ECE 411

LED Cube Project: Test Plan

Authors:	Nikolay Nikolov, Lance Kailiuli, Artem Kulakevich, Ignacio Mejia				Group #1
Github	https://github.com/nnikolov3/ECE411				
Version #:	1.0				
Date:	04-Dec-2019				

1.0 Introduction

1.1 This Document

The Test Plan was developed to document and track the essential information required to soundly define methods for testing the LED cube and ensure that it functions correctly based on the specifications defined in PDS.

The Test Plan was created before the device modules were assembled on the PCB right after the PCB was delivered. The team broke down the test planning based on the component modules and applied unit testing and integration tests.

The intended audience for the Test Plan is the project team, student peers, and professors. Some portions of this document may on occasion be shared with the other peers and other stakeholder whose input/approval into the testing process is needed.

2.0 References

2.1 Design Documents

Product Design Specification	Version 1	October 19, 2019
https://github.com/nnikolov3/ECE411/blob/master/Practicum_Project_Proposed_Ideas/PDS_TEAM1.pdf		

Functional Decomposition	Version 1	November 14, 2019
https://github.com/nnikolov3/ECE411/blob/master/Functional%20Decomposition/Homework%205%20System%20Design_%20Functional%20Decomposition%20(1).pdf		

System Schematic	Rev 0.1	November 20, 2019
https://github.com/nnikolov3/ECE411/blob/master/Layout%20and%20Schematics/Schematics/ECE_411_project.pdf		

Layout FPT_Front	*Version 1	November 20, 2019
https://github.com/nnikolov3/ECE411/blob/master/Layout%20and%20Schematics/Layout/ECE411_FTP_Front.pdf		

Bill of Material	*Version 1	November 14, 2019
https://github.com/nnikolov3/ECE411/blob/master/Orders%20and%20BOM/Practicum%20BOM%20-%20Sheet1-3.pdf		

ATmega328P [DATASHEET]	7810D–AVR	January 15, 2019
http://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf		

Arduino as ISP and Arduino Bootloaders	---	January 20, 2018
https://www.arduino.cc/en/tutorial/arduinoISP		

3.0 Resources

3.1 Equipment

- Oscilloscope - MSO 4054
- Power Supply - GW Instek GPS-3303
- Digital Multimeter - Fluke 87
- Soldering Iron / Soldering Equipment
- Standard 5v USB Power Supply
- Tape Measure
- Breadboard

3.2 Personnel and Skills

- At least one individual is required with experience in:
    - Soldering
    - Oscilloscope and Power Supply Use
    - General Troubleshooting

3.3 Project Specific Hardware

- Arduino UNO 3
- ATMega328p DIP Version
- MPU-6050 on DaughterBoard
- WS2812 LED Strip
- MT3608 Boost Converter
- TP4056 Charge Board
- Personal Computer

3.4 Software

- Arduino IDE (1.8.9) and related drivers
- KiCAD Schematic/Layout Viewer (5.1.4)
- Excel/Google Sheets (2010+)
- Windows 7+ or Linux /MacOS equivalent with support for software listed above
- Demo MPU-6050 and WS2812 Code

3.5 Modules

- One UUT: ATMega 328p with necessary biasing circuitry, LED strip, MPU-6050, on breadboard
- Two UUT: Arduino UNO3 with LED strip, and MPU-6050
- One UUT: Buck Converter on PCB

- One UUT: Assembled PCB, with all components soldered
- One UUT: Assembled PCB, with Acrylic case, and Charge Stand
- One UUT: Battery Connected to TP4056 Charge Board

4.0 Objectives

The objective of this document is to test the acrylic light cube against all of our requirements. This will be done by evaluating modules in our system and performing the types of tests listed below.

4.1 Unit Test

Multiple individual units will have to best tested using various equipment to verify functionality of individual modules.

4.2 Integration Test

Integration tests involves combined multiple units and testing them together to verify that the modules will interact as expected before the whole system is entirely closed up inside the box.

4.3 Functionality Test

Functionality testing will be used to confirm basic functionality, without strict parametric test. The modules should be able to turn on and switch between states after certain inputs.

4.4 Stress Test

Stress testing will verify the stability and reliability of the system to determine robustness.

4.5 Parametric Test

Parametric testing will verify that the observed data is distributed according to our design parameters.

4.6 Acceptance Test

The purpose of this test is to evaluate the system’s compliance with the design requirements and assess whether it is acceptable or not.

5.0 System Tests

All tests are performed in a controlled laboratory environment and personnel performing tests are required to abide by NFPA 70E guidelines for electrical safety in the workplace.

5.1 Unit Tests

5.1.1 Boost Converter (Test ID: LC-UT-01)

PDS Related Requirement: Device uses one battery .

Unit Test: Boost Converter

Module	Module ID: _Solder Boost Converter Solder Boost Converter onto the board. he MT3608 is a constant frequency, 6-pin SOT23 current mode step- up converter intended for small, low power applications. The MT3608 switches at 1.2MHz and allows the use of tiny, low cost capacitors and inductors 2mm or less in height. Internal soft-start results in small inrush current and extends battery life.
Inputs	3.7 V and 50mA
Outputs	5V after the potentiometer has been adjusted
Functionality	Current mode step- up converter intended for small, low power applications.
Test	Voltage applied and measured at the input and output, output was measured with oscilloscope for any oscillations

Unit Test: Boost Converter (Matrix)

Test Writer: Lance Kailiuli,Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov			
Test Case Name:	Boost Converter	**Test ID:**	LC-UT-01
Description:	The boost converter was tested for any oscillations at the output and after the potentiometer has been adjusted for output of 5V when the input is 3.7 V and current is 50 mA	**Type:**	black box
Tester Information			
Name of Tester:		**Date:**	12/01/19
Hardware Ver:		**Time:**	1 : 00 PM
Setup:	Boost Converter was soldered on the board and then tested using a voltage source in the lab with output 3.7V and current of 50 mA		

Step	Action	Expected Result	Pass	Fail	N/A	Comments
1	Applied voltage of 3.7 V and current of 50mA	Voltage output is greater than input				
2	Output was tested using oscilloscope	No oscillations				
3	Adjusted potentiometer on the boost converter	5V output				
Overall test result:						

5.1.2 Linear Regulator (Test ID : LC-UT-02)
PDS Related Requirement: Device uses one battery.

Unit Test: Linear Regulator

Module	Linear Regulator : The LP2985 family of fixed-output, low-dropout regulators offers exceptional, cost-effective performance for both portable and nonportable applications. Available in voltages of 1.8 V, 2.5 V, 2.8 V, 2.9 V, 3 V, 3.1 V, 3.3 V, 5 V, and 10 V, the family has an output tolerance of 1% for the A version (1.5% for the non-A version) and is capable of delivering 150-mA continuous load current. Two linear regulators used to distribute the voltage out of one voltage source to 3.3 V and 3.7 V
Inputs	3.7V and we limit the current to 50 mA
Outputs	3.3 V and 3.7 V
Functionality	In normal operation, the device will output a fixed voltage corresponding with the orderable part number. The device can deliver 150 mA of continuous load current.
Test	White and Black-box. Voltage was applied from the power supply and measured at the output

Unit Test: Linear Regulator (Matrix)

Test Writer: Lance Kailiuli,Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov							
Test Case Name:		Linear Regulator				**Test ID:**	LC-UT-02
Description:		Measure the output for the linear regulators independently, under one test				**Type:**	white box
Tester Information							
Name of Tester:						**Date:**	
Hardware Ver:						**Time:**	
Setup:		The voltage regulators were soldered on the PCB and tested using a power source and a voltmeter.					
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**	
1	Applied voltage of 3.7 V and current of less than 50mA	Voltage is 3.3					
2	Applied voltage of 3.7 V and current of less than 50mA	Voltage is 3.7V					
Overall test result:							

5.1.3 Microprocessor Bootloader and Program on PCB (Test ID : LC-UT-03)

PDS Related Requirement: The device must have a processor that is programmable on the PCB.

Test Writer: Lance Kailiuli,Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov			
Test Case Name:	Microprocessor Bootloader and Program on PCB	**Test ID:**	LC-UT-03
Description:	The microprocessor is placed on the PCB and using an Arduino board as an in-system program (ISP) the bootloader is burned to ATmega328P. After the completion, the microcontroller the device is turned on and inspected. The functionality of the new ATmega328P has to be identical to the original where the	**Type:**	white box

		bootloader was burned from.Hence, no LEDs should be off and all LEDs should be capable to output the same color.				
Tester Information						
Name of Tester:		TEAM			**Date:**	
Hardware Ver:					**Time:**	
Setup:		Have microprocessor soldered down to PCB, have the 0 ohm resistance data connection between the microprocessor and LEDs short. Have a demo version of the software burned onto the microprocessor. Supply power to both the LED strip and the microprocessor.				
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Apply 5v to the processor and the LEDs. Wait 30s for processor to boot.	All LEDs should output the same color, no LEDs are off.				

5.2 Integration Tests

5.2.1 Boost Converter & Linear Regulator **(Test ID:** LC-IT-01)

PDS Related Requirement: Device uses one battery.

Test Writer: Lance Kailiuli,Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov			
Test Case Name:	Boost Converter and Linear Regulator	**Test ID:**	LC-IT-01
Description:	Checks interaction of Boost Converter and Linear Regulator	**Type:**	black box
Tester Information			
Name of Tester:	TEAM	**Date:**	
Hardware Ver:		**Time:**	
Setup:	The Linear Regulator and the voltage boost converter were soldered on the PCB. The PCB was connected to a voltage source and the output was measured if the current was below 50mA		

Step	Action	Expected Result	Pass	Fail	N/A	Comments
1	Apply 5v to the processor and the LEDs. Wait 30s for processor to boot.	All LEDs should output the same color, no LEDs are off.				
Overall test result:						

5.2.2 LEDs & Microcontroller (Test ID: LC-IT-02)

PDS Related Requirement: Device must respond to change in angular velocity.

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov						
Test Case Name:	Microcontroller validation				**Test ID:**	LC-IT-02
Description:	Verify that all LEDs in the array turn on, and that all LEDs in the array produce the same color.				**Type:**	black box
Tester Information						
Name of Tester:					**Date:**	
Hardware Ver:					**Time:**	
Setup:	Have microprocessor soldered down to PCB, have the 0 ohm resistance data connection between the microprocessor and LEDs short. Have a demo version of the software burned onto the microprocessor. Supply power to both the LED strip and the microprocessor.					
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Apply 5v to the processor and the LEDs. Wait 30s for processor to boot.	All LEDs should output the same color, no LEDs are off.				
Overall test result:						

5.3 Functional Tests

5.3.1 LEDs Respond to motion (Test ID: LC-FT-01)
PDS related requirement: Device must respond to change in angular velocity.

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov						
Test Case Name:		LED responsiveness to motion			**Test ID:**	LC-FT-01
Description:		When the user moves the cube in different directions the LED change their appearance based on the direction			**Type:**	black box
Tester Information						
Name of Tester:					**Date:**	
Hardware Ver:					**Time:**	
Setup:		Initialize rotation mode by setting the cube to the rotation setting before starting the test. No other equipment is required.				
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Rotate the cube to left	LED colors				
	Rotate the cube to the right	LED transition to a different color				
	Rotate the Cube 360 degrees to the left	LED transition successfully through different sets of colors				
	Rotate the Cube 360 degree to the right	LED transition successfully through different sets of colors				
Overall test result:						

5.4 Stress Tests

5.4.1 Durability Test (Test ID: LC-ST-01)
PDS related requirement: The device must be durable.

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov						
Test Case Name:		Durability Test			**Test ID:**	LC-ST-01
Description:		Drop the LED cube from 10 ft. and see if it functions, subject the product to flexion tests and ship product across country using ISTA standards			**Type:**	black box
Tester Information						
Name of Tester:					**Date:**	
Hardware Ver:					**Time:**	
Setup:		Reset the cube				
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
	Drop cube from 10 ft on each face, each joint and each corner	Cube still functions with minimal structural damage				
	Apply reasonable flex to cube	Cube still functions and joints remain intact				
	Ship cube across the country	Cube still functions with minimal to no structural damage				
Overall test result:						

5.4.2 Continuous Use Test (Test ID: LC-ST-02)

PDS related requirement: The device must be durable.

Test Name: Battery Safety after prolonged operation

The purpose of this test is to evaluate the safety of the battery after the device has been used for more than 12 hours, charged and discharged. The test is performed after the device is fully charged and inspected for any damages.
When the device has been charged, the tester begins to interact with the device moving it in different directions and placing the LED Cube on a flat surface and using it as ambient light source for 3 hours. Then the tester evaluates the condition of the battery and interacts with the device. In the process if any battery damage is suspected the test fails immediately. Then the device is placed again for 3 hours on a flat surface.
The process is repeated 4 times total, for a sum of 12 hours. For the test to pass the battery should not have any observable damage such as cracks, when touched it is not hot, no leaks of any sort and discoloration.

5.5 Parametric Test

5.5.1 LEDs response to angular velocity (Test ID: LC-PT-01)

PDS Related Requirement: LEDs must respond to changes in angular velocity.

The purpose of this test is to evaluate the sensitivity of the device to circular motion greater to 1 degree per second.

The LED Cube is fully charged and inspected for any damages. In order to perform the test, it requires more than two people or specialized equipment to rotate the device in constant angular velocity and time the LEDs responsiveness. If there is not available a speciality device, one tester is responsible for rotating the device around its axis and the other tester times the intervals when

the LEDs state changes. For accuracy the test has to be performed at least 10 times and calculate the average.

The test begins when the tester starts to rotate the device. For velocity equal to 1 degree per second and 360 degrees, for a full revolution is required 360 seconds, which is equivalent to 6 minutes. Hence, for the accuracy of the test, the testers have to establish a baseline of how fast the tester has to rotate the Cube in order to maintain angular velocity greater than 1 degree per second, however within the limits of regular use. Once the baseline is established the tester rotates the device and the responsiveness of the LEDs is timed. It is preferable the testers to get as many samples as possible and take the average, however the lowest number of tests is 10.

5.5.2 Responsiveness (Test ID: LC-PT-02)

PDS related requirement: Delay should be less than .5 seconds between sensor inputs and actuator outputs

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov						
Test Case Name:		Responsiveness			**Test ID:**	LC-RT-01
Description:		Measure delay between sensor input and LED output			**Type:**	black box
Tester Information						
Name of Tester:					**Date:**	
Hardware Ver:					**Time:**	
Setup:						
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Initiate lamp mode	All LED's turn on white within 0.5s				
	Initiate water effect mode	All LED's turn on blue within 0.5s				

	Initiate wave 1 mode	3 LED's turn on red, blue, green within 0.5s				
	Initiate wave 2 mode	All LED's turn on different colors within 0.5s				
Overall test result:						

5.5.3 Response off of charger (Test ID: LC-PT-03)

Related Requirement: LEDs turn ON after one second when Cube detects that it is withdrawn from the charging station.

The purpose of this test is to ensure that the LED Cube detects correctly within a given period of time (1 second) that it is no longer connected to the charging station and turns on. The initial setup for the test requires that the device's battery is not empty, and preferably is fully charged. Then the tester places the device on the charging station and verifies that the device is connected properly and it charges or indicates full charge. After the device is placed the tester(s) pick the device from the charging station and observe and time responsiveness of the device. A successful test should indicate that the average time after the device is removed from the charging station and it turns ON is within 1 second. For a test to be valid the tester(s) need to perform at least attempts and calculate the average time that it takes for the LED Cube to turn ON.

5.6 Acceptance Test

5.6.1 Ambient Source of light (Test ID: LC-AT-01)
PDS related requirement: The cube is static and becomes source of ambient light (night light, desk lamp etc).

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov			
Test Case Name:	Ambient Light	**Test ID:**	LC-AT-01
Description:	The cube becomes a source of ambient light when static on a flat surface	**Type:**	black box

Tester Information						
Name of Tester:					**Date:**	
Hardware Ver:					**Time:**	
Setup:						
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Place cube on a flat surface and wait 5 seconds.	All LEDs should output the same color, no LEDs are off.				
Overall test result:						

5.6.2 LED Cube Shut Down Test (Test ID: LC-AT-02)

PDS related requirement: The device must be safe and have a way to conserve energy.

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov						
Test Case Name:		Turn OFF LED Cube			**Test ID:**	LC-AT-02
Description:		The Cube is tilted at an angle greater than 45 degrees with zero motion and it is observed if it turns off			**Type:**	black box
Tester Information						
Name of Tester:					**Date:**	
Hardware Ver:					**Time:**	
Setup:		Reset and turn on the LED Cube ensure battery is charged				
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Tilt the left side of the cube at an angle greater than 45 degrees without any motion and wait 5 seconds	The LED Cube turns OFF				

2	Tilt the right side of the cube at an angle greater than 45 degrees without any motion and wait 5 seconds	The LED Cube turns OFF				
3	Tilt the LED Cube to less than 45 degrees to the right for 5 seconds	The LED Cube does not turn off				
4	Tilt the LED Cube to the front to more than 45 degrees for 1 second	The LED Cube does not turn off				
5	Tilt the right side of the cube at an angle greater than 45 degrees without any motion and wait 2 seconds	The LED Cube does not turn off				
Overall test result:						

5.6.3 Maximum and Minimum brightness activation (Test ID: LC-AT-03)

PDS related requirement: A 90 degree tilt towards a direction should correspond with a maximum brightness output on the LED that is in the direction of tilt, and a minimum light output on the LED that is opposite of the tilt direction

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov			
Test Case Name:	Max and min brightness at 90 degrees tilt	**Test ID:**	LC-AT-03
Description:	The LED Cube is tilted at 90 degrees and the brightness of the LED is observed. A 90 degree tilt towards a direction should correspond with a maximum brightness output on the LED that is in the direction of tilt, and a minimum light output on the LED that is opposite of the tilt direction	**Type:**	black box
Tester Information			
Name of Tester:		**Date:**	

Hardware Ver:						**Time:**	
Setup:		Reset and turn on the LED Cube ,ensure battery is charged					
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**	
1	The LED Cube is tilted at 45 degrees	No maximum brightness observed					
2	The LED Cube is tilted at 45 degrees	No maximum brightness observed					
3	The LED Cube is tilted at 60 degrees	No maximum brightness observed					
4	The LED Cube is tilted at 90 degrees	maximum brightness output on the LED that is in the direction of tilt, and a minimum light output on the LED that is opposite of the tilt direction					
5	The LED Cube is placed upside down	Cycles through all modes continuously					
Overall test result:							

5.6.4 Battery Life (Test ID: LC-AT-04)

PDS related requirement: The device must last 2 hours on battery alone.

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov			
Test Case Name:	Battery lasts more than 2 hours	**Test ID:**	LC-AT-04
Description:	The battery is fully charged and the LED Cube operates continuously for more than 2 hours	**Type:**	black box
Tester Information			
Name of Tester:		**Date:**	

Hardware Ver:					Time:	
Setup:						
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Let the LED Cube operate for 2 hours	The LED Cube is ON and responds to interaction successfully				
Overall test result:						

5.6.5 Luminosity (Test ID: LC-AT-05)

PDS related requirement: Capable of 5 candle-feet of illumination in a dark setting.

Test Writer: Lance Kailiuli, Artem Kulakevich, Ignacio Mejia, Nikolay Nikolov						
Test Case Name:		Luminosity			**Test ID:**	LC-AT-05
Description:		Ambient light from cube must extend a minimum of 5 candle-feet in a dark setting.			**Type:**	black box
Tester Information						
Name of Tester:					**Date:**	
Hardware Ver:					**Time:**	
Setup:		Have completed cube placed on a flat surface in a completely dark room. Have a tape measure available to find the distance light travel from the cube on the table.				
Step	**Action**	**Expected Result**	**Pass**	**Fail**	**N/A**	**Comments**
1	Initiate lamp mode, place cube on flat surface, setup receiver at a distance of 5 feet from light source and remove all other light sources.	Receiver is visible				
Overall test result:						