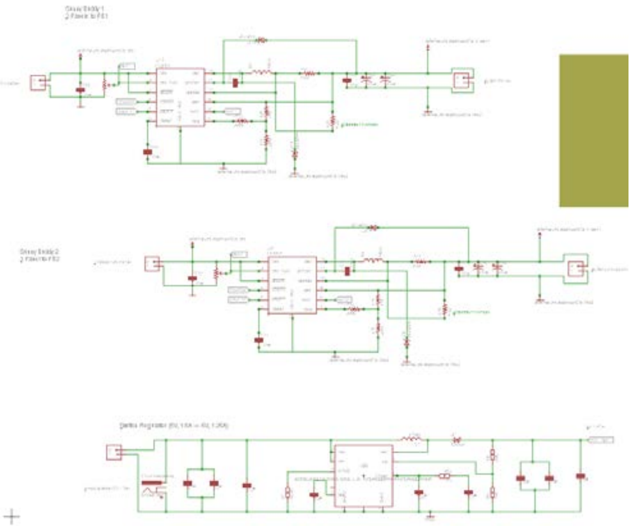

Figure 10: Two Charge Controllers (Top, Middle) and a Regulator (Bottom)

Near the top right of Figure 9 as well as the bottom of Figure 11 is the motor shield. The PWM microcontroller of the shield is powered via the VCC port of the ATMega328, while the H bridges that control the motors are powered by the regulated output of the larger power bank (see the regulator on the bottom of Figure 10). From the far left of Figure 9 all the way down are two charge controllers: one for the larger bank, and the second for the smaller bank. Both controllers connect to the panels via USB stripped wires soldered onto the through hole cables on one end, and output via stripped cables to USB to each power bank/ and can have their output voltages adjusted by moving the respected potentiometers. The bottom left of Figure 9 showcases two possible input connections for the motors via the larger bank: DC jack and through cable soldering. Although no other connection on the board utilizes a DC jack, this connection was made is a safety precaution and alternative method to charge the entire printed circuit board in case the USB connection did not function correctly for any unknown reason.

The schematic diagrams were modified from webench and atmel template models of their respective components. Any excess and unneccessary components of the original models were scraped, and only the most essential parts were kept on the final schematic. The board is 4.4" by 3.5" long, making it quite longer than the original board and motor shield. However, it contains both the main Arduino components and motor shield, 2 charge controllers with MPPT capabilities, a switching regulator the boosts the input of the power bank, and a USB-B port as well as a DC jack. Therefore, for its size, the printed circuit board is a quite complex and powerful electronic device.

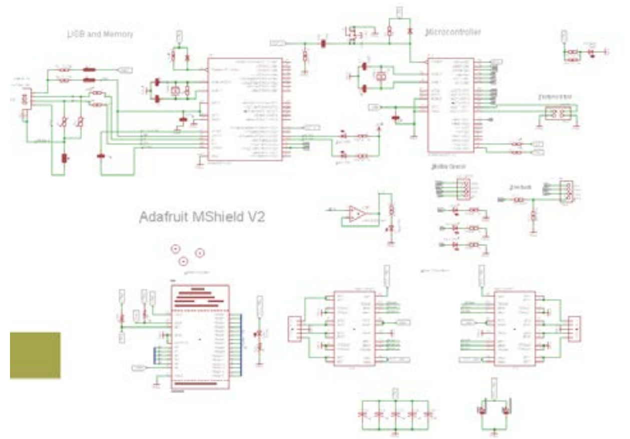

Figure 11: Arduino Uno (Top) and Motor shield (Bottom)

VI. Conclusion

This two semester long senior design project was designed to prepare senior level undergraduate students for real-world applications in both electrical and computer engineering. It trained us how to organize professional meetings, how to write technical documents, how to work together as a team and most importantly how to work under pressure. We learned a lot about the process of research and development and many of the administrative tasks involved such as funding proposals, budget management, and progress reports. It is astonishing how much this group has learned in only a short period of time.

The Senior Design project is an overall combination of the theory all the foundations and engineering courses that we covered. The lab hours from basic engineering courses such as Electrical Networks, Electronics, and Embedded Systems were extremely beneficial to the prototype phase. Charge Du Soleil is not the result of trial-and-error but of careful planning and trial-and-success.

VII. Acknowledgements

Charge Du Soleil could not have been possible without the help of the instructor Dr. Samuel Richie who guided the group through the development process. He provided suggestions and possible solutions to the design. In addition to this, he gave us the opportunity to apply for project funding from Duke Energy.

Duke Energy gave us funding for this project which we are eternally grateful for. Also, we thank Leidos for providing funds as well.

At the end of the day, we thank Theresa Collins for making sure we were reimbursed completely. That really means a lot to us from the bottom of our little hearts.

David Douglas allowed us to rent some tools which helped with electrical connections and measurement.

Our fellow Senior Design II classmates are also to thank for our project Charge Du Soleil. They took time out of their busy schedules and complex projects to offer insight through the critical design review (CDR) and let us borrow a resistor or two. That was very generous of them.

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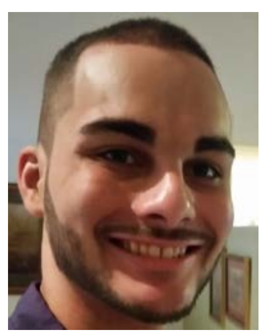
IX. Biography

Alan M Champagne is a 23-year old graduating Electrical Engineering student interested in automotive electronics. He is currently pursuing a position in the big 3 with either Mercedes-Benz, BMW, or Audi. Alan specializes in drive train electronics, active safety, driver assistance, and entertainment systems.

Aaron J Mitchell is a Computer Engineering student. Aaron has a career goal in mind to help older generations adapt to the newer technology so they would not be left behind as technology continues to advance. Aaron also has held numerous leadership roles within the National Society of Black Engineers on both the chapter and regional level.



Daniel Zapata is pursuing a Bachelor's of Science in the field of Electrical Engineering. He is a member of the Spanish Honors Society as well as the Leaders in Engineering. Daniel has serious interest in pursuing a job in the Power department, such as working on one of the four United States grid sections. In his spare time, Daniel likes to work on his motorcycle, and he hopes to one day become his own mechanic.