4. Evaluation Document

This section explains the testing and evaluation of hardware and software subsystems of the SCDLS modules. The subsystems were tested during the building and evaluation phases of the project to ensure that the modules would work as expected upon completion of the build.

4.1 Test Specifications

Table 4.1 contains the technical constraints tested as part of the evaluation of the subsystems.

Table 4.1: Evaluation Technical Constraints

Name	Test Description
Solar Generation	The solar panel must provide over 20mA of current on average during sunny weather conditions..
Battery Life	The system consumes less than 5mA of current on average.
Module to Module Communication	Modules must be able to communicate wirelessly with one another at a distance of 10 meters.
Wi-Fi Communication	Module must be able to upload traffic analytics to a remote web server.
PIR Motion Detection	This component must be able to accurately detect pedestrians at a distance of 16 feet or less.
Magnetometer Vehicle Detection	This component must be able to detect vehicles moving at a speed of at least 5 miles per hour (mph).
LED Driver	This component must be able to effectively power two or more LEDs and utilize the I^2C bus for communication with the microcontroller.
3.3V Switching Regulator	This component must be able to output 3.3 V continuous to be used by other subsystems.

The following sections detail the testing and validation for each of the subsystems listed in Table 4.1.

4.2 Test Certification - Solar Generation

For solar generation, the team chose epoxy coated polycrystalline solar panels. Epoxy coating was chosen for improved strength and polycrystalline panels were chosen over monocrystalline panels because of significant cost savings.

For this test, the solar panels were soldered to an ST Microelectronics SPV1040 chip including max power-point tracking (MPPT). The test included leaving a panel outside for a number of hours while actively recording the voltage and current fluctuations over time. By choosing a suitably sized panel, the output power was deemed more than suitable for powering our devices.

4.3 Test Certification – Battery Life

Battery life is extremely important for our unit because the only way of recharging the battery is through a solar panel. Sometimes weather does not always cooperate and its important to make sure that the system has an adequate standby time where the system can continue to function as designed until the unit can be recharged. Below, Table X.X.X details current low, high, and average current consumption for each subsystem. These calculations ensure that power will not be depleted too quickly.

Subsystem	Minimum Current	Average Current	Maximum Current

ESP 8266			
NRF 24L01+			
TI BLAH BLAH			
Atmel 328P			
EEPROM			
LEDs			

4.4 Test Certification – 2.4GHz Communication

Nordic Semiconductor's NRF 24L01+ is ideal for module-to-module communication.

4.5 Test Certification – Wi-Fi Communication

Expressif's ESP8266 SOC allows for easy implementation of a WiFi module, allowing for traffic analytics to be uploaded to a remote server with ease.

4.6 Test Certification – PIR Sensors

In our application the passive infrared sensor is extremely important because this sensor is used to detect pedestrians as they enter and exit the crosswalk. A regular crosswalk has a width of eight feet, although in several metropolitan areas, this is doubled because of the amount of regular foot traffic. For that reason, the PIR sensors must detect pedestrians at a minimum distance of 16 feet. For this test, grid lines were measured out in a controlled area and team members walked along the grid lines in order to simulate a pedestrian using a crosswalk. Figure 4.6.1 displays some of the grid lines used for testing.

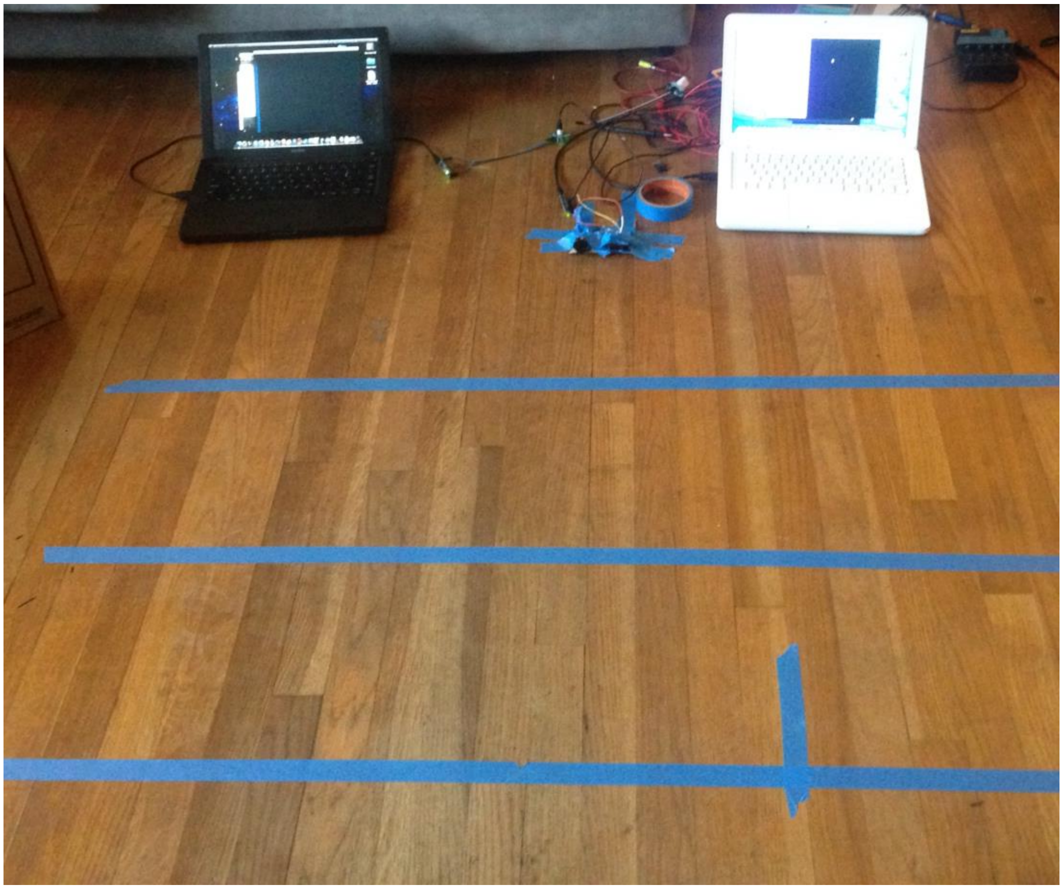

Figure 4.6.1 – Test Setup for PIR Distance Validation.

A gridline was placed every foot from the PIR sensor for twenty feet. Two computers were used to display the output of the PIR sensor. To begin the test, a team member walked along the gridline twenty feet from the PIR sensor in order to simulate a pedestrian. The team member then repeated this procedure at every other gridline until reaching the PIR sensor. The observations from the tests are shown in Table 4.6.

Table 4.6 – PIR Distance Validation Data

Distance	Pass/Fail
20 Feet	Fail
18 Feet	Pass
16 Feet	Pass
14 Feet	Pass
12 Feet	Pass
10 Feet	Pass
8 Feet	Pass
6 Feet	Pass
4 Feet	Pass
2 Feet	Pass

From the data in Table 4.6 it is obvious that the PIR sensor meets the minimum detection distance of 16 feet. The testing regiment was repeated five additional times in order to validate the data.

Because PIR sensors work off of a comparator and Fresnel lenses, there usually tends to be a fluctuation with the values outputted. This fluctuation of the output can be seen in Figure 4.6.2.

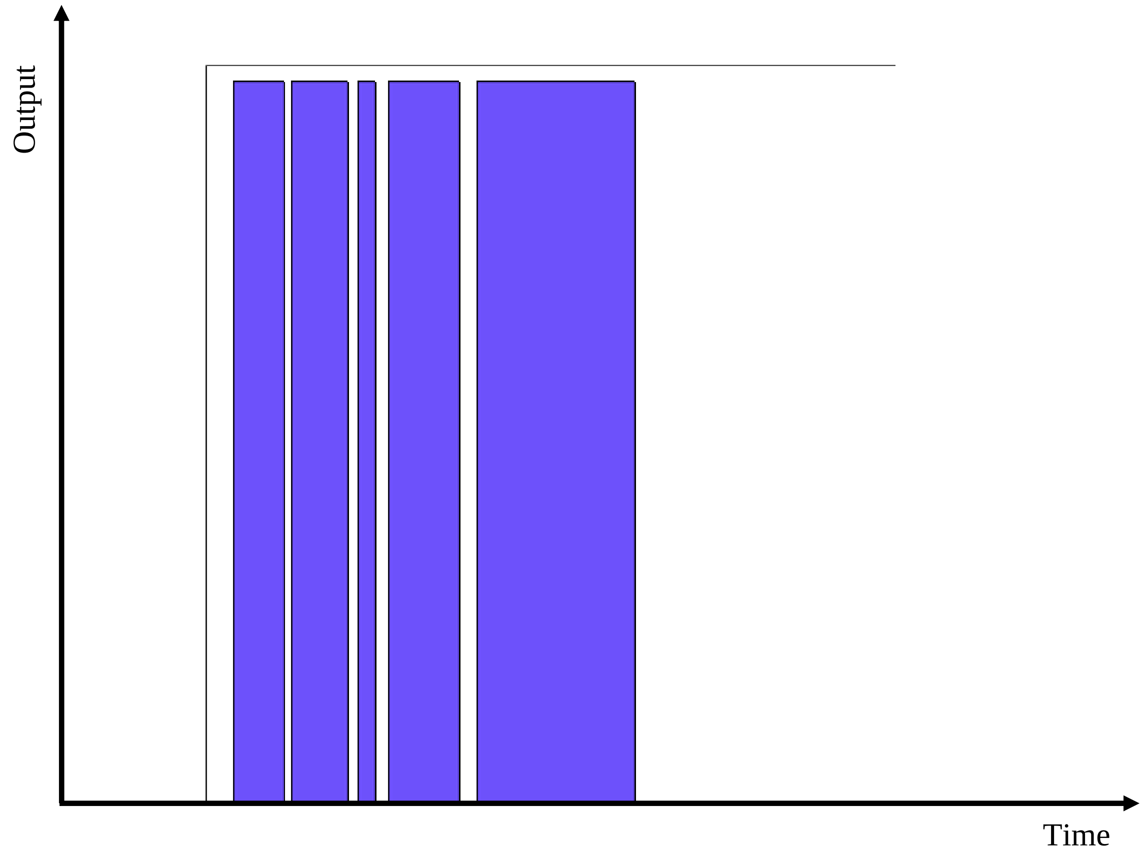

Figure 4.6.2 – Digital Output of PIR Sensor

The team has implemented filtering to remove the small "blips" between rising edges. This prevents the microcontroller to simply receive an interrupt on a rising edge of the PIR sensor output instead of needing to sample the output of the PIR sensor, thus reducing the processing load on the microcontroller and power consumption of the microcontroller.

4.7 Test Certification – Magnetometer

A magnetometer is installed in the devices to detect vehicular traffic. The large, moving body of metal creates a fluctuation in the ambient magnetic field that can be detected. The device needs to be able to accurately detect traffic moving at speeds of at least 5 mph.

To verify this functionality, a test device was placed in the road, then vehicles were driven over the device (taking care not to crush the device with the vehicle's tires). The device sampled the magnetic field every 50 milliseconds, then processed the data through the vehicle-detection algorithm. The results were captured and graphed, as shown in Figure 4.7.1. In this graph, the x axis is in the units of samples (which occur every 50ms), and the y axis is in arbitrary units read from the magnetometer. It is easy to see that the three colored lines, which correspond to the feeds from the magnetometer, begin to fluctuate at about sample 20. The algorithm's Boolean output is represented by the black line; a high value corresponds to "vehicle present," and a low value corresponds to "vehicle absent." The algorithm detects the vehicle very accurately.

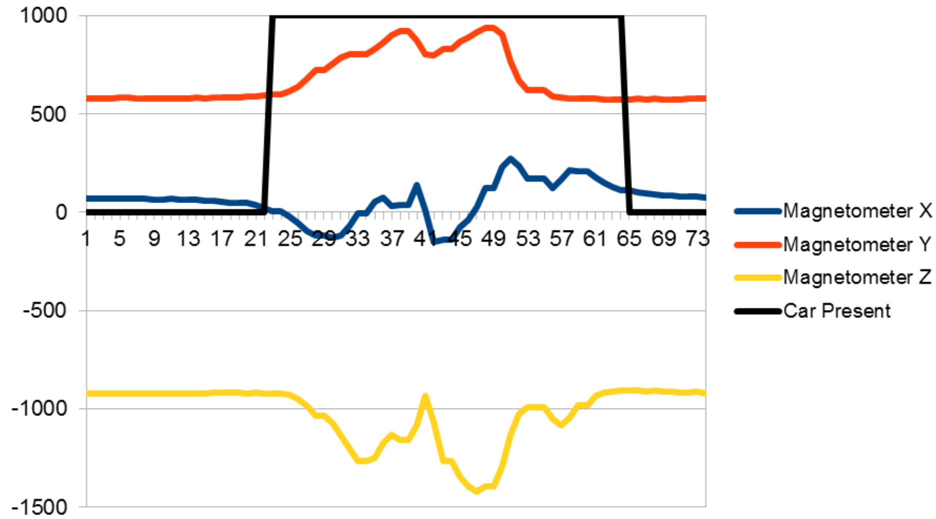

Figure 4.7.1 – Sample test data from 5mph vehicle drive-over

Because the flux in magnetic field increases with vehicle speed, this test demonstrates that the device can meet its requirement of 5 mph minimum detected vehicle speed.

4.8 Test Certification – LED Drivers & LEDs

The microcontroller communicates with the LED driver using the I^2C serial bus. In order to show the I^2C communication between the microcontroller and the LED driver, a Bus Pirate multitool was used to sniff the I^2C bus. First, the microcontroller had a test program flashed to it that would initiate a series of test I^2C transactions with the LED driver. Then, the Bus Pirate was connected to the SCL and SDA lines. The Bus Pirate was then connected to a computer using USB. Then, a serial terminal was used to communicate with the Bus Pirate and start its I^2C bus sniffer. Finally, the microcontroller was reset so it would begin performing the test I^2C transactions. The first six test transactions can be seen in Figure 4.7.1.

Figure 4.8.1: I^2C Transaction Between the Microcontroller and LED Driver

The first two test transactions initialize the mode registers of the LED driver. The next four transactions set the LED output control registers to use the pulse width modulation (PWM) registers to control the output of LEDs. The PWM registers are used to control the dimming of each of the LED outputs. The rest of the test transactions are similar to the sixth transaction in Figure 4.x.1 and consist of setting the PWMs to the desired values. This test transaction was also used to test the RGB LEDs used in the system. Using this test transaction the RGB LEDs should be a violet color at maximum brightness. Figure 4.7.2 is a picture of the LEDs driven by the LED driver after completion of the test I^2C transactions.

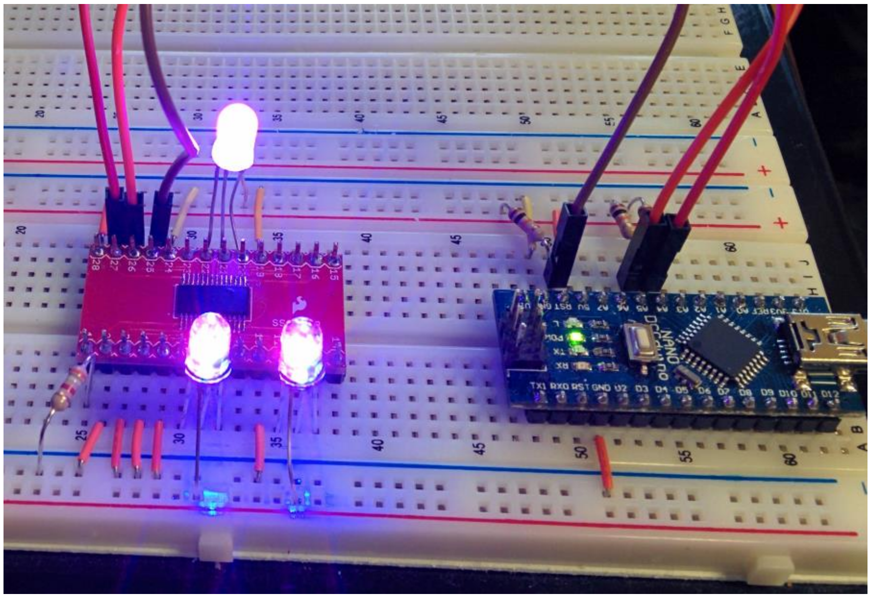

Figure 4.8.2: Picture of the Test of the RGB LEDs

It is difficult to tell the color of the LEDs in Figure 4.7.2. However, in person it was plainly obvious that the LEDs were violet. The test procedure was then repeated multiple times by setting the LEDs to the colors red, green, blue, yellow, and orange at different dimming values. The tests confirmed the operation of I^2C communications between the microcontroller and LED driver and the operation of the RGB LEDs used in the system.

4.9.1 Test Certification – Solar panel charging circuit

A combination SPV1040 MPPT boost converter and L6924 Li-Ion battery charger integrated circuits were used to efficiently convert solar power to usable energy in order to charge the battery. Pictured below is a test circuit showing the selected solar panel charging the selected battery. The schematic for this charging circuit is shown below in figure 4.8.2 and is a reference design by ST microelectronics.

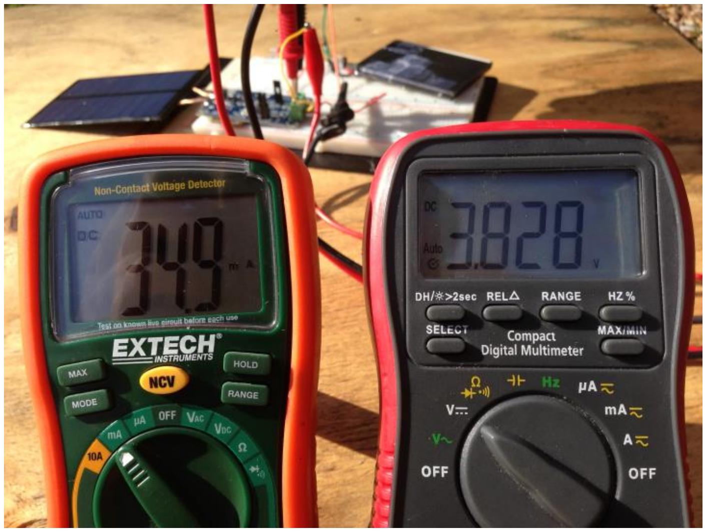

Figure 4.9.1: Picture of the solar panel charger test

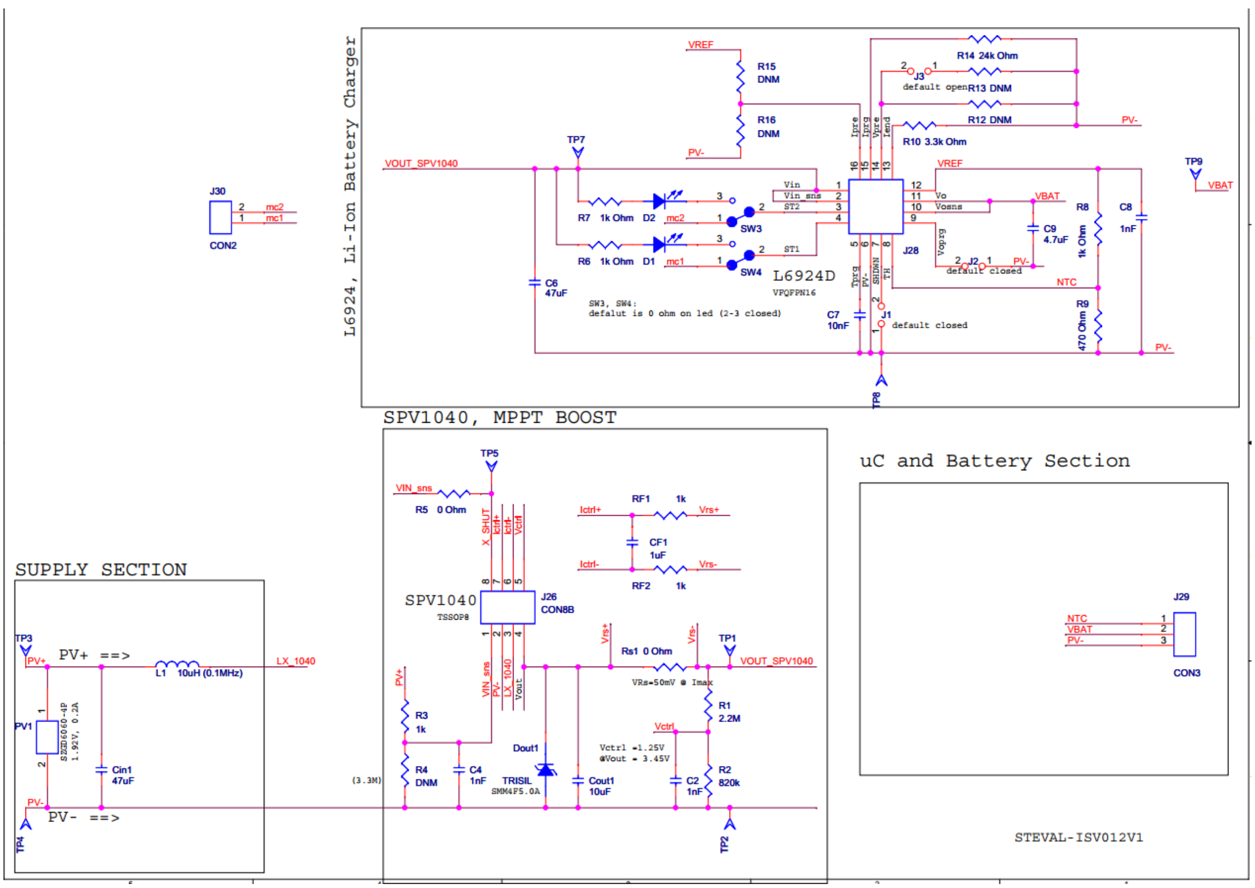

Figure 4.9.2: Schematic of Solar panel charger circuit

4.9.2 Test Certification – 3.3V Switching Regulator

The TPS62240 regulator was utilized to provide a constant voltage to all components and peripherals. The output voltage is selected based on an equation from this part’s data sheet. The values of 680k for R1 and

150k for R2 were chosen to produce a voltage of 3.32V ideally.. The output was then tested and verified by use of a multimeter as shown in Figure X.X.X below.