School of Engineering Science
Simon Fraser University, Burnaby BC V5A 1S6
mpc8@sfu.ca

November 17, 2011

Professor Mike Sjoerdsma
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 305 Design Specification for the Solar Panel Cubic Charger Accessory

Dear Professor Sjoerdsma:

Technical guideline for the design of Solar Panel Cubic Charger Accessory from OMG Studio is attached. This accessory will take in solar energy to charge up mobile devices. Optimizing its charging efficiency according to the lighting is the ultimate goal of the project.

Design specifications described in this document will discuss in-depth detail of concept functionality. Future improvements will be briefly touched upon but will not be used for implementation.

If you have any questions or concerns, please feel free to contact me at mpc8@sfu.ca or by phone at (604)780-9199.

Sincerely,

Michael Chen
President and CEO
OMG Studio

Enclosure: *Solar Panel Cubic Charger Design Specification*

Michael Chen | Molly Hou | Chris Chen | Yu Bu

Solar Panel Cubic Charger Design Specification

Yu Bu: yba3@sfu.ca
Michael Chen: mpc8@sfu.ca
Chris Chen: cyc19@sfu.ca
Shuyang Hou: sha58@sfu.ca

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EXECUTIVE SUMMARY

Within the design specification for the Solar Panel Cubic Charger Accessory, detailed descriptions for the design and development process will be clearly explained. Some concept ideas will be touched upon but will not be used for current stage of implementation. Main functions will be explained step by step to avoid any confusion.

This document will outline the design of the charger and also provide reasoning for component decisions. Sizing of our product is crucial for the current market. Not only will the choice of size be explained, individual components such as micro-controller and sensor choices will also be thoroughly covered. Placing these components is one of the greatest challenges for us to overcome. Sensor placement to maximize accuracy, closing the accessory while gaining maximal inner space for the circuitry, and choosing a stylish design while maintaining current space are some main problems to resolve. Software process will be included in this document. Codes and device testing will be shown under the test plan section.

During the design and implementation stage, we are aware that there are quite a bit of problems to overcome. Making a universal charger has a lot of details that requires a lot of attention in order for this product to be stable and safe. For this device to be fully tested and carefully designed, the completion date for development process will be January 5, 2012.

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Glossary

7-Segment LED - a form of electronic display device for displaying decimal numerals that is an alternative to the more complex dot-matrix displays

Anode - an electrode through which electric current flows into a polarized electrical device.

Cathode - an electrode through which electric current flows out of a polarized electrical device.

Decimal - a base-10 number system most widely used by modern civilizations.

Diode - a type of two-terminal electronic component with a nonlinear current–voltage characteristic.

Hex - Hexadecimal, a base-16 number system often used in computer nomenclature

LED - light-emitting diode is a semiconductor light source.

Micro-controller - a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals.

Monocrystalline - a material in which the crystal lattice of the entire sample is continuous and unbroken to the edges of the sample, with no grain boundaries.

NPN - one of the two types of bipolar transistors, consisting of a layer of P-doped semiconductor (the "base") between two N-doped layers.

PNP - a type of BJT is the PNP, consisting of a layer of N-doped semiconductor between two layers of P-doped material.

Polycrystalline – these materials are solids that are composed of many crystallites of varying size and orientation.

RGB –an additive color model in which red, green, and blue light is added together in various ways to reproduce a broad array of colors.

Series/parallel Circuit - A circuit composed solely of components connected in series is known as a series circuit; likewise, one connected completely in parallel is known as a parallel circuit.

USB - Universal Serial Bus

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Voltage regulator - an electrical regulator designed to automatically maintain a constant voltage level.

Zener Diode - a special kind of diode which allows current to flow in the forward direction in the same manner as an ideal diode, but will also permit it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage.

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1 Introduction

Solar Panel Cubic Charger Accessory is an accessory that will take in solar energy for charging mobile devices. Not only does the accessory come with the charging function, the thermal sensor built into the device will also detect the current temperature and display it by sending data to the micro-controller. Fully charging a mobile device under a reasonable time is the ultimate goal of the product. Moreover, it will eliminate the user from any frustration find the power outlet for their mobile device. Technical design and safety features will be guided through.

1.1 Scope

Design specifications and requirements to fulfill will be explained. Ways of meeting the requirement will be shown. We are focusing on the concept idea of the final product. Electrical schematics and flow charts will help facilitate the construction of the charger accessory.

1.2 Intended Audience

All members of OMG Studio will use this design specification as a guideline. Design engineers will use this guide for maximal space efficiency while keeping the charger small. Test engineers will use this document to implement and measure all the safety and stable features to keep the product reliable for consumers.

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2 System Overview

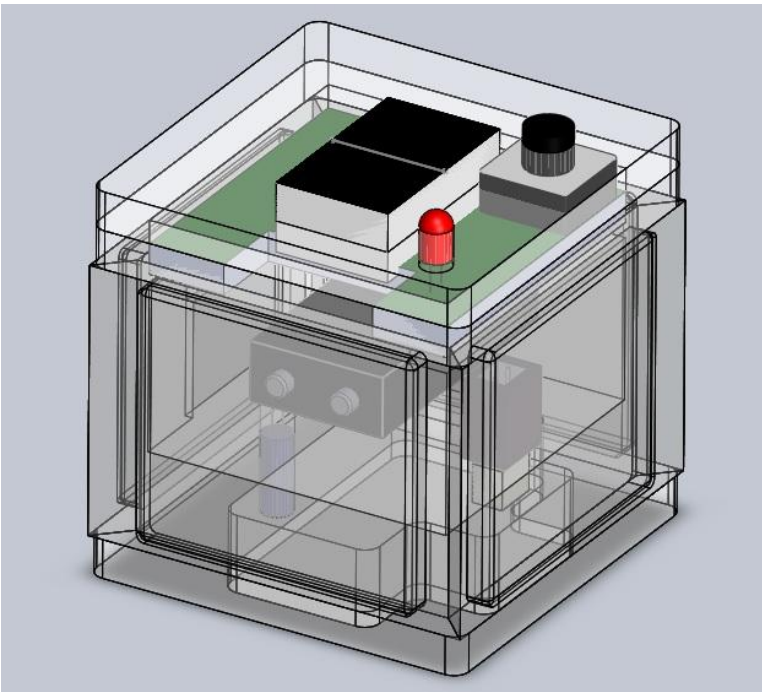

Figure 1: Product Overview

Solar Panel Cubic Charger uses four solar panels to gain energy. The energy then goes to the built-in battery providing power for charging devices and displaying the temperature with 7-segment LED display simultaneously. Micro-controller is programmed to display the current temperature onto the two 7-segment LEDs. The micro-controller shows the user the current energy of the built-in battery by flashing different colors of the bi- color LED. Block diagram of the whole system is shown below:

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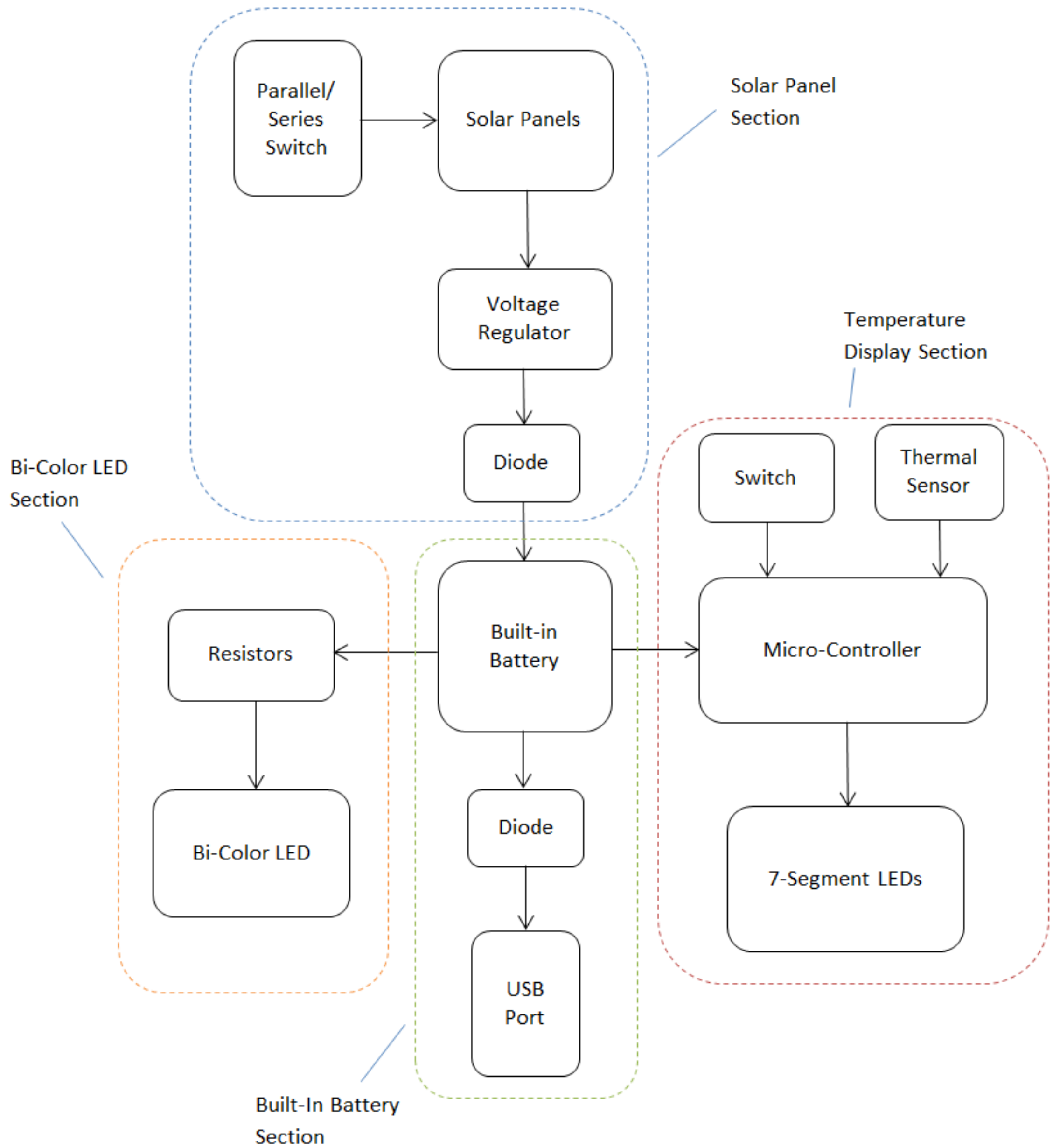

Figure 2: Block diagram of the whole system

As shown in the Figure, we divide the circuit design into four parts: Solar Panel Section, Temperature Display Section, Built-in Battery Section, and Bi-Color LED Section.

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3 Solar Panel Section

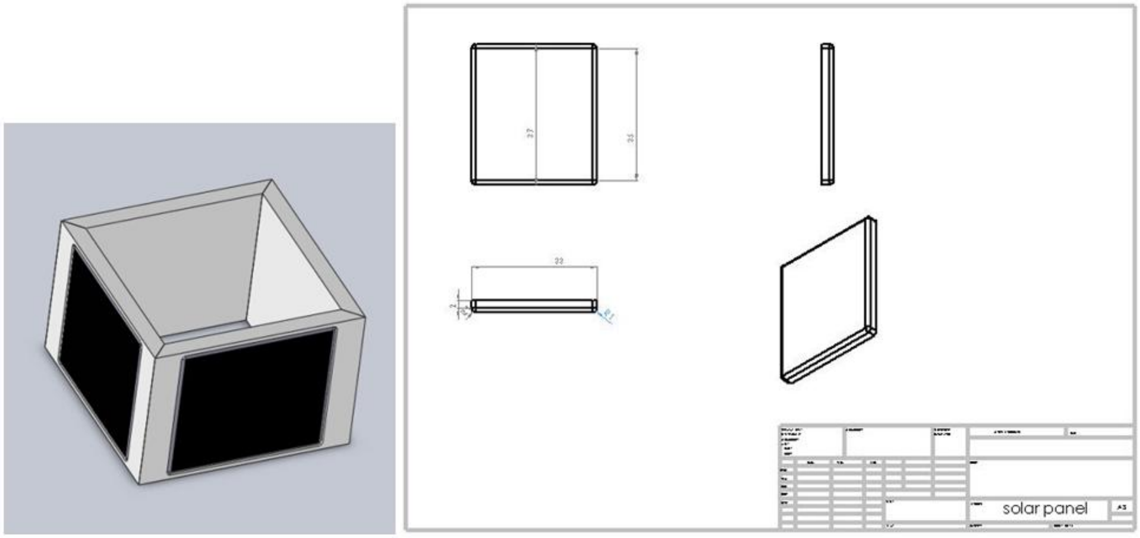

Figure 3: Solar Panel Overview

- Monocrystalline Solar Cell
- Better efficiency than Polycrystalline Solar Cell under dim lights
- Perfect sizing for our Solar Panel Cubic Charger design

Solar Panel Cubic Charger has four SCC3733 Monocrystalline solar panels. Under room light, each solar panel can provide 2.5 V, whereas under direct sun light, the voltage is increased to 6.4 V. In order to charge the built-in battery under various light conditions, Solar Panel Cubic Charger provides a switch to interchange between parallel and series connection.

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3.1 Parallel Mode – two solar panels connected in series, then connected in parallel with the other two that is already connected in series.

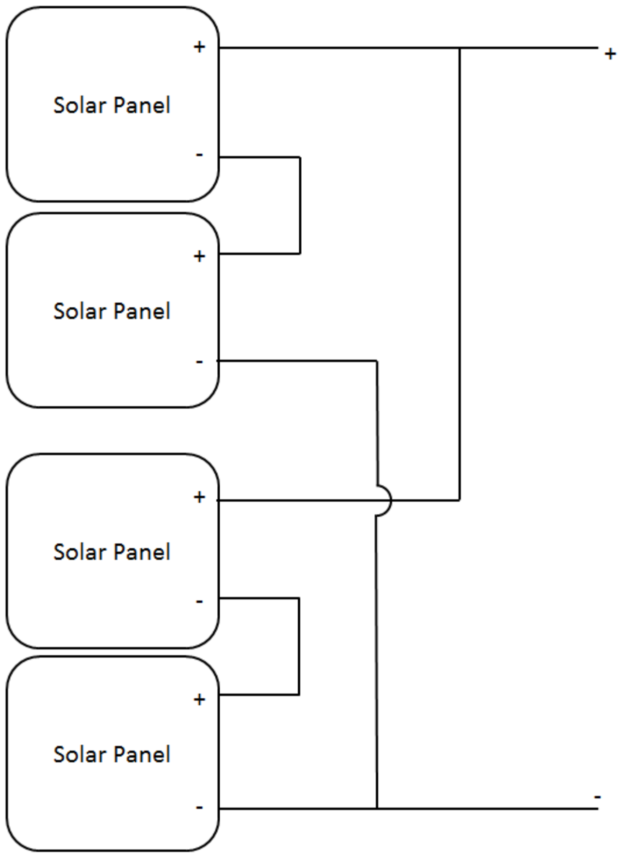

Figure 4: Solar Panels in Parallel mode

This arrangement is used under direct sun light when each solar panel is providing its maximum efficiency. For most electronic devices such as PlayStation Portable (PSP), cellphone, and MP3 players, 5 V meets the charging requirement. This arrangement creates greater current while maintaining 5 V for charging requirement. As current increases, the charging efficiency will also increase.

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3.2 Series Mode – four solar panels connected in series.

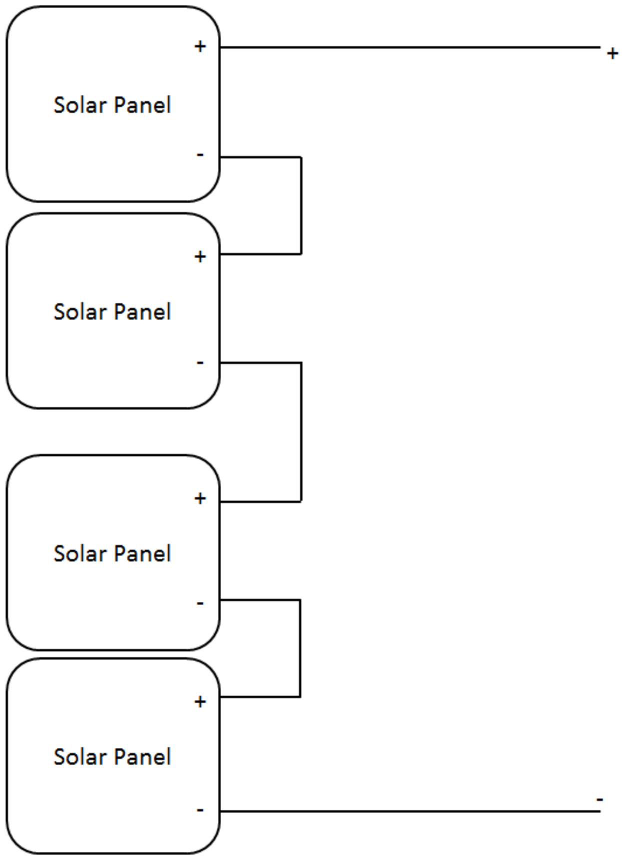

Figure 5: Solar Panels in Series mode

Under a fairly light limited environment, such as a cloudy day, solar panel takes in less energy. In order for the charger to meet the voltage charging requirement for most devices, connecting the four solar panels together in series will generate a lot more voltage but sacrificing the current value. Even though the speed of charging is decreased, at least the device will still be charging.

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3.3 Switch – switch between Parallel Mode and Series Mode

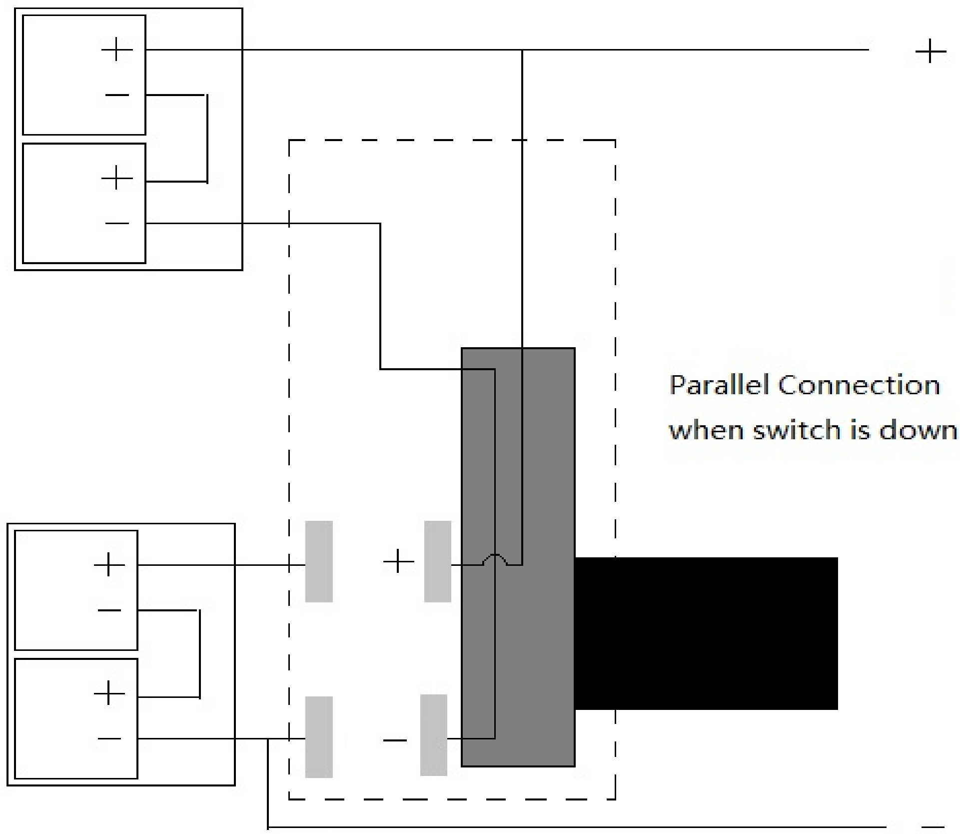

Figure 6: Switch to Parallel mode

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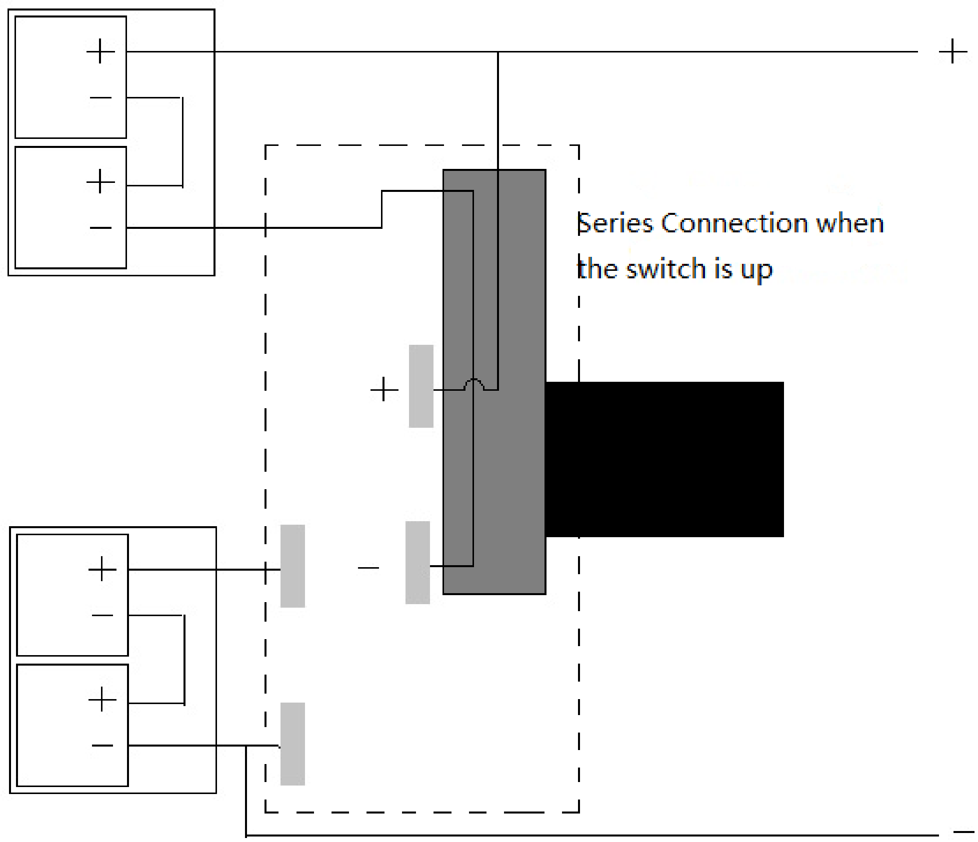

Figure 7: Switch to Series mode

Pushing the switch up and down can change the connection between parallel and series. When the voltage provided by solar panels is less than 5 V, a red LED light turn on to notify the user that the voltage is not enough for charging. It will be best for the user to switch from parallel connection to series in order to keep the device charging. If the LED is still on after switching to series, that means the light is too dim to charge.

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3.3.1 Low power indicator for solar panels

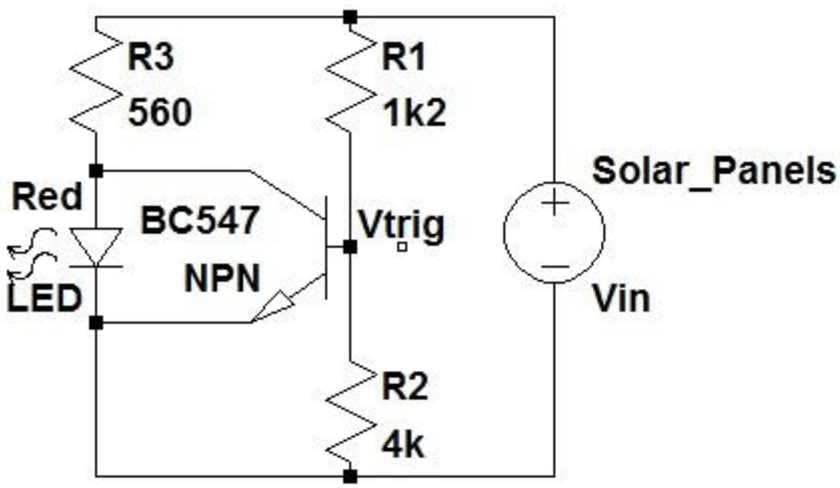

Figure 8: Circuit of low power LED

The purpose of the following circuit shown in Figure 6 is to inform the user with LED when the solar panel does not have efficient amount of energy to charge the battery. The red LED will come on when the battery voltage drops below the level set by the resistors (R_1 and R_2). Since we are going to charge mobile phone batteries at the range of 3.6 ~ 4.2 V, the battery will not be charged if solar panels only provides 3.5 V. For our purpose, we will have it set at approximately 3.5 V by using the following values of:

R_1 = 4.8 kΩ
R_2 = 1.2 kΩ
R_3 = 560 Ω
Transistor = 2N3904

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3.3.2 Theory

The 2N3904 has a base-emitter voltage of 0.7 V meaning that the transistor will require approximately 0.7 V at the base to turn on. Since resistors R_1 and R_2 acts as voltage divider, the point between them (V_{trig}) will be at a voltage of:

$$V_{trig} = V_{in} \times (\frac{R_2}{R_1 + R_2})$$

When V_{trig} drops below 0.7 V, the transistor will turn off and the red led will turn on. The use of *R3* is to limit the current to the LEDs.

Calculations:

$$V_{trig} = 0.7 \text{ V}$$
$$V_{in} = 3.5 \text{ V}$$
$$\text{Let } R_2 = 1.2 \text{ k}\Omega$$
$$V_{trig} = V_{in} \times \left(\frac{R_2}{R_1 + R_2}\right)$$
$$2.7 = 3.5 \times \left(\frac{1200}{R_1 + 1200}\right)$$
$$R_1 = 4800\ \Omega$$

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4 Temperature Display Section

As shown in Figure below, power is given to both the thermal sensor and the micro-controller. Using the micro-controller, it will convert values taken in values from the thermal sensor in order for the 7-segment LED to display. The 74HC595 is only a shift register used to feed individual bits into the 7-segment LED by rotating through the pins.

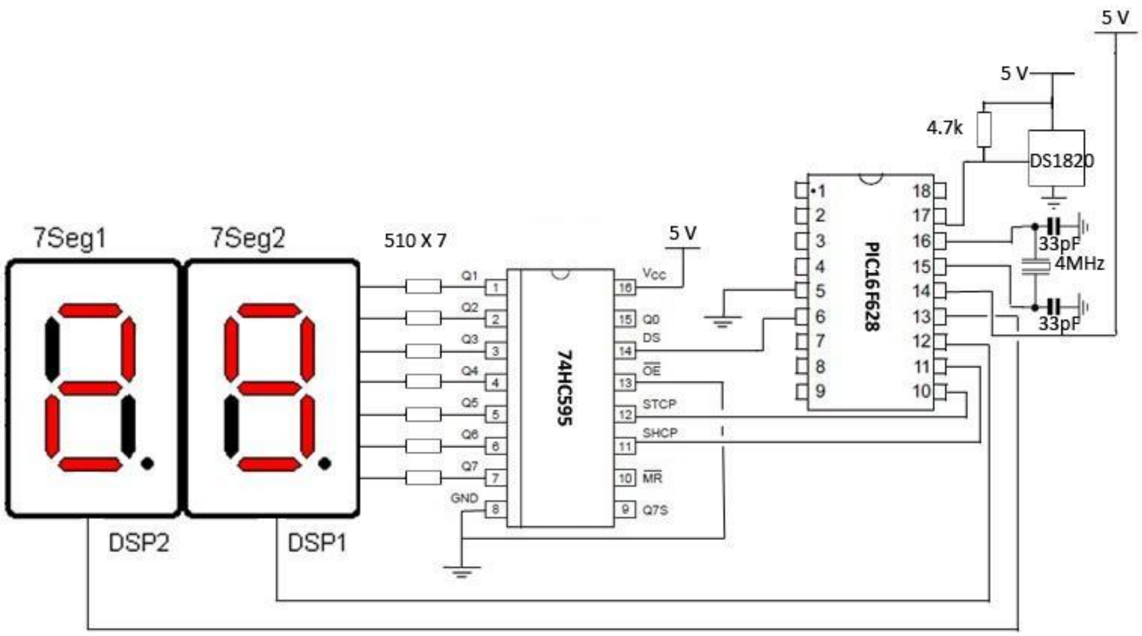

Figure 9: Circuit for Thermal Display

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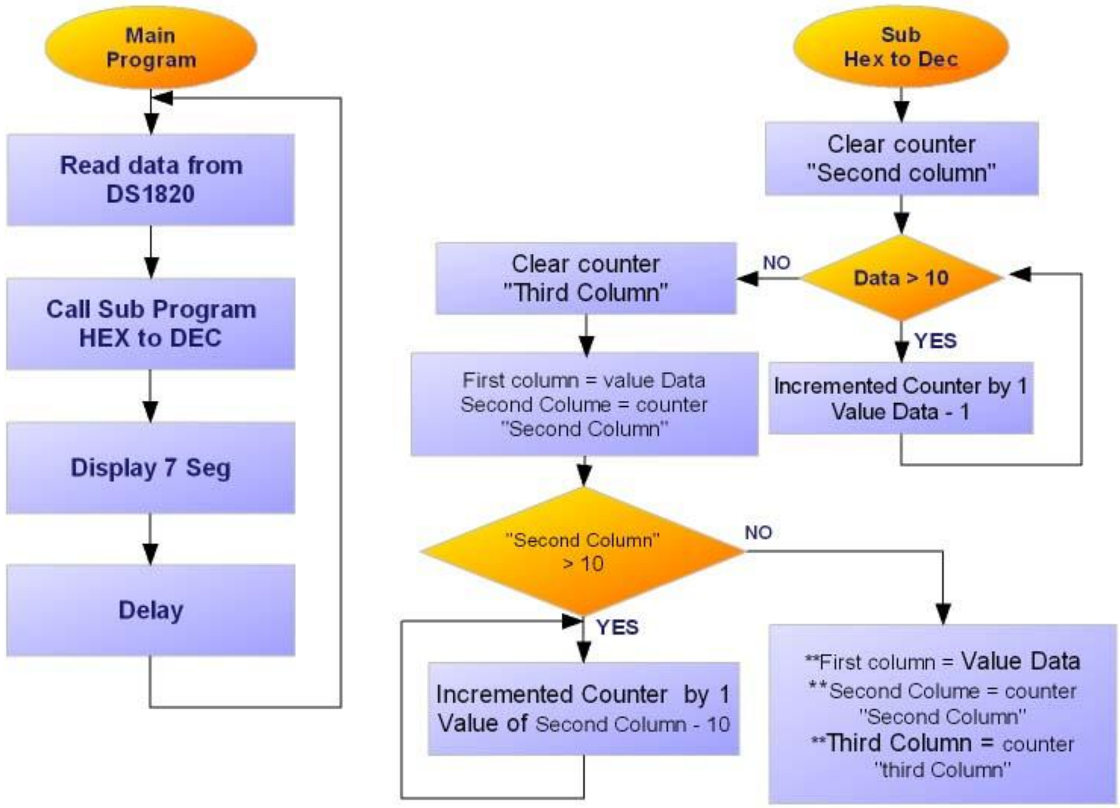

Figure 10: Flowchart of Temperature Display Section

As we can see from the above flowchart, the initial stage of the system is to read the data from the temperature sensor. After the sensor captures the temperature value, it converts the value into the corresponded number in Hex. After the micro-controller receives the Hex number from the sensor, it would call the sub function to convert the number from Hex to decimal. Lastly, the decimal value data would be sent to the shift register (74HC595) to perform the 2 digits display of 7-segment LEDs.

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4.1 PIC

A PIC, or Programmable Interface Controller, is used to control the various analog and digital devices. It will receive digital input from the thermal sensor, convert the signal into decimal number and control the 7 segment LED to display the temperature.

The following table shows the connections needed to the micro-controller:

Table 1: Micro-controller connections

Device Name	Connection Type	Number of Connections
8-Bit Shift Register	Output	3
7-Seg LED Control	Output	2
ON/OFF Button	Input	1
Thermal Sensor	Input	1
4MHz Resonator	Input	2

After extensive product search, the PIC16F628 micro-controller was chosen for its compact size, low power consumption, and various built-in modules with enough pin counts.

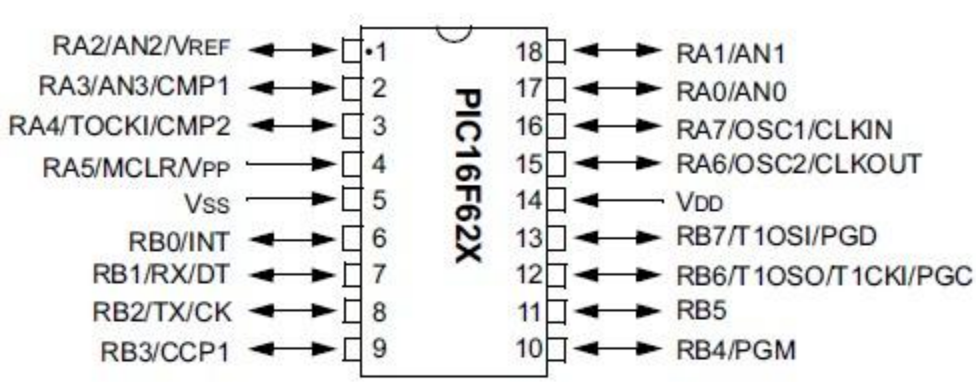

Figure 11: Micro-controller pin specification

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Table 2: Micro-controller Pin Specification

PIN #	Symbol	Input/output	Description
5	GND	Input	Connect to ground
6	RB0	Output	Sending data to the shift register 74HC595
10	RB4	Output	Connect to the shift register (latch)
11	RB5	Output	Giving the clock signal to the shift register 74HC595
12	RB6	Output	Control the first 7-segment LED ON/OFF
13	RB7	Output	Control the second 7-segment LED ON/OFF
14	VDD	Input	Power Source steady ~3.7V (3.3~5.5V)
17	RA0	Input	Receive the data from the thermal sensor DS1820

4.2 8-Bit Shift Register

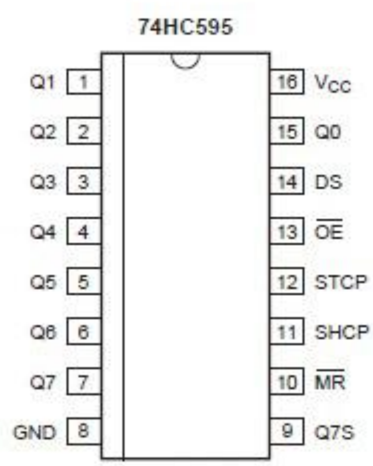

Figure 12: 8-Bit shift register

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Features and benefits:

- 8-bit serial input
- 8-bit serial or parallel output
- Storage register with 3-state outputs
- Shift register with direct clear
- 100 MHz (typical) shift out frequency

Following table shows the pins we will use:

Table 3: 8-bit shift register pin assignment

Pin #	Symbol	Description
1	Q1	parallel data output 1 connect to 7-segment LED
2	Q2	parallel data output 2 connect to 7-segment LED
3	Q3	parallel data output 3 connect to 7-segment LED
4	Q4	parallel data output 4 connect to 7-segment LED
5	Q5	parallel data output 5 connect to 7-segment LED
6	Q6	parallel data output 6 connect to 7-segment LED
7	Q7	parallel data output 7 connect to 7-segment LED
8	GND	connect to ground (0V)
10	MR	master reset (active LOW)
11	SHCP	shift register clock input
12	STCP	control the first 7-segment LED
13	OE	control the second 7-segment LED
14	DS	data receive from the micro-controller
15	Q0	control the decimal point
16	V_{CC}	power supply

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4.3 Digital Thermometer

The temperature sensor we used is the DS18S20 digital thermometer. It has various features and advantages comparing with other sensors. One of the main features is its direct-to-digital temperature. The sensor output has 9-bit resolution corresponding to 0.5 ℃ steps, which is very easy to implement it with a micro-controller. Another feature of the DS18S20 is the ability to operate without an external power supply (through V_{DD}). Normally, the DS18S20 derive power directly from the data line Power Supply (V_{DD}) between3.0 V to 5.5 V. If an external power is not applied, the sensor can be instead supplied through the 1-Wire resistor at the DQ pin when the bus is high. The high bus signal also charges an internal capacitor (CPP), which then supplies power to the device when the bus is low.

PIN Description:

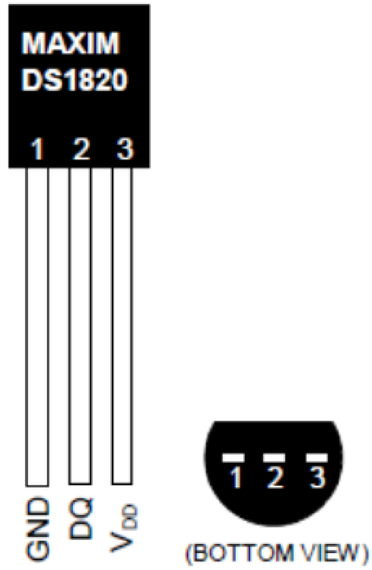

Figure 13: Digital Thermometer

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Table 4: Digital Thermometer Pin Specification

PIN	NAME	FUNCTION
1	GND	Ground
2	DQ	Data Input/output. Open-drain 1-Wire interface pin. Also provides power to the device when used in parasite power mode.
3	VDD	Optional VDD. VDD must be grounded for operation in parasite power mode.

4.4 DS18S20 Block Diagram

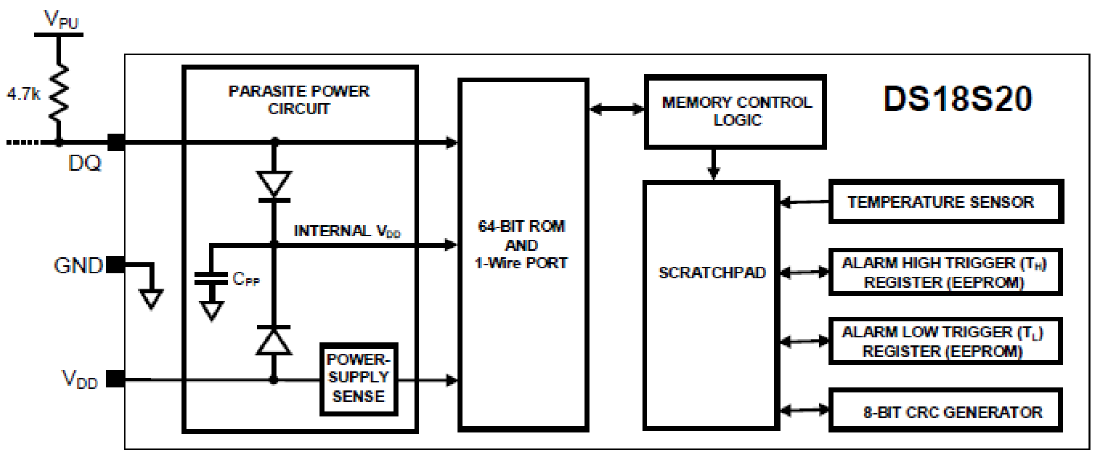

Figure 14: DS18S20 Block Diagram

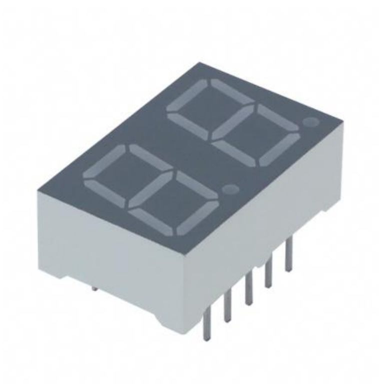

Figure 15: Two 7-Segment LEDs

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Dimension of the device is shown on Figure below.

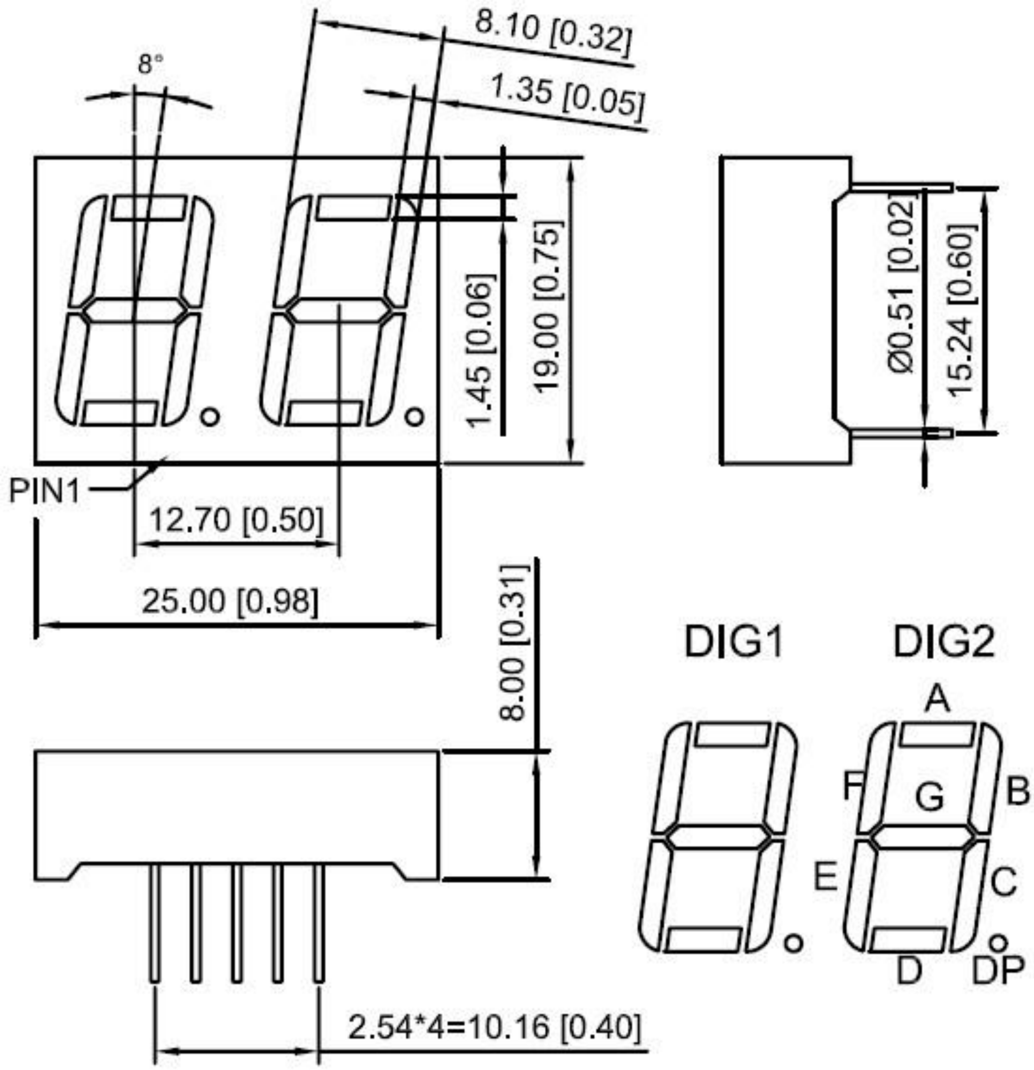

Figure 16: Dimensions of 7-segment LED

The difference between the two pin assignments is the common anode/cathode property. Common anode, upper pin assignment of the figure on top, is the one we are currently using. This particular pin assignment is used for the HS5261AS2 device.

Figure 17 shows the pin assignment of the 7-segment LED.

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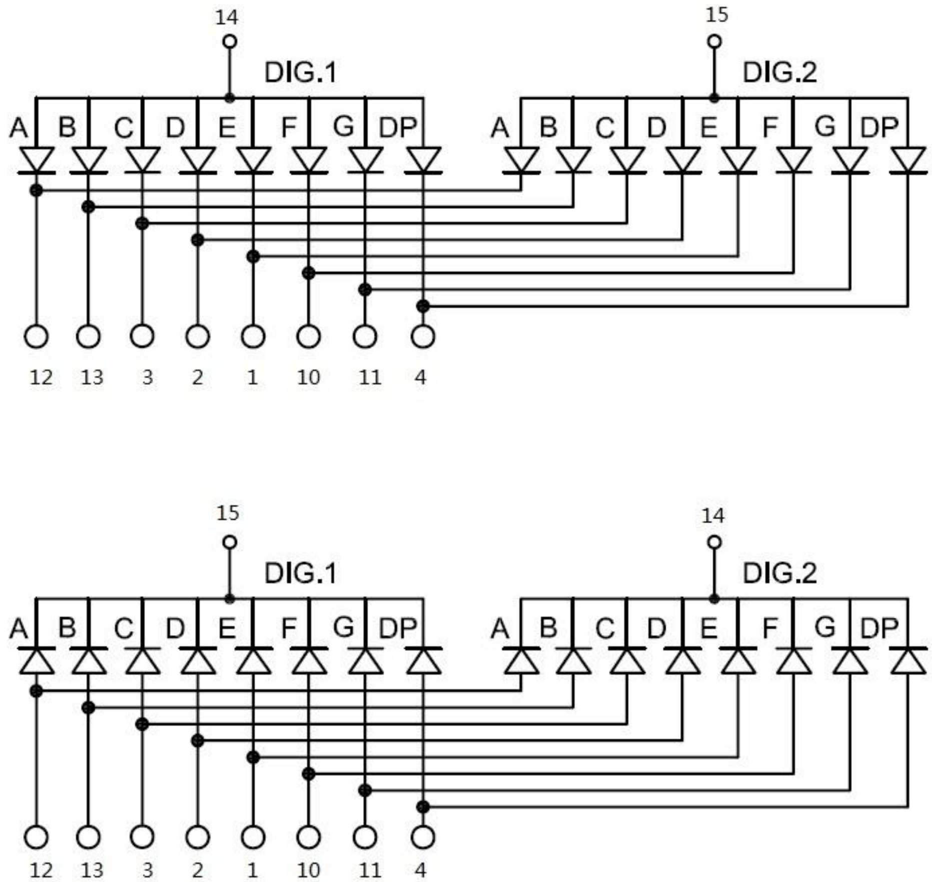

Figure 17: 7-segment LED pin assignment

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5 Built-in Battery Section

The built-in battery is the heart of Solar Panel Cubic Charger. It provides power to the charging device and micro-controller. The built-in battery we chose has large capacity of current so that it has a higher charging current limit than regular batteries. That means charging the built-in battery is faster than charging regular batteries. As long as the built-in battery has power, Solar Panel Cubic Charger will function well.

5.1 Charging Built-In Battery

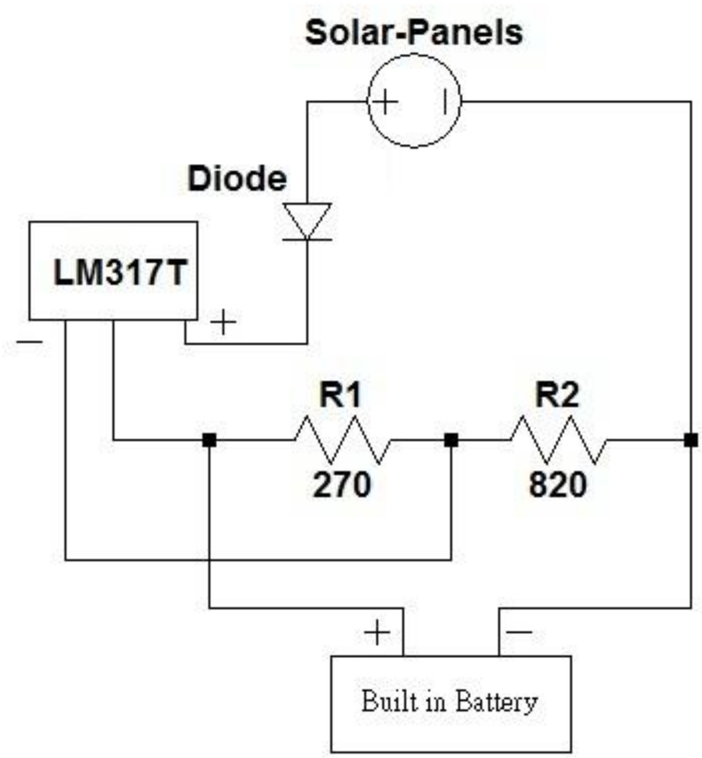

Figure 18: Circuit for charging built-in battery

In order to regulate the voltage from our solar panel, we used an LM317T chip. The value for R_1 is 270 Ω and 820 Ω for R_2 in order to limit the voltage to around 5.05 V. The resistors are calculated using equations below:

$$R_2 = R_1 \times \left(\left(\frac{V_{OUT}}{1.25}\right) - 1\right)$$

Since our desired charging voltage is 5 Volts, R_2 would be:

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Let $R_1 = 270\ \Omega$

$$R_2 = 270 \times \left(\left(\frac{5}{1.25}\right) - 1\right) = 810\ \Omega$$

This is not a standard resistor size. However, we had a 820 Ω resistor producing an output voltage of 5.05 V.

6 Bi-Color LED Section

DEVICE DRAWING

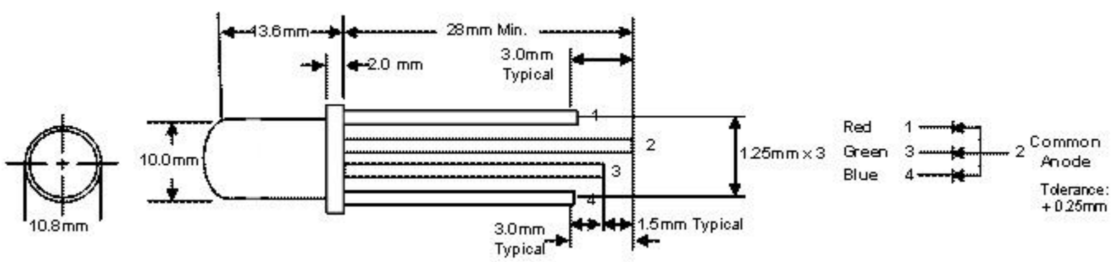

Figure 19: Bi-Color LED Specification

From the Figure, we can see that 3 of the 4 leads on the LED will be used to change the color of the light according to the voltages we feed. The first lead will control the intensity of the red color. Second lead will be the grounding lead. Third and fourth lead will control the intensity of the blue and green color, respectively. The highest intensity for red will be generated when the first lead receives 2.5 V. The highest intensity for blue and green will be generated when the third and fourth lead receives 4.5 V.

Table below verifies the minimum and maximum values for RGB LED under room temperature.

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Table 5: Voltage specification for different color

Electro-optical Characteristics (Ta = 25^{0}C)

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Forward Voltage (Red)	V_F (Red)	I_F = 20mA	1.7		2.6	V
Forward Voltage (Green)	V_F (Green)	I_F = 20mA	3.0		3.7	
Forward Voltage (Blue)	V_F (Blue)	I_F = 20mA	3.0		3.7	V
Dominant Wavelength (Red)	I_D	I_F = 20mA	465		475	nm
Dominant Wavelength (Green)	I_D	I_F = 20mA	505		525	
Dominant Wavelength (Blue)	I_D	I_F = 20mA	625		635	nm
Luminous Intensity (Red)	I_V	I_F = 20mA		800		mcd
Luminous Intensity (Green)	I_V	I_F = 20mA		1,000		mcd
Luminous Intensity (Blue)	I_V	I_F = 20mA		800		mcd

6.1 Battery Monitor for the Built-in Battery

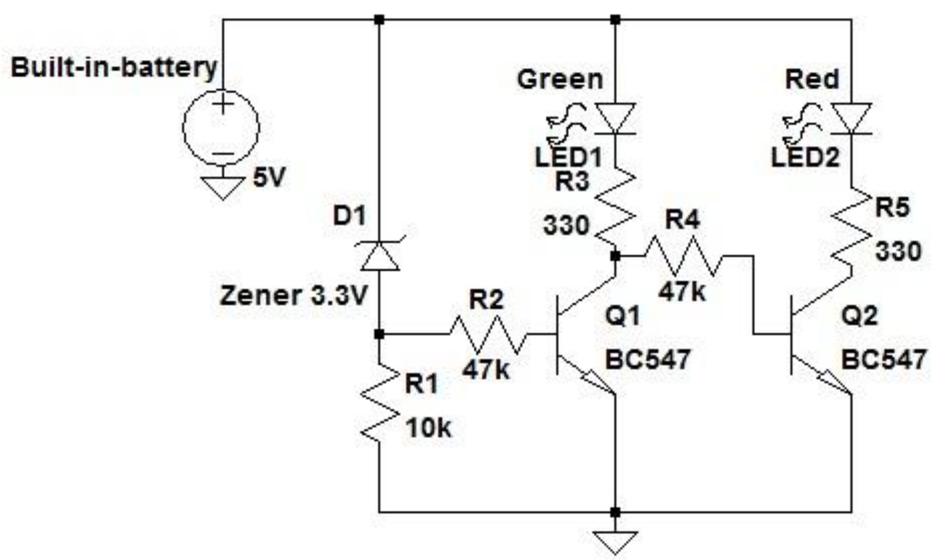

Figure 20: Circuit for battery monitor

The circuit above is a 5V battery monitor which has 2 LEDs, one green which will light up when the battery voltage is higher than 3.3 volts and one red LED which will light up when the battery voltage is below 3.3 volts.

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7 User Interface

7.1 ON/OFF Switch

- Push to make switch
- Enable LED display while user pushes the button

7.2 Temperature Display

- Two 7-segment LEDs with decimal point
- Display current temperature within a range of -45 ℃ to +45 ℃
- The decimal point at the right corner indicates minus degrees

7.3 Segment Lock

Figure 21: Segment Lock

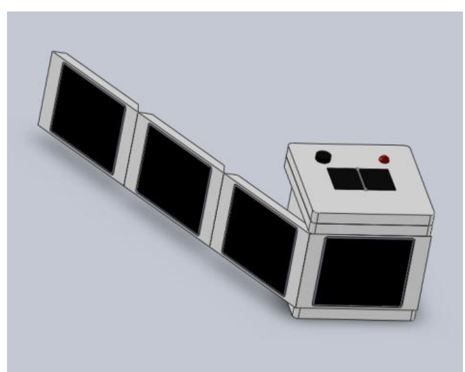

Figure 22: Expanded Casing

- This type of segment lock will be used in between the last piece of the expanded solar panel and the stationary casing.

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7.4 Changeable Adapter

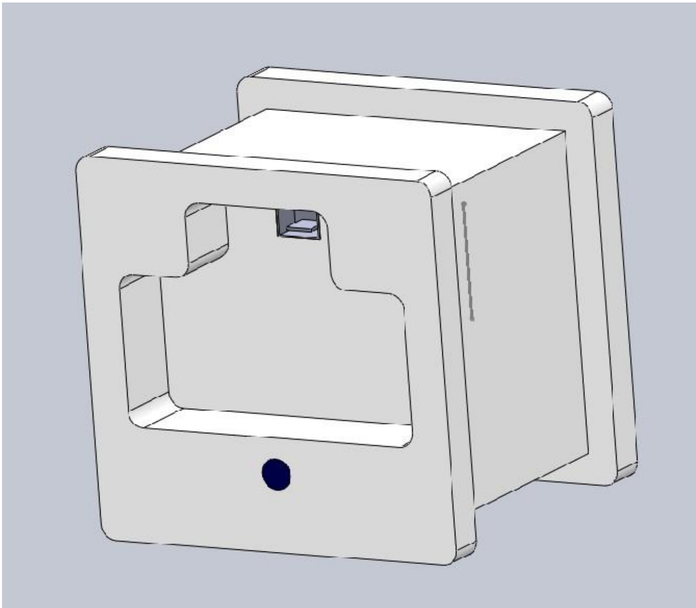

Figure 23: Adapter Socket

- Adapters are held inside Solar Panel Cubic Charger as shown in the above figure
- Adapters are designed with mini-USB port at one end and device charging port at the other end with no additional wire in between. The figure below shows iPhone adapter as one example.

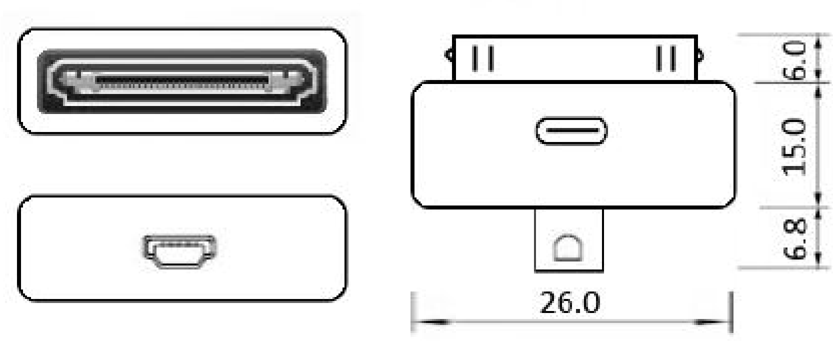

Figure 24: iPhone adpater

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- User can put customized adapter inside Solar Panel Cubic Charger. However, Solar Panel Cubic Charger can only hold one adapter at a time.

7.5 Battery Level Indicator

- Bi-Color LED shows the built-in battery's power level
- Red LED is on means built-in battery level is less than 3.3 V

7.6 Solar Panel Switch

- A red LED indicates the user that the light is too dim to make the Solar Panel Cubic Charger to work efficiently
- A switch is designed for the users to change the solar panels from series mode to parallel mode
- User can switch the solar panels from series mode to parallel mode in order to charge faster when the red LED is on

8 Test Plan

8.1 Scenario 1

- User Input: Button Pressed
- Condition: Device fully charged, really bright daylight, and user wanted to know what the current temperature is.
- Expected Result: Since the device is fully charged, bi-color LED lights GREEN and 7-segment LED displays the current temperature. Light level indicator LED stays off so the user will not have to change the solar panel setup.

8.2 Scenario 2

- User Input: Button Pressed
- Condition: Device in low on power and user wants to know the current temperature during a cloudy day when the charger is set on parallel.
- Expected Result: Since the device is running low on battery, bi-color LED lights RED. 7-segment LED displays the current temperature.

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Light level indicator LED turns on so the user will know to switch the solar panel setup to series connection

8.3 Scenario 3

- User Input: Connection between phone and charger established
- Condition: The user would like to charge their mobile device under bright light when connection is on parallel mode.
- Expected Result: The user's mobile device will start charging at its optimal efficiency without changing the solar panel setup

8.4 Scenario 4

- User Input: Button Pressed
- Condition: The current temperature is below 0 degree Celsius with very limited light while connection is on parallel
- Expected Result: The thermal sensor will detect accurately as the range of viable temperature is very broad. Since the light is very limited and user is on parallel mode, light indicator LED turns on, requesting the user to switch over to series mode for charging requirement.

9 Conclusion

The designing process in order to satisfy our proposed function specification has been discussed in this document. At the stage of actual implementation, this document will be closely followed as a guideline for all members of the company. In order to ensure quality control, more scenarios that are not listed under the test plan will be examined.

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10 Reference

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