UArizona

Team 21057

Final Report

Elbit Systems of America

SWIR Transmitting Optical Beacon (STrOBe)

Table of Contents

Scope and Introduction

The goal of this project was to design and develop a small, portable infrared beacon (STrOBe) that can be deployed by drone and used to mark targets in the field.

Short-wave infrared (SWIR) beacons have been used by the military for marking targets to be destroyed, landing zones, and allied troops to prevent friendly fire. This team designed a device that can mark a target in the field by emitting at 1550 nm, detectable to those equipped with SWIR vision technology. The STrOBe beacon is small, portable, remotely programmable, rugged, and bright enough to be seen from a distance. The device is controlled remotely via bluetooth connectivity through the team’s custom-designed app that allows for powering the beacon and changing the pulse repetition rate. Up to three individual STrOBe devices can be controlled using this same app.

Referenced Documents

The referenced documentation which was utilized in the beginning phase of the STrOBE project are listed below:

Infrared Beacon Evaluation: Applications for Law Enforcement, Charlie Mesloh,Mark Henych, Ross Wolf, Kirt Gallatin, 2008

On Bluetooth Proximity Models, IEEE, 2016

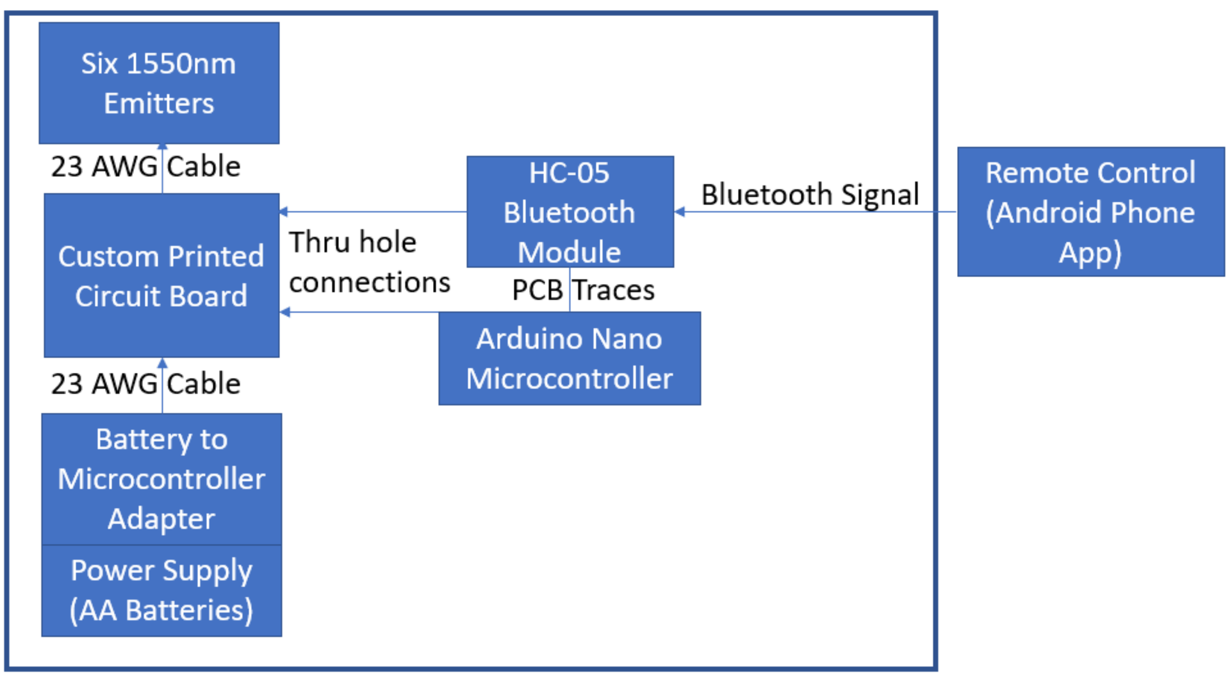
Properties of Some Metals and Alloys, The International Nickel Company, 1982

Beacon light with reflector and light emitting diodes, Dialight Corporation, 2013

Tactical Light Device, Nathan Esham, 2019

All documents referenced in this section were used as research in the design phase of this project. We got to understand the benefits of infrared beacon technology, we understood different models on bluetooth proximity, we learned about the properties of differing metals and alloys, we understood different applications of beacon light that uses reflectors and light emitting diodes, and finally we learned about tactical light devices.

System Description / System Block Diagram



As shown in the System Block Diagram, the STrOBe is comprised of a light emitting system that allows users with night vision or SWIR vision capabilities to visualize its position through the emission of high intensity, short-wave infrared light. The light emitting system is comprised of an Arduino nano microcontroller with an HC-05 bluetooth module, AA battery power supply, custom printed circuit board, and controlled by an Android phone using a bluetooth terminal app.

UArizona

Team 21057

Technical Data Package (TDP)

Elbit Systems of America

SWIR Transmitting Optical Beacon (STrOBe)

TDP Table of Contents

Introduction

Our team will develop a prototype “Portable Beacon (STrOBe)” for Elbit Systems of America. The device can be used to identify a target in the field by emitting in the short-wave infrared (SWIR) range. The SWIR Transmitting Optical Beacon (STrOBe) shall be small, portable, remotely programmable, rugged, and bright enough to be seen from a distance. Functions for the device shall be entered and controlled remotely (via bluetooth connectivity) through a developed app that allows for powering the beacon and changing the pulse repetition rate. Once the project is finished, three different working prototypes of the STrOBe shall be independently operable while fully controlled through the remote operation.

System Description

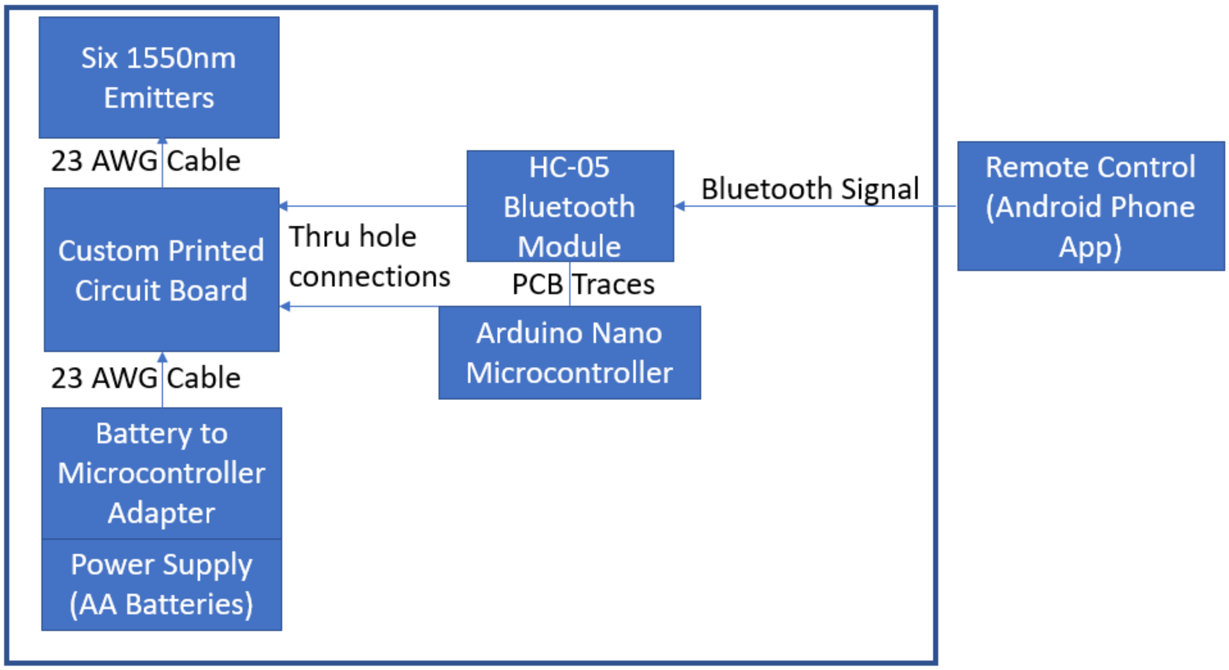


Figure 2.1

As shown in the System Block Diagram, the STrOBe is comprised of a light emitting system that allows users with night vision or SWIR vision capabilities to visualize its position through the emission of high intensity, short-wave infrared light. The light emitting system is comprised of an Arduino UNO R3 microcontroller with a bluetooth module, power supply, a transistor circuit, SWIR source, and remote control.

System Architecture

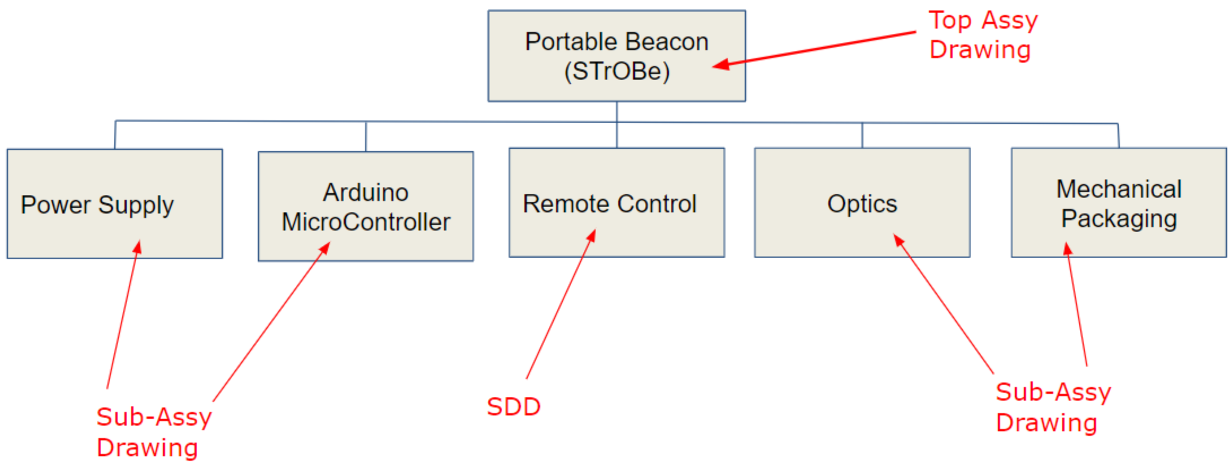


Figure 3.1

The STrOBe System shall be composed of five major parts: the power supply, Arduino MicroController, Remote Control, the Optics, and Mechanical Packaging. Of these components, the remote control will be well represented in the system design document (SDD). As for the last four components, they will be part of our sub-assembly drawings.

Requirements Traceability to Subsystems

Each subsystem of our portable beacon (STrOBe) will contribute to complying with our system requirements. Figure 1.3 (depicted below), describes the traceability of our system requirements to each of our subsystems. Yellow indicates which test verifications are included in the Acceptance Test Procedure (ATP) and the level at which they are performed

System Requirements	SubSystems				
	Power Supply	MicroController	Remote Control	Optics	Mechanical Packaging
4.1.1 Run Time (D): The STrOBe shall continuously run for 30 or more minutes.	1. (D-Direct Flow) Upon startup will run continuously for 30 or more minutes before powering down.		1. (D-Allocated) Will give command to power on device 30 or more minutes without user intervention.		
4.1.2 Operation Function (T): The STrOBe shall allow the user to turn it on and off and control the pulse repetition rate between CW and 100 Hz.	2. (A-Direct Flow) Operates by command of user input.	1. (A-Direct Flow) The microcontroller shall allow the user to change the rep rate of the STrOBe	2. (D-Direct Flow) Will operate on/off function and pulse repetition rate of STrOBe.		
4.1.3 Operation Control (D): The STrOBe shall have an app that allows for control of three different devices at range.	3. (D-Direct Flow) Operates by command of user input.		3. (D-Direct Flow) Will allow for control of three different devices at range.		
4.1.4 Radiant Power (T/A): The radiant power of the emitter shall be greater than 150mW.	4. (A-Direct Flow) Optical components > 150 mW of radiant power.			1. (I-Allocated) Radiant power of emitter > 150 mW.	
4.1.5 Output Power (T): The output optical power distribution shall have a max of 20% variance in uniformity over the FFOV.	5. (D-Direct Flow) Need a uniform source of voltage to avoid variance in output power			2. (T-Allocated) The Emitters we order will have a consistent output power.	
4.1.6 Output Angle (T/A): The STrOBe shall have an angle measuring between 120 FFOV to 140 FFOV.				3. (T-Allocated) FFOV of the emitter will be between 120 and 140 degrees	
4.1.7 Output Wavelength (I): The STrOBe shall have an output wavelength in the 15xx nm band.				4. (I-Direct Flow) The emitter used will be in the SWIR 15xx band	
4.1.8 Modulation (T): The STrOBe shall output ranging from CW to 100 Hz repetition at 50% duty cycle.				5. (T-Direct Flow) The emitter shall sustain a duty cycle of 50% for the entire runtime	
4.2.1 Dimension (I): The STrOBe shall fit in a 5"x5"x5" box.					1. (I-Direct Flow) Mechanical packaging needs to be within size constraints
4.2.2 Shelling (I): The STrOBe shall have rubber shelling for shock absorption.					2. (I-Direct Flow) Rubber shelling on the casing will absorb the shock of up to a 6 foot drop.
4.2.3 Deployment (T): The STrOBe shall be able to be thrown or dropped by both humans and drones from a height of six feet, land emitter side up, and remain stationary on a surface slanted up to 45°					3. (I-Direct Flow) 3D geometry needs to allow for self-correction of orientation
4.2.4 Weight Specification (I): The STrOBe shall weigh no more than 5 pounds with batteries.	6. (A-Allocated) Less than .424 lb (8 batteries weight	4. (A-Allocated) Less than .06 lb		6. (A-Allocated) less than .5 lbs	4. (A-Allocated) Less than 4 lbs

4.2.2 Shelling (I): The STrOBe shall have rubber shelling for shock absorption.					2. (I-Direct Flow) Rubber shelling on the casing will absorb the shock of up to a 6 foot drop.
4.2.3 Deployment (T): The STrOBe shall be able to be thrown or dropped by both humans and drones from a height of six feet, land emitter side up, and remain stationary on a surface slanted up to 45°					3. (I-Direct Flow) 3D geometry needs to allow for self-correction of orientation
4.2.4 Weight Specification (I): The STrOBe shall weigh no more than 5 pounds with batteries.	6. (A-Allocated) Less than .424 lb (8 batteries weight	4. (A-Allocated) Less than .06 lb		6. (A-Allocated) less than .5 lbs	4. (A-Allocated) Less than 4 lbs
4.2.5 Reuse (I): The STrOBe shall be reusable after replacing batteries.		5. (I-Direct Flow) Operate without hesitation.		7. (I-Direct Flow) Operate without hesitation.	
4.2.7 Durability (D/I): The STrOBe shall be able to operate at full capacity after being dropped from a height of six feet.	7. (I-Direct Flow) Will perform startup without hesitation after up to 6 foot drops.	6. (I-Direct Flow) Operate without hesitation after up to 6 foot drops.		9. (I-Direct Flow) Operate without hesitation after up to 6 foot drops.	5. (I-Direct Flow) Durability of STrOBe is dependant on the structual integrity of the mechanical packaging
4.2.8 Temperature (T): The temperature of the heatsink or emitter shall not exceed 100°C					6. (T-Direct Flow) Heat Sinks and ventilation in the packaging will prevent the emitters from surpassing 100°C over the 30 minute runtime

Figure 3.2

Prediction of Performance

In predicting our performance, margins, and accuracy against each of our system requirements, we displayed our modeling methods to be used. While the system requirements, Radiant Power, Output Power, and Output Angle can each be demonstrated through LightTools modeling, our final four system requirements must be modeled through aspects of electrical, optical, and mechanical engineering. The first requirement of which, Operation Function, shall be modeled through app and Arduino code in order to display how user functions may be controlled through the prototype's smartphone application. The requirement, Modulation, shall be tested and modeled using radiometry to hit the margin output ranging between CW and 100Hz. Our deployment system requirement can be best modeled through a functioning drop test where we will test how accurately our prototype can be thrown or dropped from heights of 6 feet and land emitter side up while remaining stationary on surfaces slanted up to 45 degrees. Then our final system requirement to be discussed is Temperature, whose modeling methods are to be determined. Each of our system requirements to be tested and/or analyzed are depicted below in model 4.1, where predictions were also made on requirement performance accuracy.

System Requirement	Model(s)	Prediction	Margin
4.1.2 Operation Function (T): The STrOBe shall allow the user to turn it on and off and control the pulse repetition rate between CW and 100 Hz.	App Code & Arduino Code	duty cycle of 50%, and modeled cw function	CW 100 Hz
4.1.4 Radiant Power (T/A): The radiant power of the emitter shall be greater than 150mW/stradian.	LightTools	average of 130 mW/stradian over the FOV	120mW+
4.1.5 Output Power (T): The output optical power distribution shall have a max of 20% variance in uniformity over the FFOV.	LightTools	24% above ideal irradiance of 150 mW/sr, 60% below ideal	< 20%
4.1.6 Output Angle (T/A): The STrOBe shall have an angle measuring between 120 FFOV to 140 FFOV.	LightTools	120°	120°+
4.1.8 Modulation (T): The STrOBe shall output ranging from CW to 100 Hz repetition at 50% duty cycle.	Radiometric	The STrOBe shall output ranging from CW to 100 Hz repetition at 50% duty cycle.	CW 100Hz
4.2.3 Deployment (T): The STrOBe shall be able to be thrown or dropped by both humans and drones from a height of six feet, land emitter side up, and remain stationary on a surface slanted up to 45°	Drop Test	55% success when dropped from 3 ft onto flat surface	<45°
4.2.8 Temperature (T): The temperature of the heatsink or emitter shall not exceed 100°C	TBD	TBD	<100°C

Figure 4.1

Mechanical Design

Drawings

a. Assembly Drawings

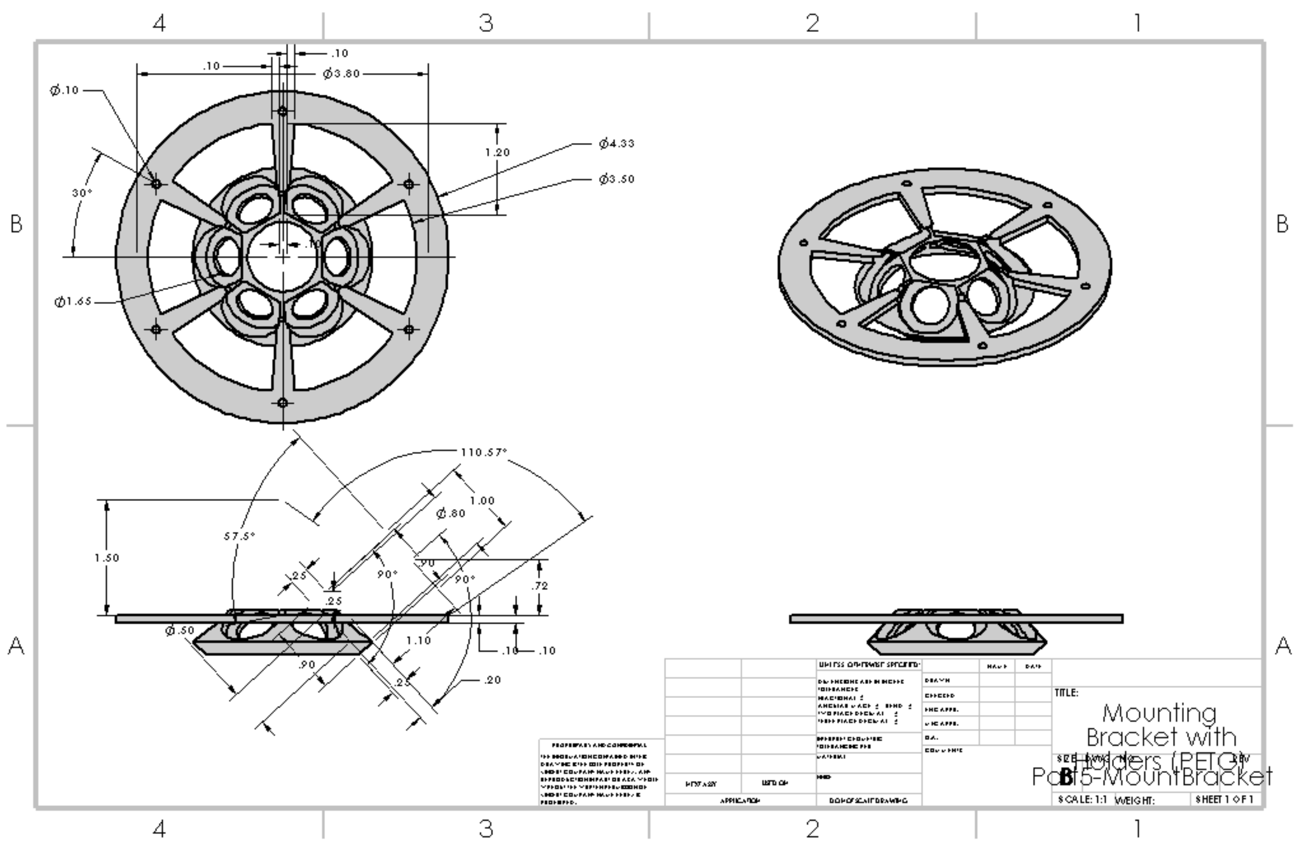


Fig 5.1 Heatsinks Mounting Bracket

b. Piece Part Drawings

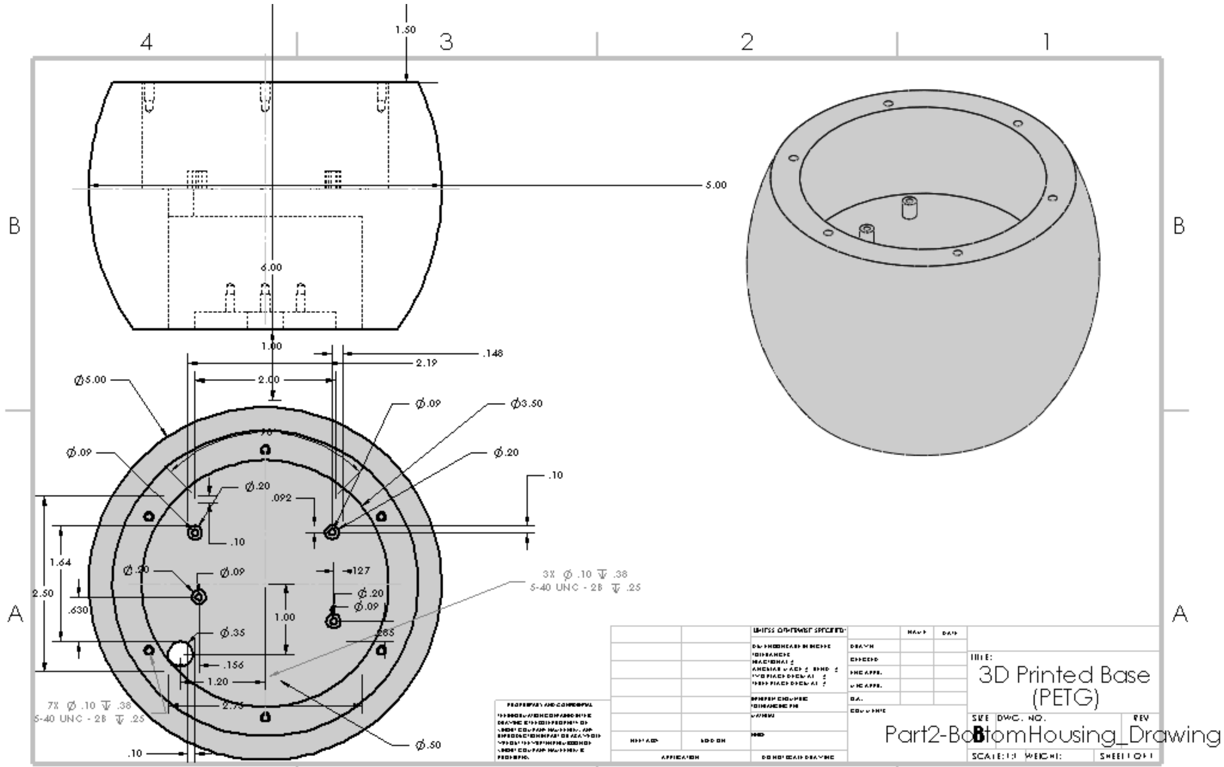


Fig 5.2 Main Bottom Housing Drawing #1

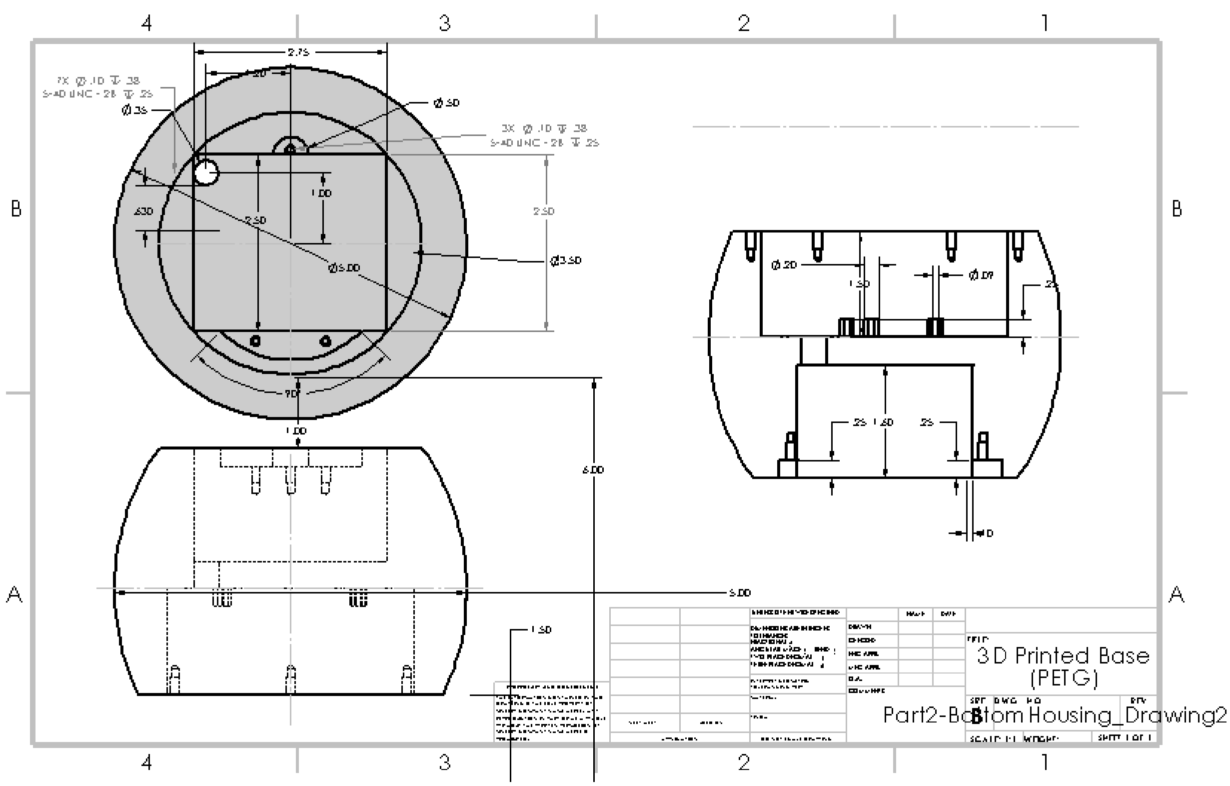


Fig 5.3 Main Bottom Housing Drawing #2

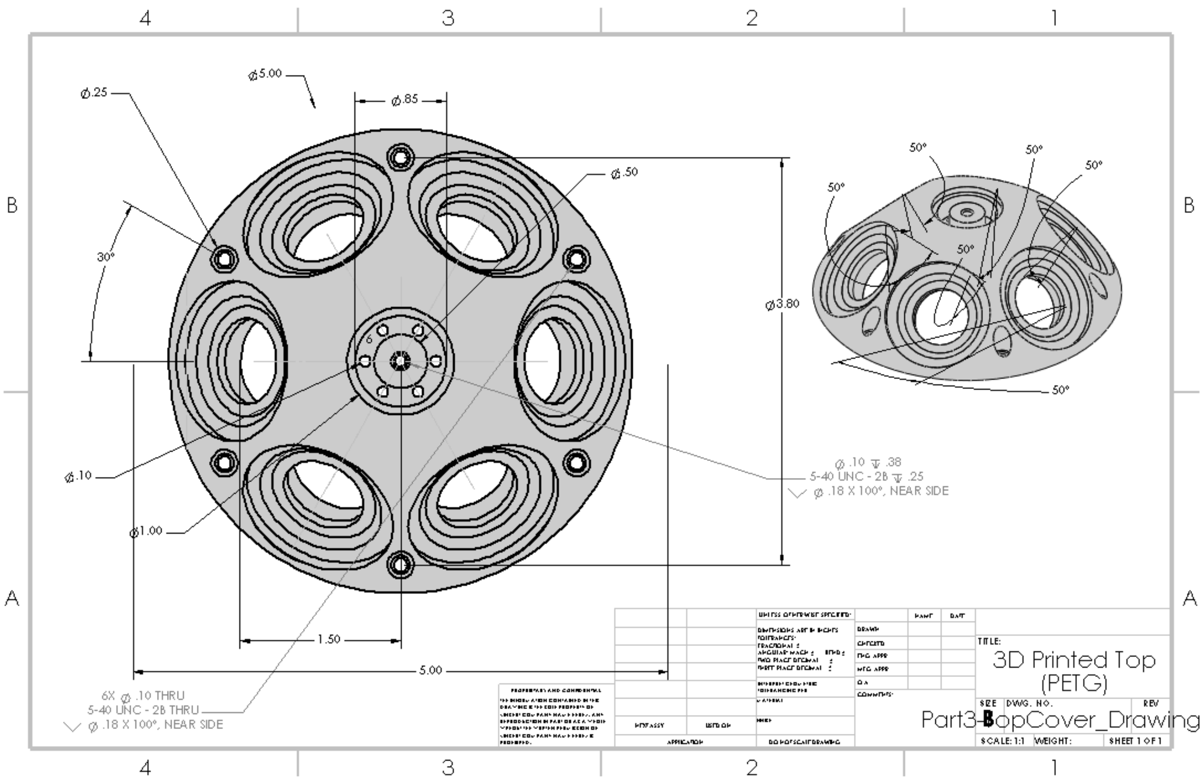


Fig 5.4 Top Housing Drawing #1

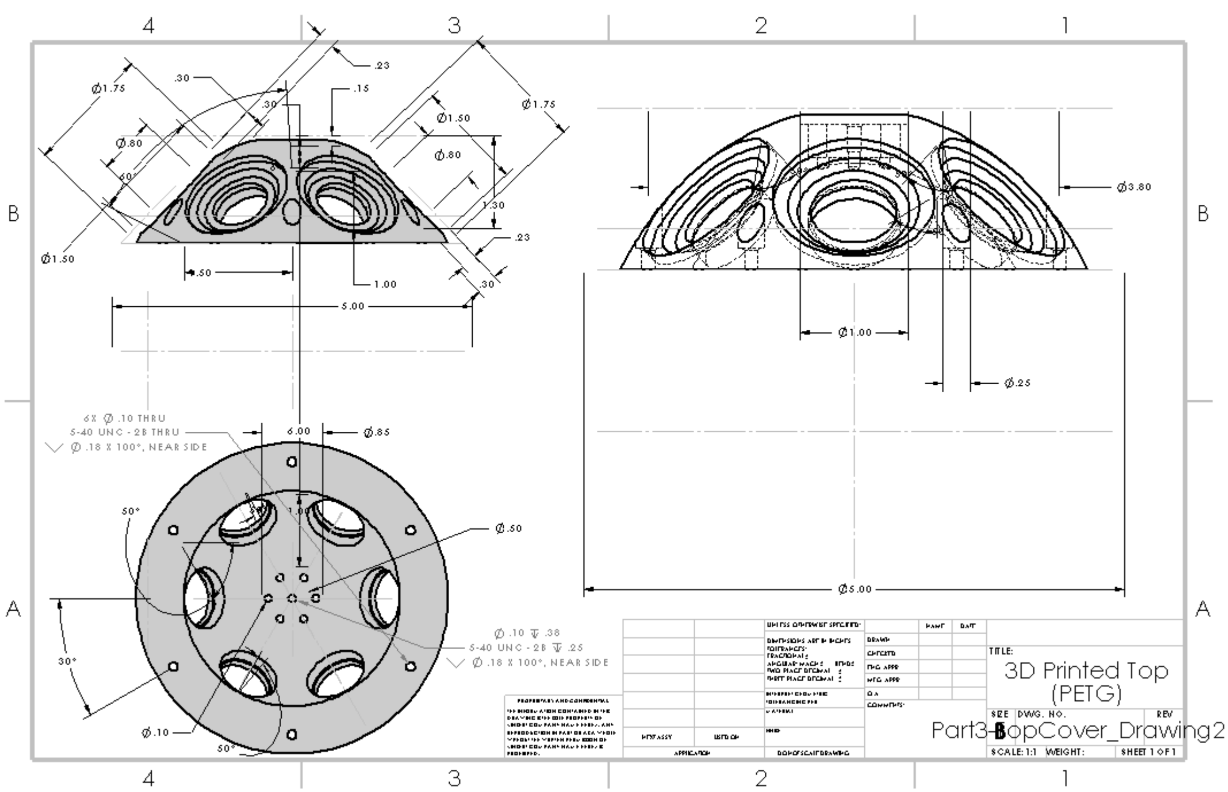


Fig 5.5 Top Housing Drawing #2

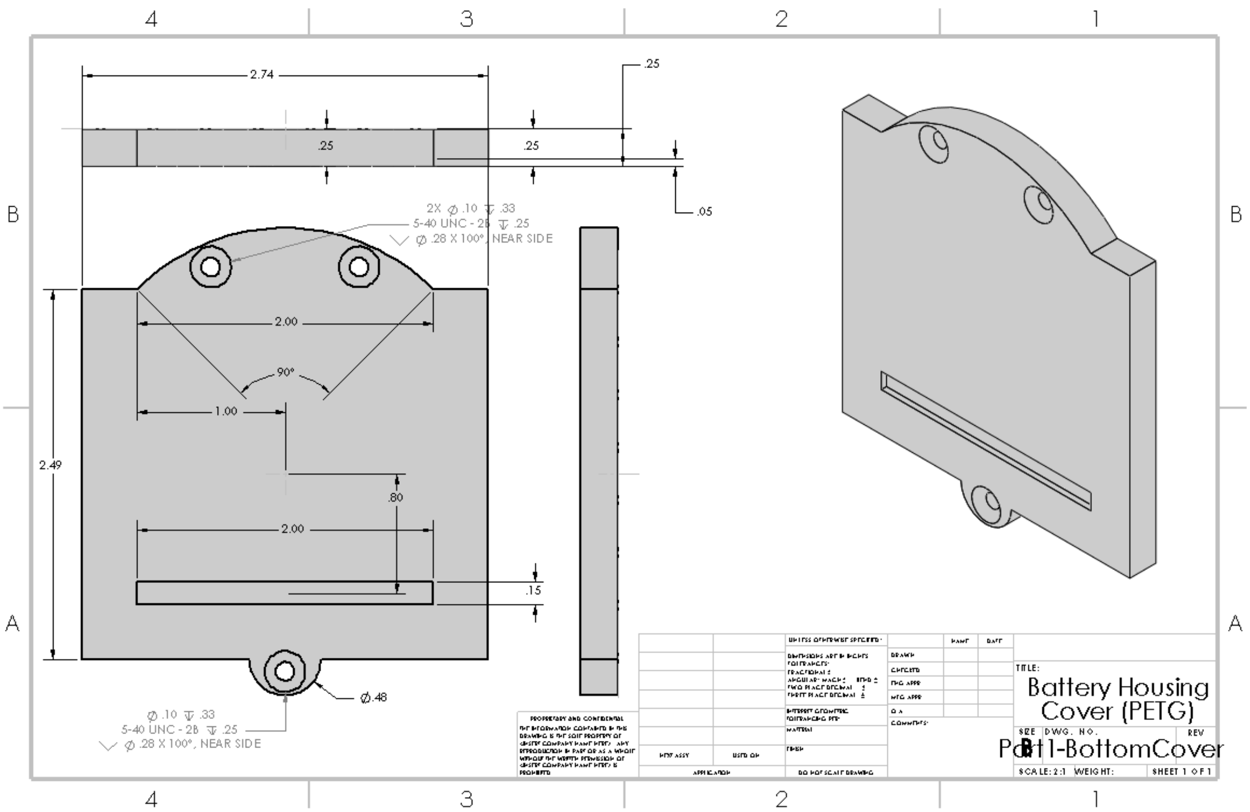


Fig 5.6 Bottom Housing Battery Section Cover

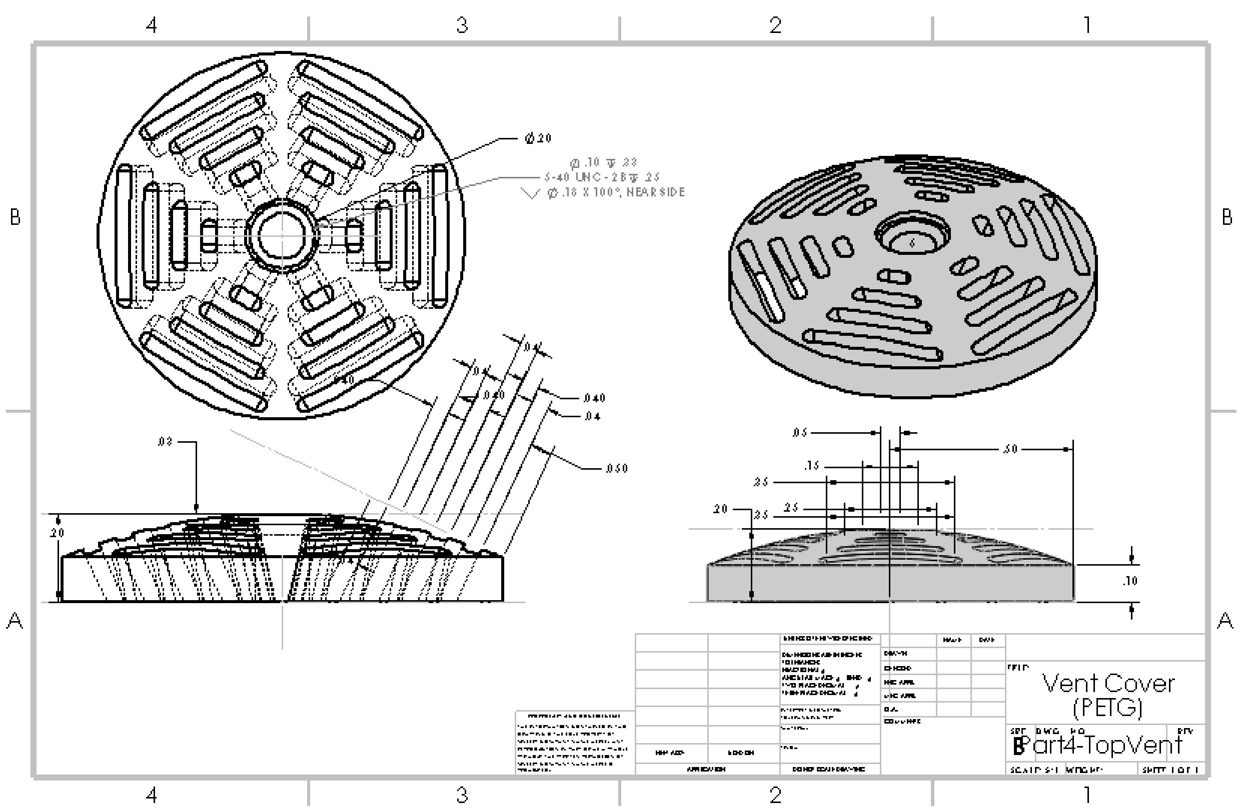


Fig 5.7 Top Housing Ventilation Cover

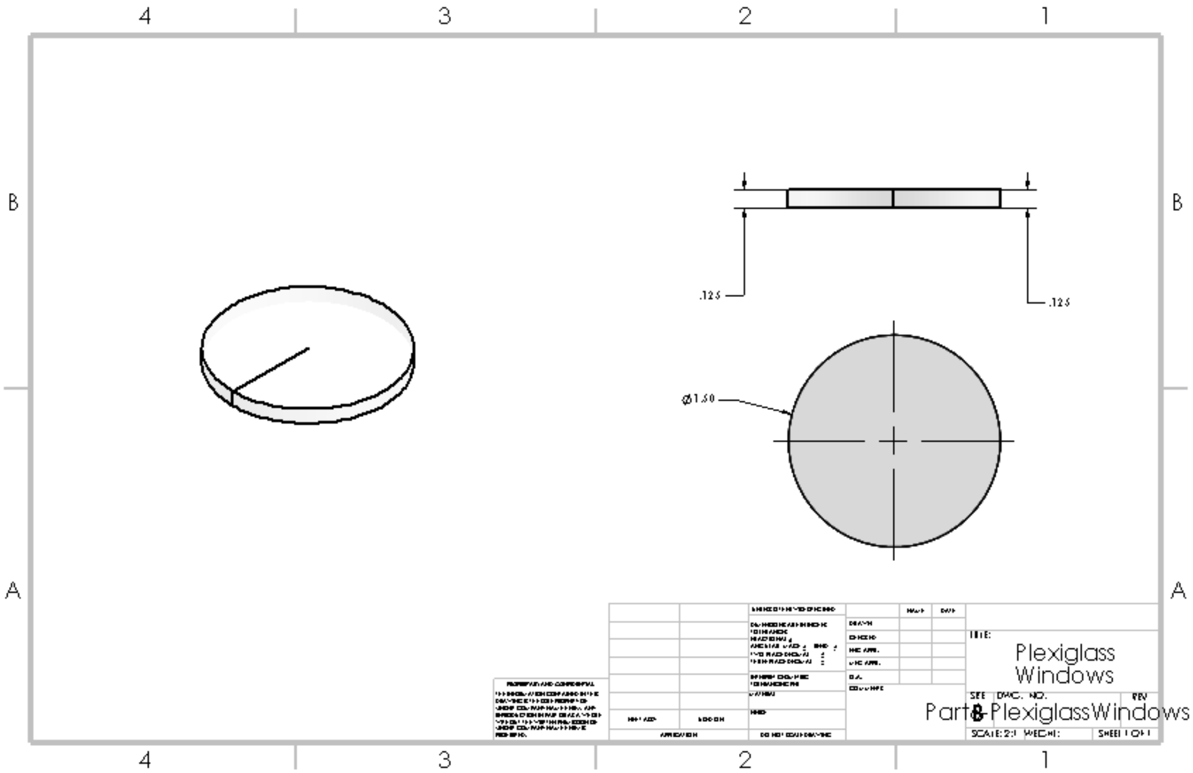


Fig 5.8 Plexiglass Windows/Covers for Emitter Housings

Schematics

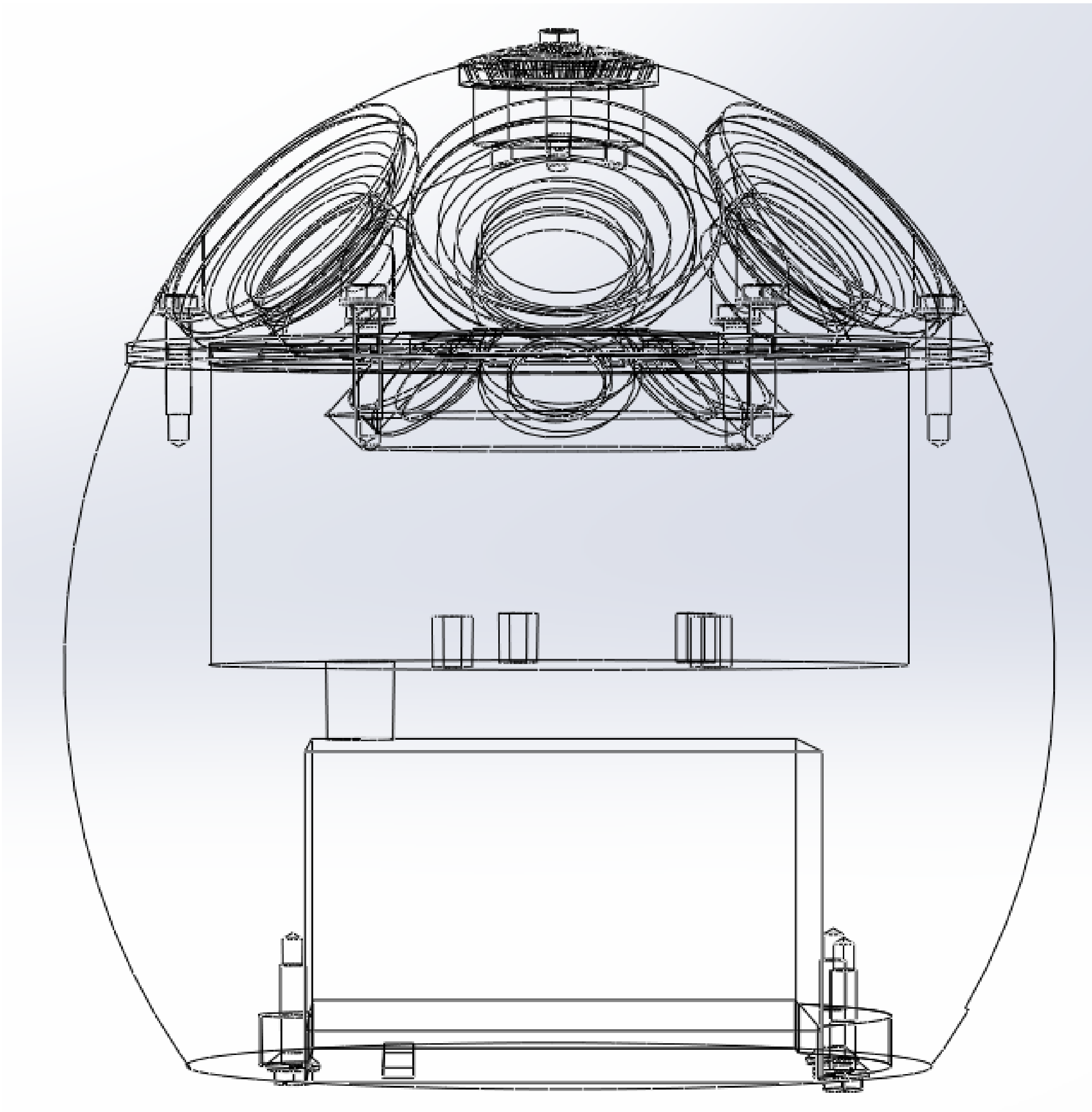


Fig 5.12 Mechanical Packaging Wireframe

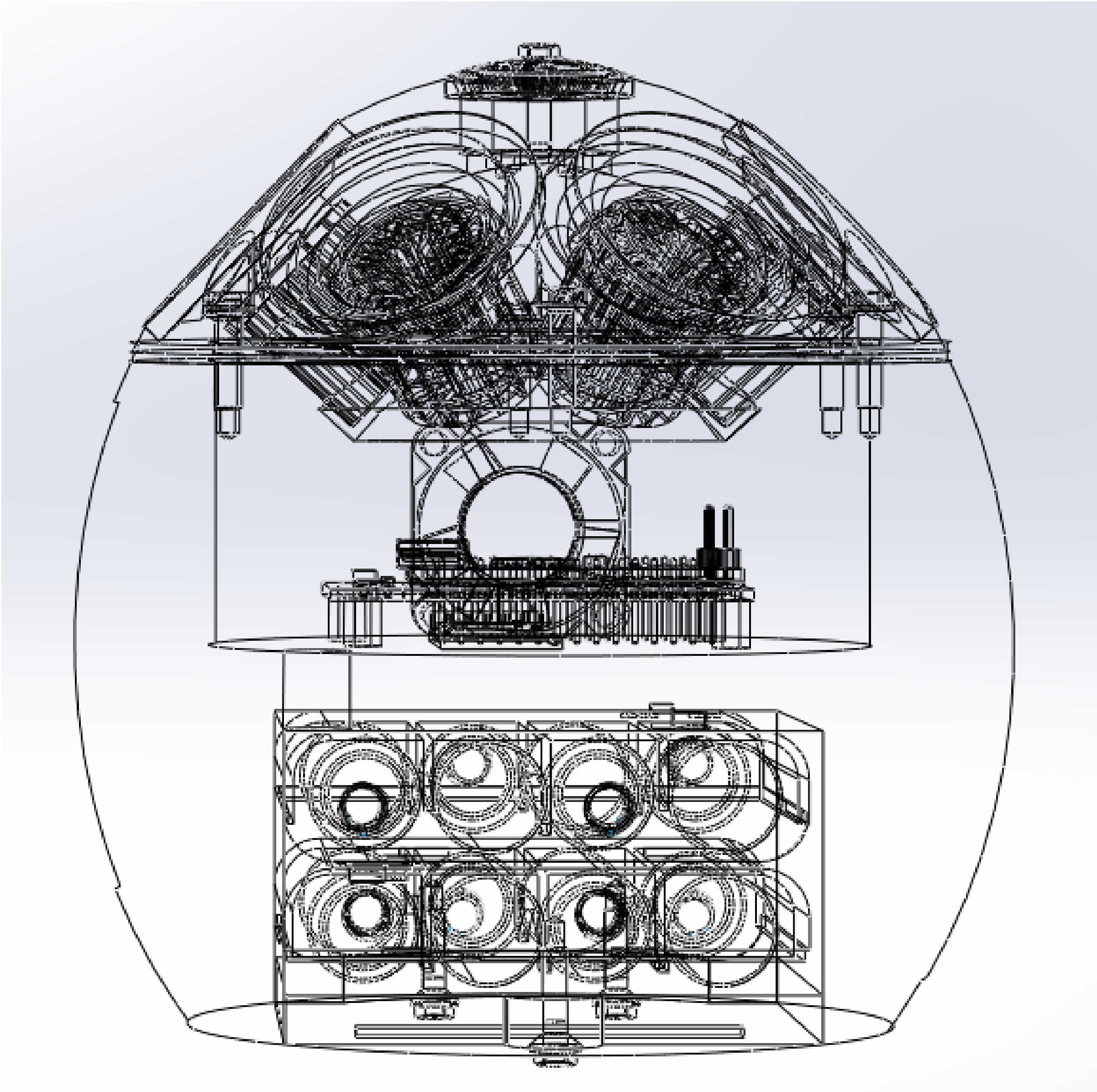


Fig 5.13 Device Assembly with main components wireframe

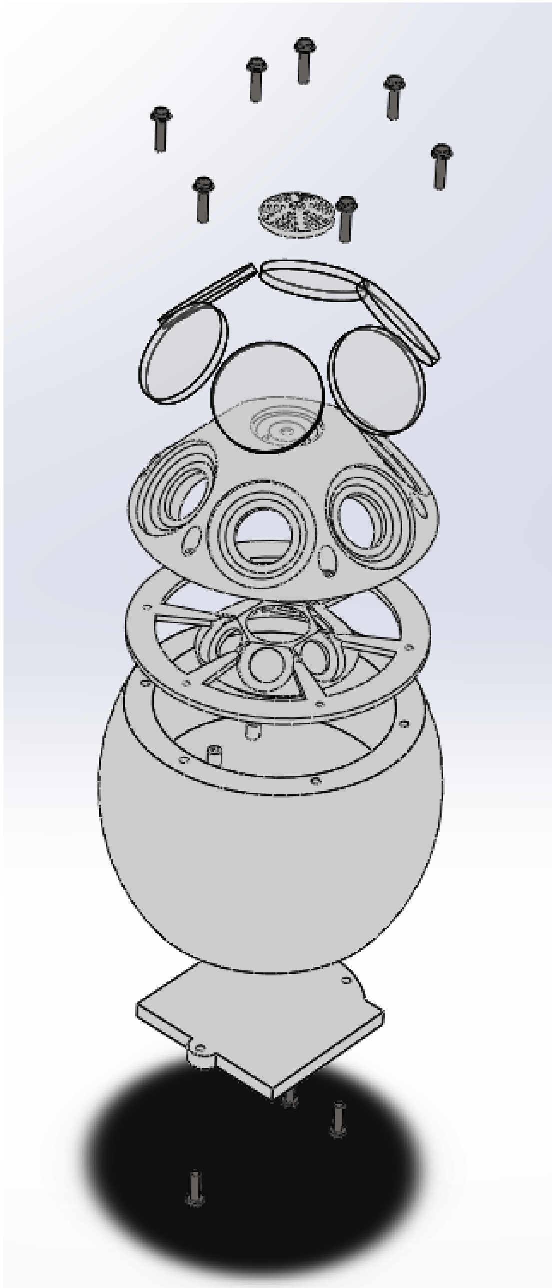


Fig 5.14 Exploded Mechanical Assembly

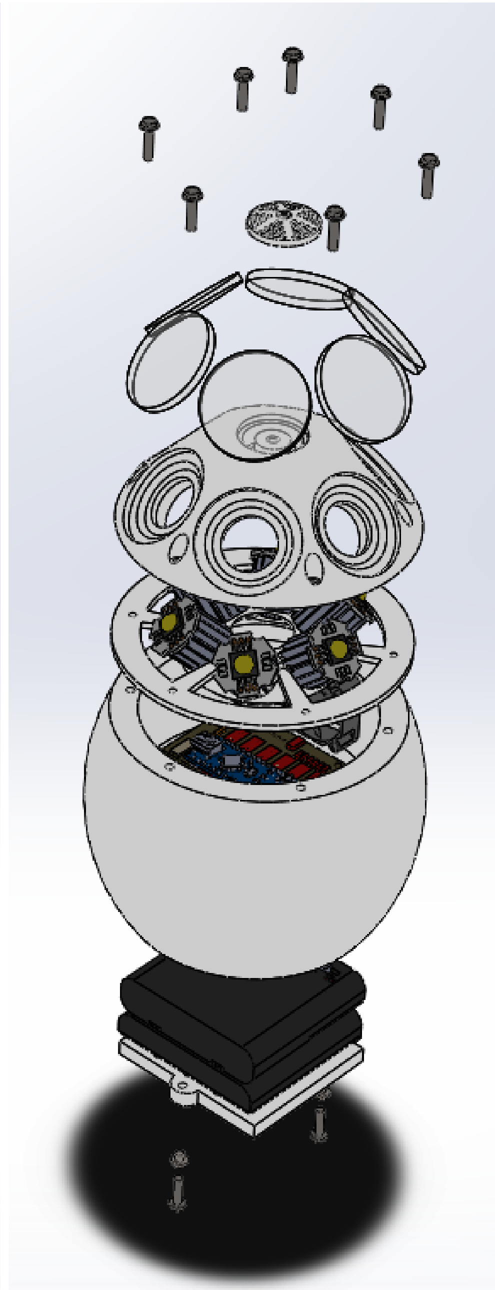


Fig 5.15 Exploded Full Assembly

Circuit Schematic:

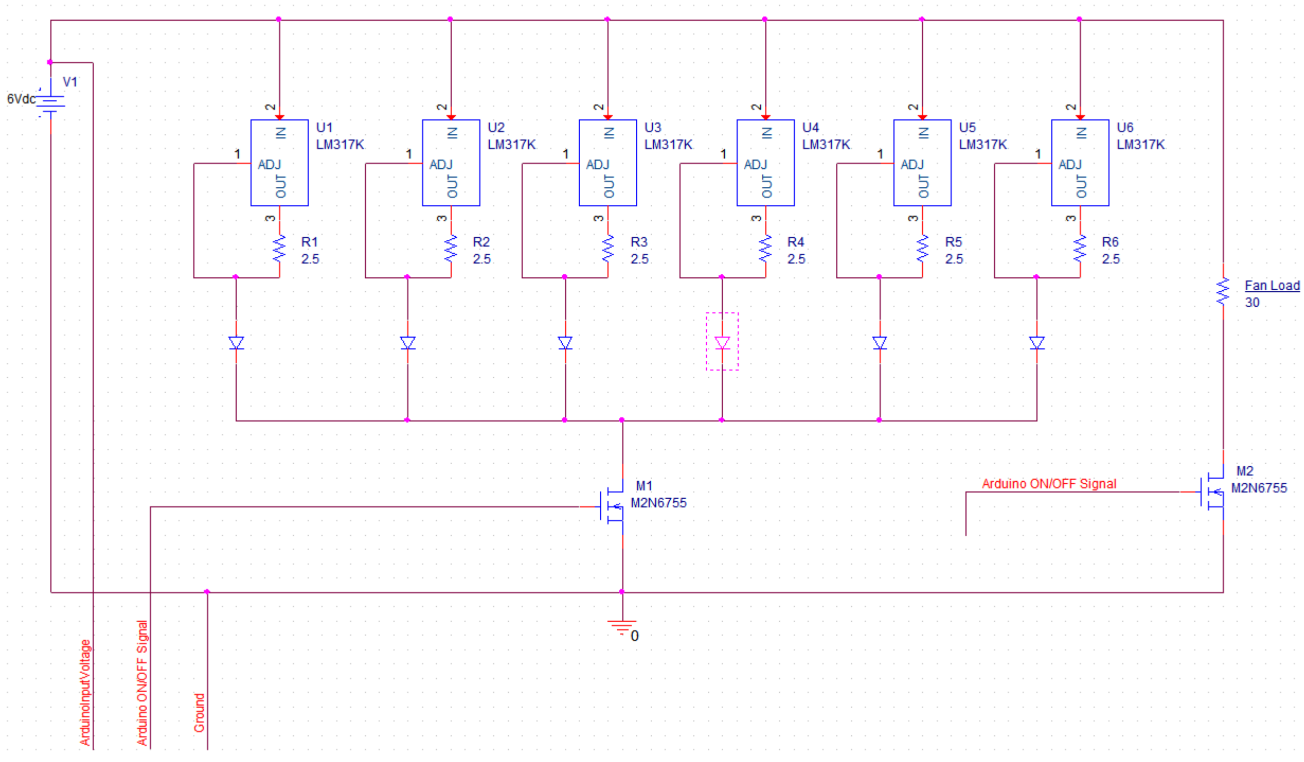


Fig 5.16 P-Spice Circuit Schematic

PCB Schematic:

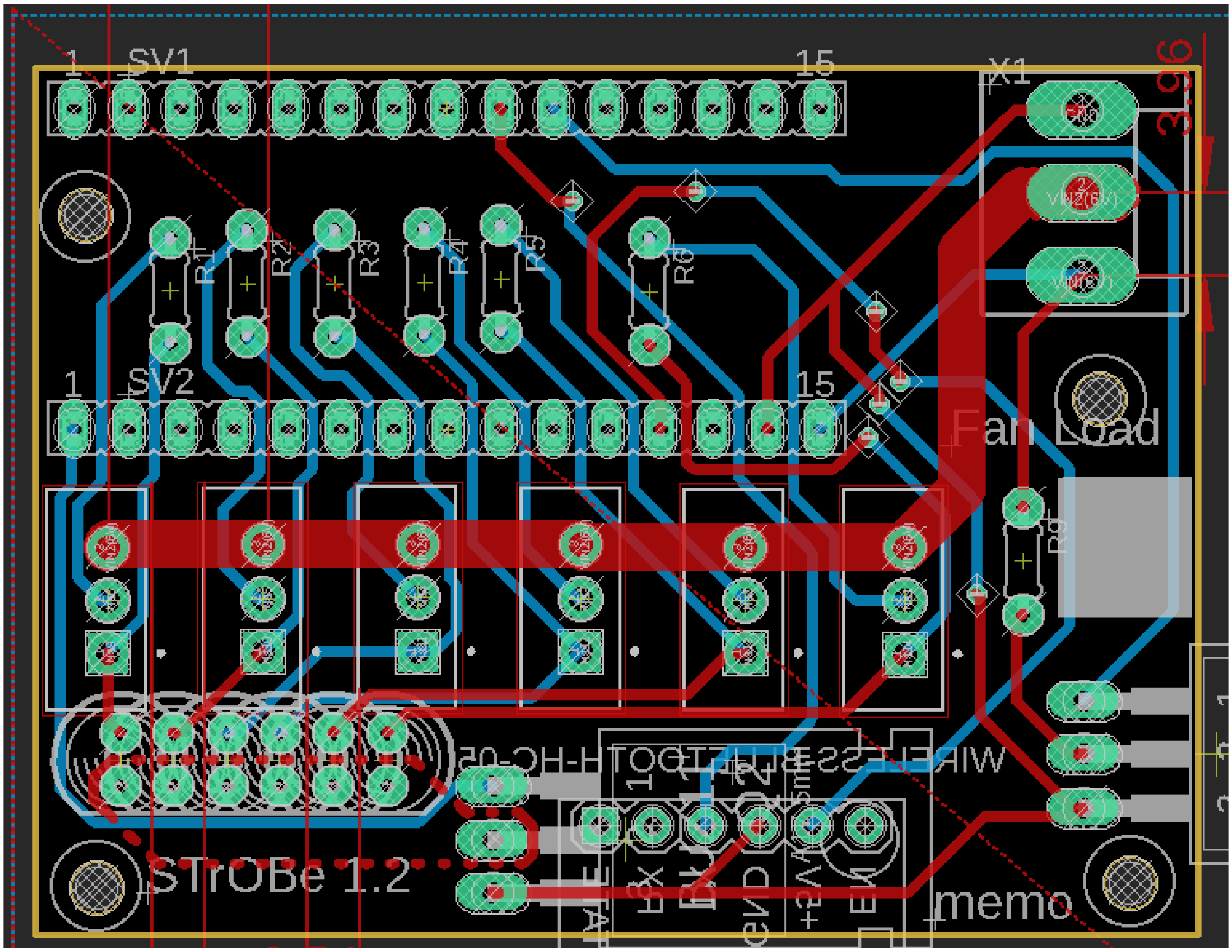
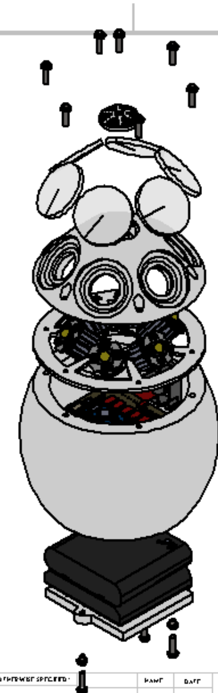


Fig 5.17 PCB Schematic

c. Part Lists / Bill of Material

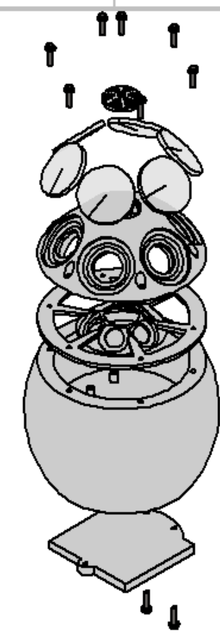
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	BOTTOM HOUSING	3D PRINTED BASE (PETG)	1
2	TOP HOUSING & COVER	3D PRINTED TOP (PETG)	1
3	TOPVENT COVER	VENT COVER (PETG)	1
4	BOTTOM HOUSING COVER	BATTERY HOUSING COVER (PETG)	1
5	EMITTER WINDOWS	PLEXIGLASS WINDOWS	6
6	IN-HWMS 0.125-40X0.5X0.5-N	SCREWS	10
7	MOUNTING BRACKET	MOUNTING BRACKET WITH HOLDERS (PETG)	1
8	EMITTERMODULE	EMITTER + STAR PCB + HEATSINK	6
9	HC05	BT MODULE	1
10	CPU FAN V2.STEP	INTERNAL FAN FOR COOLING	1
11	BATTERYPACKFULL	BATTERY PACK WITH 4 BATTERIES	2
12	IN-HWMS 0.125-40X0.125X0.125-N	SCREWS	3
13	NANOV3 V4.STEP	NANO MICROCONTROLLER	1
14	PCB_FINAL.STEP	CUSTOM PCB FOR WIRING AND CONTROL	1



TITLE:
SIZE B DWG. NO. PartsList_ISR REV
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

Fig 5.18 Complete Parts List & BOM

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Bottom Housing	3D Printed Base (PETG)	1
2	Top Housing & Cover	3D Printed Top (PETG)	1
3	TopVent Cover	Vent Cover (PETG)	1
4	Bottom Housing Cover	Battery Housing Cover (PETG)	1
5	Emitter Windows	Plexiglass Windows	6
6	IN-HWMS 0.125-40x0.5x0.5-N	SCREWS	10
7	Mounting Bracket	Mounting Bracket with Holders (PETG)	1



MechanicalPartsList-ISR

SCALE: 1:2 SHEET 1 OF 1

Fig 5.19 Mechanical Parts List & BOM

SWIR STrOBe

Software Design Document

Document Number 101

February 6, 2021

Table of Contents

1.0 Scope

1.1 Identification.

This Software Design Document describes the code architecture, interfaces, and functionality of the Android application and Arduino software, along with the specifications and use of hardware including the HC-05 and Arduino Mega, all of which are crucial to the success of Elbit's STrOBe.

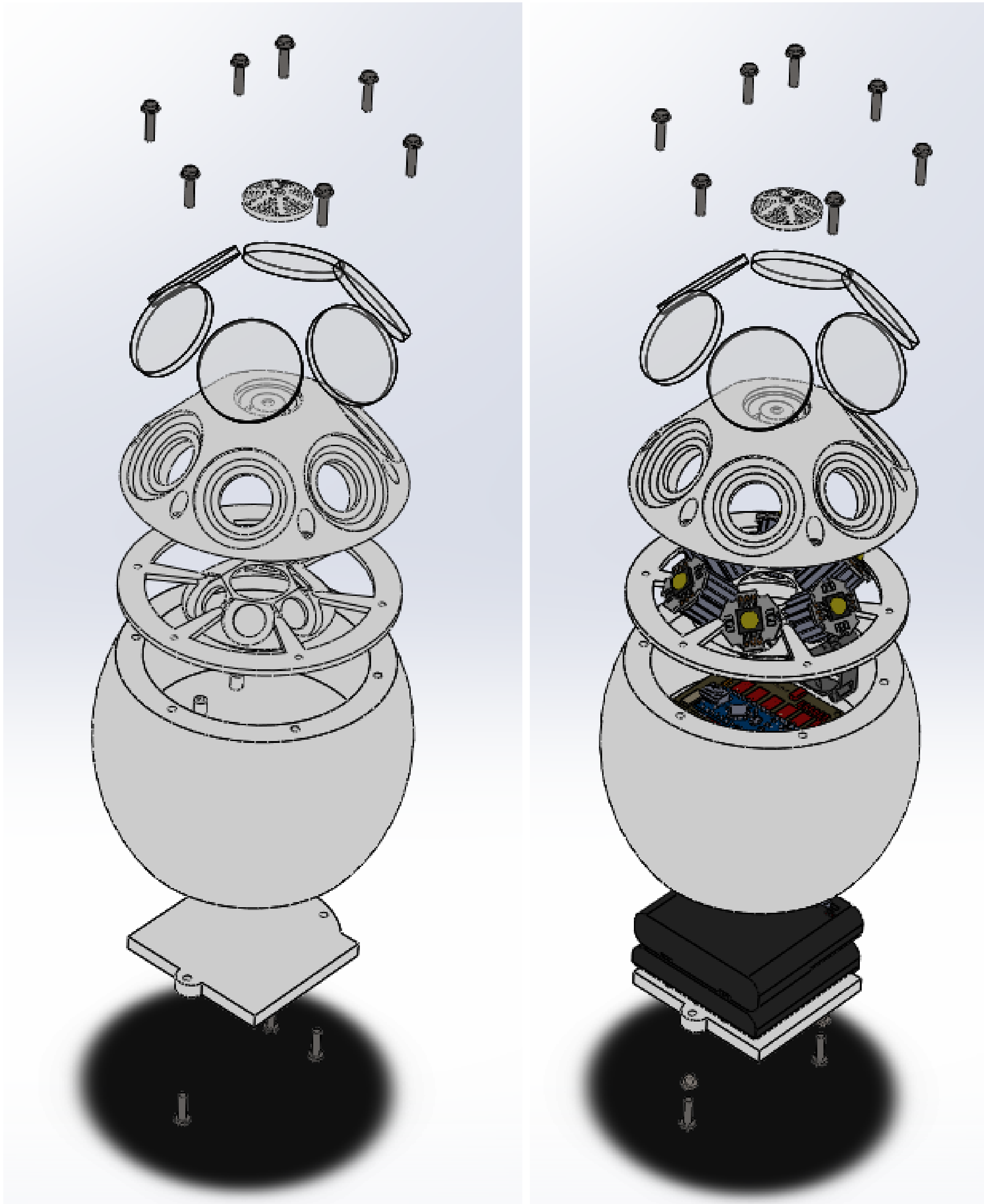


Figure 6.1: The STrOBe.

1.2 <u>System overview</u>:

The sponsor of this project is Elbit Systems of America. They are looking to create an accessible short wave infrared transmitting optical beacon for the consumer market to use for varying purposes. Historically, SWIR emitters have been used in the military for marking targets to be destroyed, landing zones, and friendly troops to prevent friendly fire from the air. SWIR emitters must be rugged and able to survive usage in varying environments--both of which were considered when theorizing how to develop the STrOBe internally.

The STrOBe shall have the capability to be deployed and controlled from a distance with the purpose of marking targets and objectives for those who have the technology to see in the short wave infrared spectrum. It is imperative that the STrOBe can connect and sustain connection to an Android application while operating, as to retain full functionality. This will be done via a bluetooth connection facilitated with an HC-05 bluetooth module connected to an Arduino Mega. The android application will present the user with two screens. The first screen will present the user with all bluetooth devices listed. The application will wait for the user to press icons that represent devices to be connected to. After selecting the device, the application will show the user with an interface allowing the user to change the state of the STrOBe: On/Off, Continuous Wave (CW) Emission, or 100 Hz Emission.

1.3 <u>Document overview</u>:

This document shall illustrate the modeling and design of the STrOBe's software, for the android application and arduino code. Unified Modeling Language will be utilized to describe the logic behind the android application via interaction, use-case, and class diagrams. The STrOBe's SDD will include code from the phone application to facilitate a concrete understanding of the inner workings of Elbit's product. While arduino code will be explained through non UML diagrams, i.e. wiring diagram with specificity down to the pin, and code snippets.

2.0 <u>Referenced documents</u>.

The following documents are referenced in this SDD.

2.1

https://components101.com/sites/default/files/component_datasheet/HC-05%20Datasheet.pdf

2.2

https://medium.com/swlh/create-custom-android-app-to-control-arduino-board-using-bluetooth-ff878e998aa8

2.3

https://medium.com/@droiduino.cc/a-simple-way-to-give-your-arduino-project-a-bluetooth-capability-eb6400c95bae

3. CSCI-wide design decisions.

Figure 6.2: Arduino Nano is a compact microcontroller that can be interfaced with a USB connection to upload code from a computer, this device pairs well with the HC-05 bluetooth module, as the same connection can be established. For the HC-05 we have no use for the TX pin, and we only desire receiving commands from the RX pin. So the RX pin will be connected to the microcontroller via the custom pcb, the Vcc pin will be powered from an external 5V source, and ground will be connected to ground of the custom pcb.

3.1 Design Decision: Android Application to Control STrOBe:

When first reviewing the design requirements for the STrOBe assigned by Elbit, attention was brought to the "remotely programmable for field flexibility" component. There are many solutions to this requirement, from creating a remote that sends signals to the arduino via bluetooth, to developing an app. The decision for choosing an android application such as Bluetooth Terminal to control the STrOBe was relatively straightforward. Developing an application for this project has numerous benefits, however was out of the scope of this project, and it was important to not reinvent the wheel. The main difference between the Bluetooth Terminal and the custom phone application would be the custom GUI we could design providing a greater ease of use on the user. We thought that it was important to not reinvent the wheel for the application portion of the project, as time could be invested elsewhere such as creating a custom PCB for the design.

3.2 Design Decision: Interface Layout for Application

The bluetooth terminal has two different interfaces, the first being the interface to establish a bluetooth connection. Note that in order for any connections to show up, you must have found and connected to the device you desire to communicate with in your settings, secondly the other interface is a keyboard terminal. This keyboard interface will be responsible for changing our repetition rates.

The first interface will be accessible by clicking the three bars in the upper right corner. This will present you with options to make a secure or insecure connection, you can choose either for interfacing with the strobe as the type of connection is not relevant to this project.

The second interface will actually be the first interface that you are presented with but you only want to use this GUI after you establish a connection with an HC-05. This interface is a keyboard interface and different keys will reference different operating modes of the STrOBe. The continuous wave button will be key ‘a’, this button will send a signal to the arduino telling it to turn the emitters on, secondly the flicker mode which is set to 5hz will be turned on by pressing ‘b’, and lastly to turn the strobe off, the user will press the ‘c’ key.

3.3 Arduino Input Design Decision:

Facilitating orders from the user through the android application will require the HC-05 to feed data to the arduino. The arduino will take said data from the buffer stream and allocate power to the transistor based on the command that it receives. If the flicker button is pressed, key ‘b’, the arduino will read instructions and provide a pwm signal to the gate of the power mosfet to turn the emitters on and off.

3.4 Arduino Output Design Decision:

The arduino output design decision was based on the criteria provided to us by Elbit systems, the STrOBe must be able to emit at a repetition rate of 5hz at 50% duty cycle, and be able to switch to a continuous wave output.

The design for a repetition rate of 5 hz is relatively simple and can be done through pulse width modulation and the digitalWrite function cooperating with a power mosfet, while the continuous wave function is even simpler as it requires the mosfet to be in a constant off state.

3.5 Module Design Decision:

The HC-05 was chosen based on its dependability, its ability to fit well in our system based on our criteria, and it's cheap price around 8 dollars. The HC-05 can sustain a connection over 20 feet, and boasts varying baud rates.

4. CSCI architectural design.

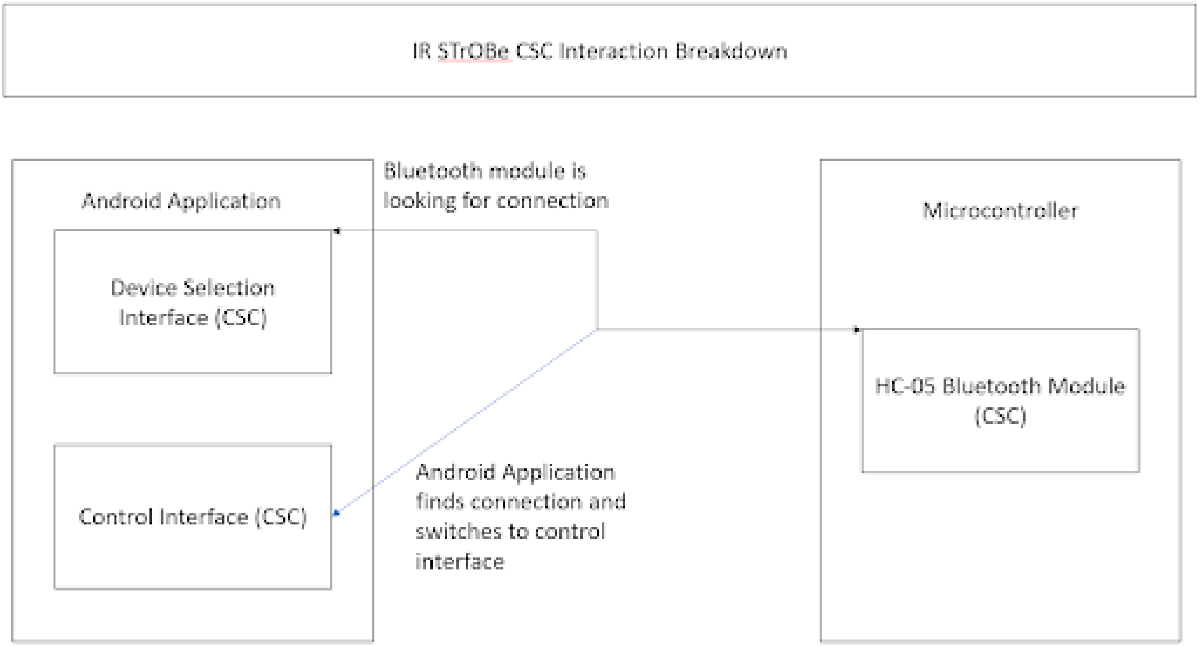


Figure 6.5: Interaction Breakdown between CSC components in the stage of facilitating an over the air connection between the application and the microcontroller.

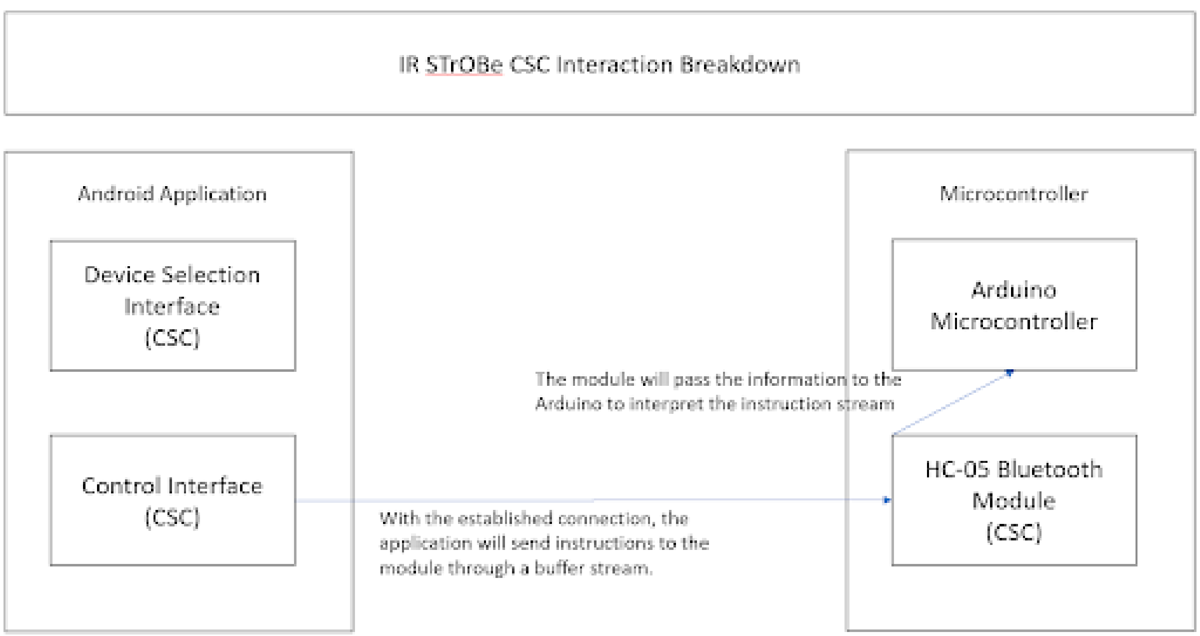


Figure 6.6: Interaction Breakdown after the connection between application and microcontroller has been established, the interface is sending command streams to the module which is passed to

the microcontroller for interpretation.

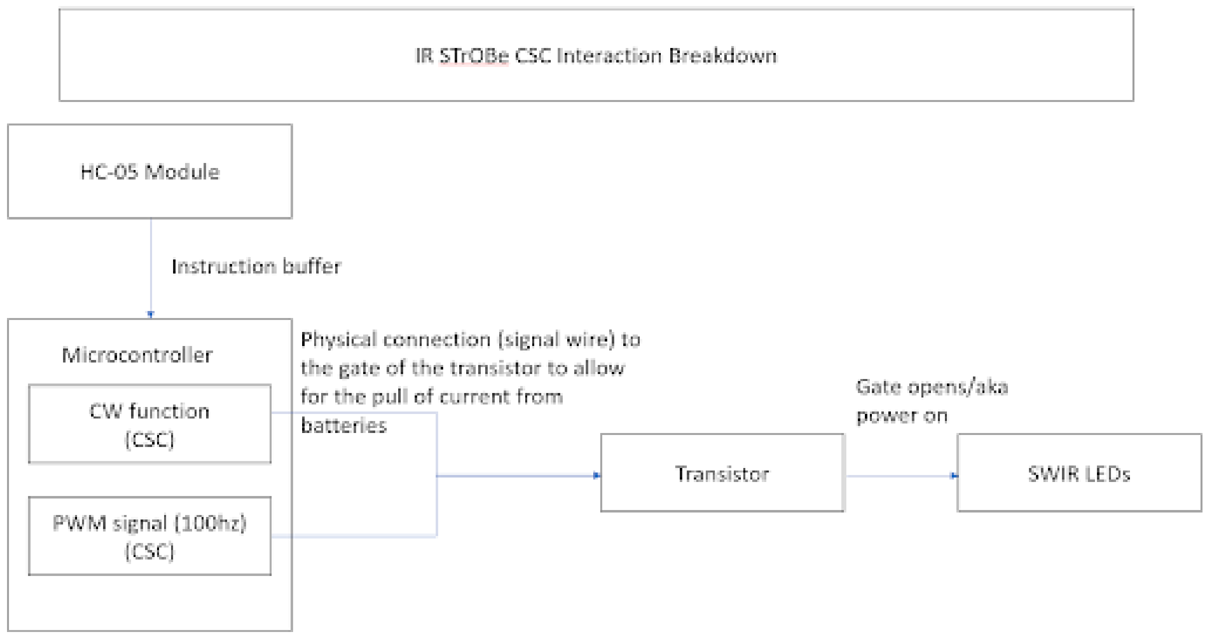


Figure 6.7: Interaction breakdown between the CSC and the hardware components. A signal wire will transmit a pwm signal/continuous wave signal to the transistor's gate.

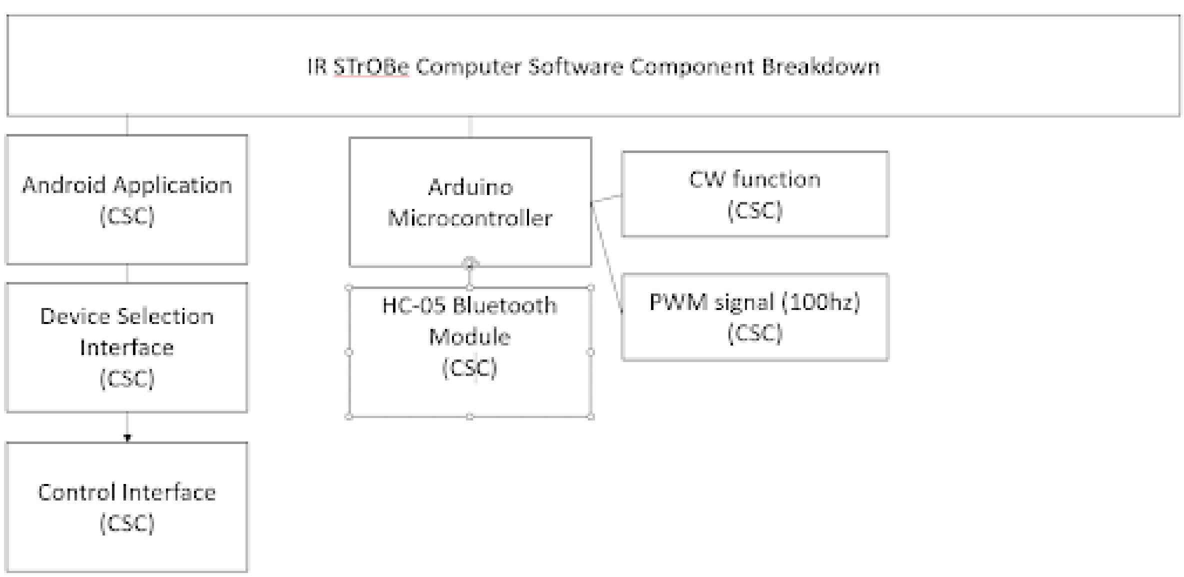


Figure 6.8: Above is the CSC Breakdown of the software components that are integral to the design of the project.

4.1 CSCI components.

Arduino Code: The arduino code will comprise 3 different sections, the first being the bluetooth module's code, the second being the pwm output, and finally the last being the continuous wave output.

HC-05: Firstly, this component of the electronics is responsible for the ability of establishing our connection with any sort of device. The HC-05 was interfaced with the software serial library to allow for communication between the Arduino Nano through non communication pins but rather PWM enabled pins.

PWM output: The PWM mode is simple, and requires 5V and 0V to be sent to the gate of the power mosfet, the 5V shall be on as long as the 0V signal. Allowing for the current to flow through the LED's at a rate that in turn allows them to flicker.

Continuous Wave: The continuous wave mode is very simple. The Arduino Nano simply needs to supply 5 volts to the gate of a power mosfet to allow current to flow through the emitters, through the mosfet and then ultimately to ground.

5. CSCI detailed design:

[Included in this section: Unit design decision, such as the CW model, 100hz repetition rate, languages]

5.1 Language:

The only language used for software design is for the arduino application, this will be written in cpp.Arduino must be coded in c/c++ as this is the language that is standard and the only language that is understood by the arduino.

5.2 Continuous Wave Algorithm:

This section is tbd, and will be updated with future iterations of the SDD and the STrOBe. The constraint for this portion of the design is that since the continuous wave is an analog signal and the arduino only handles digital signals, it will be a challenge to implement the modeling of an analog signal with a digital one.

5.3 Logic:

Receiving an input from the bluetooth terminal...

6. Requirements traceability.

4.1.2 Operation Function (T): The STrOBe shall allow the user to turn it on and off and control the pulse repetition rate between CW and 100 Hz.	2. (A-Direct Flow) Operates by command of user input.	1. (A-Direct Flow) The microcontroller shall allow the user to change the rep rate of the STrOBe	2. (D-Direct Flow) Will operate on/off function and pulse repetition rate of STrOBe.		
4.1.3 Operation Control (D): The STrOBe shall have an app that allows for control of three different devices at range.	3. (D-Direct Flow) Operates by command of user input.		3. (D-Direct Flow) Will allow for control of three different devices at range.		
4.1.8 Modulation (T): The STrOBe shall output ranging from CW to 100 Hz repetition at 50% duty cycle.				5. (T-Direct Flow) The emitter shall sustain a duty cycle of 50% for the entire runtime	

7. Notes.

The Github repository for this project can be found by following the link provided: https://github.com/lewisk1899/IRSTrOBe.git. This repository will contain all of the code necessary to the STrOBe, including detailed explanations of the logic and design of the code, as well as other functionalities.

8. Appendice.

The appendice will be included at the end of this whole document.

ATP (Acceptance Test Procedure)

Test Equipment: The test equipment will consist of:

1. Pyroelectric Radiometer
2. Voltmeter
3. Oscilloscope

Test Facility:

This project will require an outdoor, open testing environment with a range of different ground settings and heights. (Dirt, Grass, Rocky, Concrete).

For testing the power and field of view of the emitter, we will need access to a lab with a detector that can profile the intensity distribution of the emitter when housed in the mechanical packaging.

Final Acceptance Test Date:

Final system acceptance testing is planned for **4/27/21** in time for the FAR.

Overall Plan:

Five STrOBe System level tests (Operation Function, Radiant Power, Output Power Variance, Output Angle, and Modulation), and one MicroController Subassembly test are planned to verify requirements at the system level. Additionally, two Optics Subassembly tests are included for confidence that the system level acceptance can be performed.

Test Procedures:

1. Operation Function Test (4.1.2)
    a. Device will be initially powered on and connected to a remote control.
        i. The remote control will be an android phone.
        ii. Will stay powered on for 30 mins.
2. Radiant Power Test (4.1.4)
    a. A pyroelectric radiometer with an ND (neutral density) filter will be used to make sure the power is at least 150mW with a 20% variance.
3. Output Power Test (4.1.5)
    a. A radiometer will be used to measure output power across FFOV.
4. Output Angle Test (4.1.6)
    a. Angular sweep will be made with the radiometer around emitters to test angle requirement.
5. Modulation Test (4.1.8)
    a. A radiometer will be attached to an Oscilloscope in order to monitor duty cycle.

6. Deployment Test (4.2.3)
    a. Drop test in various environments and analyze behavior
        i. Grass, gravel, dirt, concrete, pavement, and uneven surfaces, etc.

Design Study

At PDR we brainstormed 3 different designs for the STrOBe: the “Russian Doll”, the “Puck”, and the “Cheese Wheel” (Shown from left to right below).

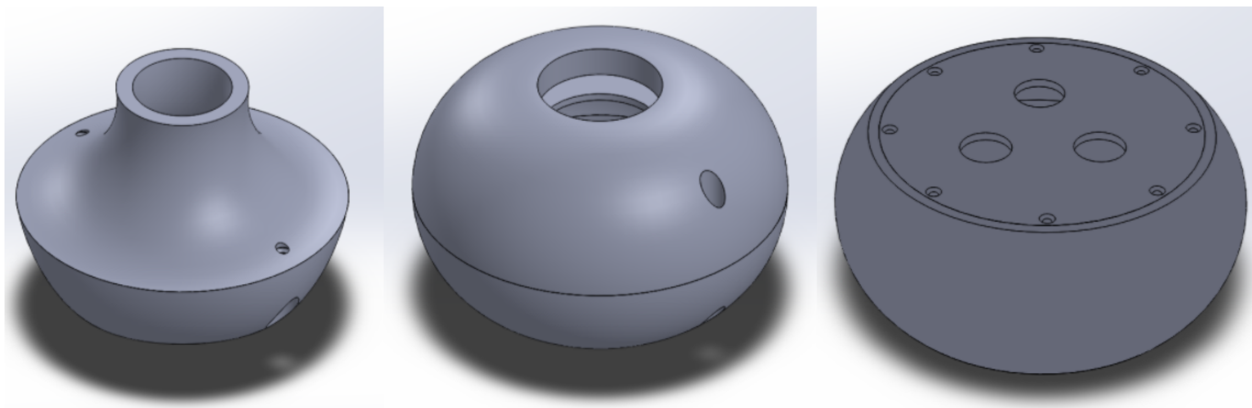


Figure 6.1

After analyzing each of these preliminary designs, we determined that the russian doll was structurally fragile, and only had room to hold one emitter. We determined that the oval puck was very unlikely to stay stationary on a 45 degree slope. Our overall winner at PDR was the Cheesewheel design. The Cheesewheel featured large flat surfaces on both the top and bottom of the device, making it ideal for landing flat on the ground. Additionally, these large flat surfaces provide high amounts of friction to stop the STrOBe from sliding down 45 degree slopes, and provide ample surface area to mount three emitters. Here’s a diagram of the Cheesewheel’s output intensity in LightTools:

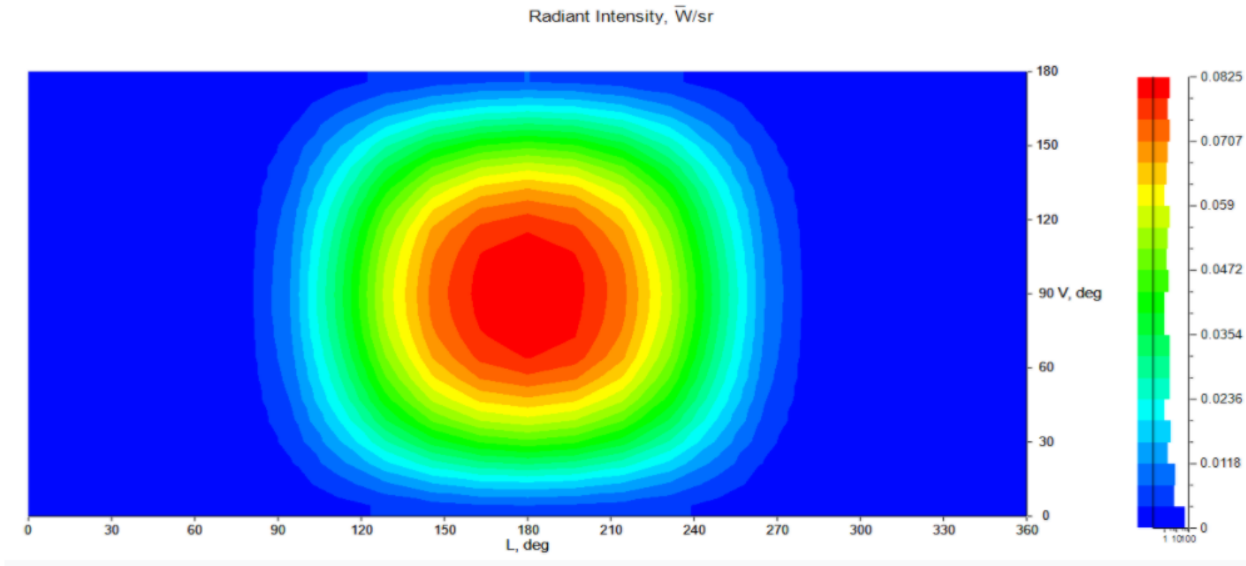


Figure 6.2

There are 2 problems with this diagram. First, it peaks at 82.5 mW/Str in the center, and our requirement is 150 mW/Str across the field of view. Second, the distribution is not even across the field of view. We require no more than 20% variance in intensity across the field. This diagram peaks at 82.5 mW/Str, and drops off to 35 mW/Str giving a 135% difference between the max and minimum. Our two main takeaways from PDR were that we would need more than 3 emitters to achieve our desired intensity output, and that we would have to angle the emitters outwards to illuminate our desired field of view.

This feedback led us to an improved design at CDR:

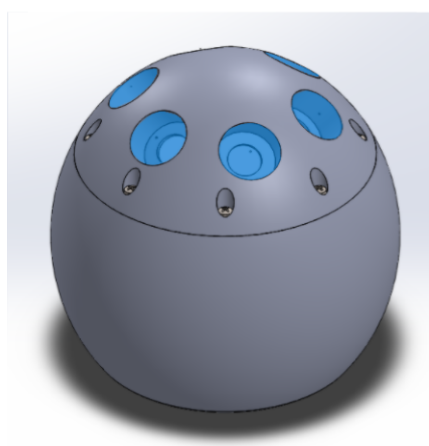


Figure 6.3

This design incorporates 6 emitters on top of the STrOBe as well as a curved surface on top of the device to angle the emitters outwards and improve field of view. Additionally, mirrored surfaces were added to the walls of each of the windowed emitter chambers. Mechanically, this design has a flat bottom that is made of a heavier material relative to the rest of the housing. This allows the STrOBe to roll until it lands on its flat side and remains still with the emitters facing upright. Here is the LightTools intensity diagram from CDR:

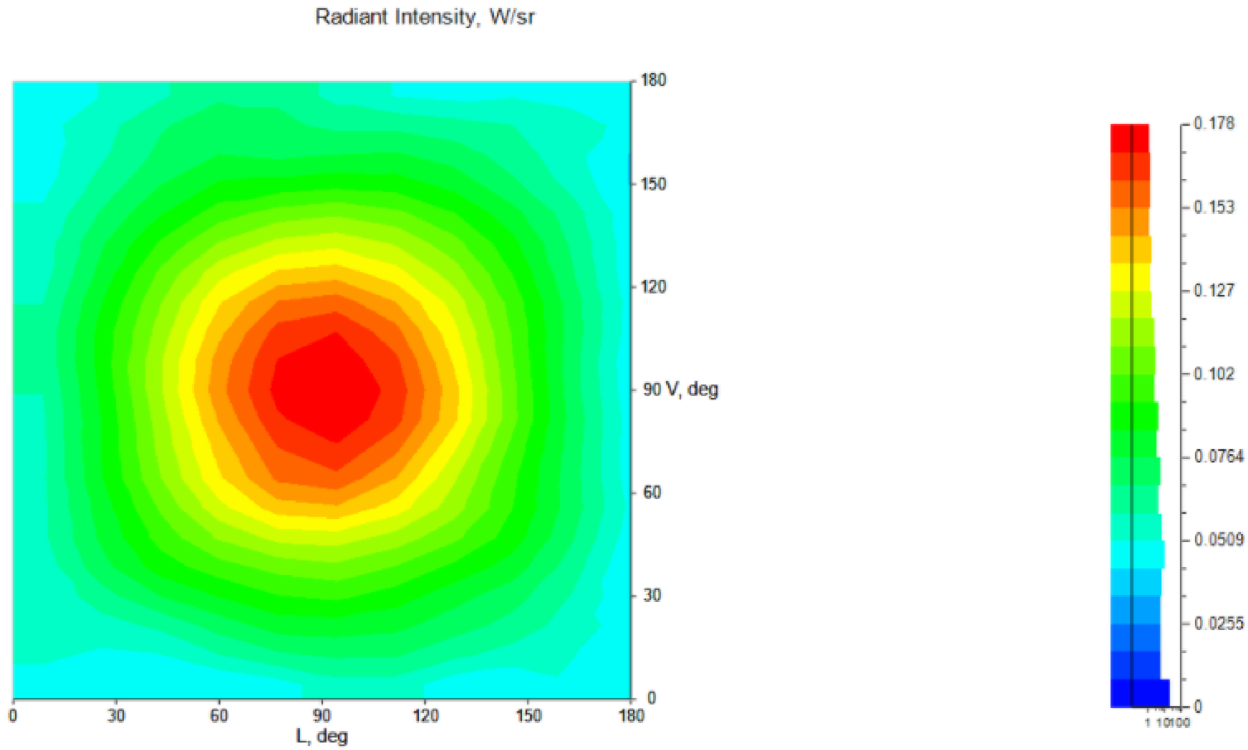


Figure 6.4

As we expected, doubling the amount of emitters roughly doubled the peak intensity in the center. Tilting the emitters away from pointing vertically upright also helped reduce the center spot size and transfer some intensity towards the outside of the field of view. This is an improvement, but only the areas that are orange or red fulfill the intensity requirements of 150 mW/Str. Improvements can still be made.

For CDR 2 multiple small adjustments were made to the interior design of the STrOBe. Optically, the walls around each emitter were switched from a mirrored surface to a diffuse white surface. This helps to further spread the intensity out from the center of the field of view. The walls were also changed from a straight vertical to a further outward angle to spread the light. This angle change also resulted in larger exterior windows which will release more light. Each window was also moved further downwards towards the outer perimeter of the dome to maximize field of view.

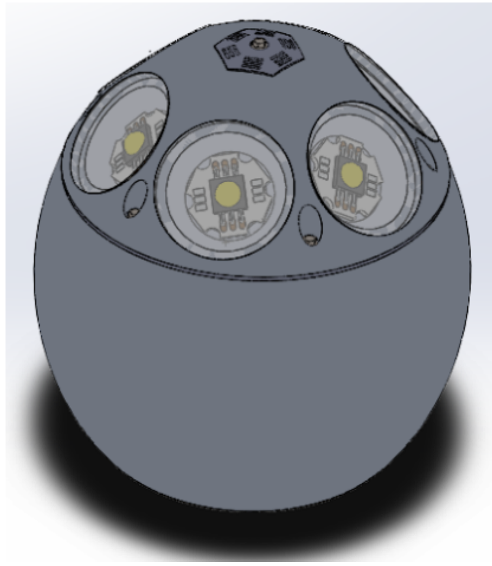


Figure 6.5

These changes resulted in our best intensity diagram so far. It has the smallest central spike in intensity, and is the closest to uniform over the 120 degree field of view. It still does not meet the requirements of 150 mW/str over the field of view.

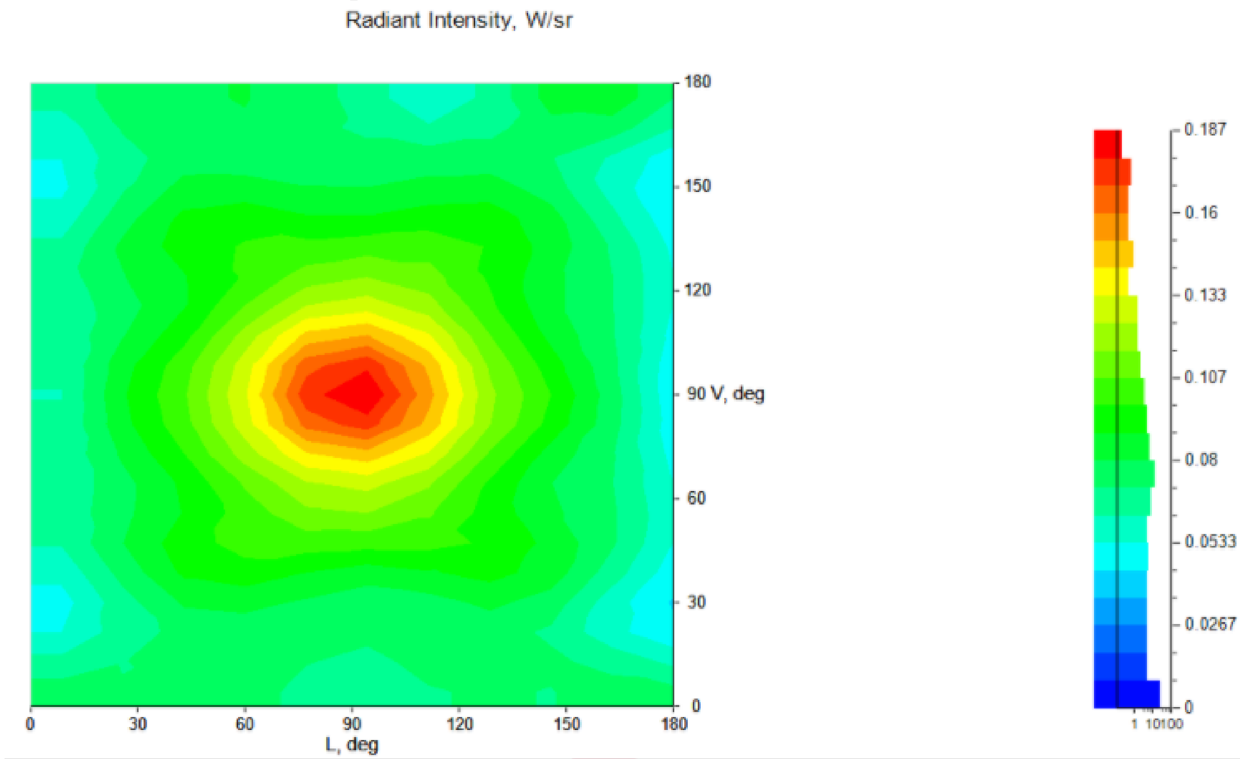


Figure 6.7

This model was the first to incorporate a heat sink design. The cylindrical heat sinks are screwed onto the central frame, the PCB boards are attached to the heat sinks using a thermal adhesive, and the emitters and wires are soldered onto the PCB.

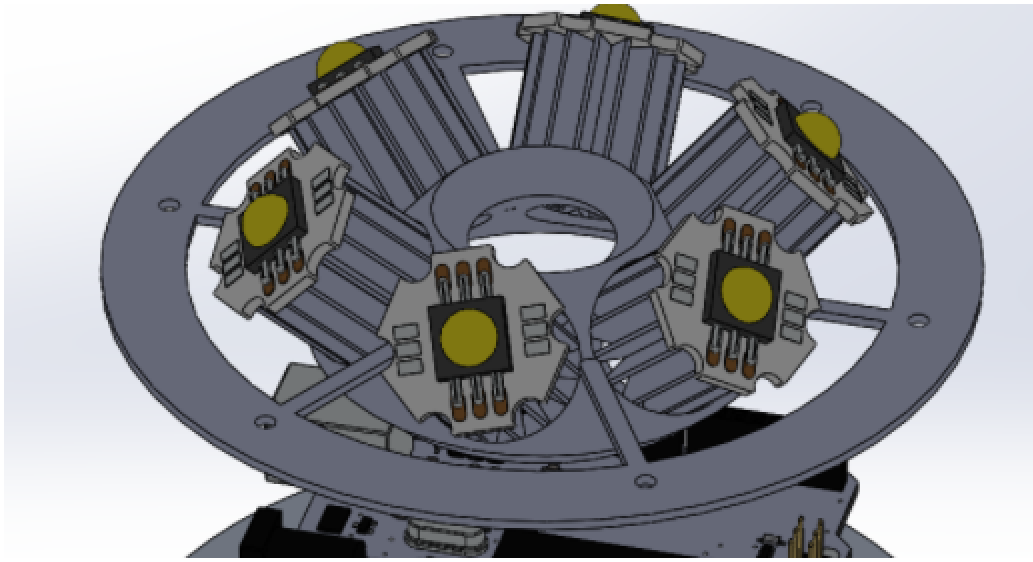


Figure 6.6

The cylindrical design was chosen to help the emitters dissipate heat effectively while also keeping in mind the spacing between the adjacent heat sinks and overall complexity of the design. The heat sinks will be attached to the inner frame that can be seen in Figure 6.6. The inner frame will have screws going through prefabricated holes in the heat sink to firmly secure these components.

The thermal adhesive that will be used to bond the PCB to the heatsink is Loctite 315. Loctite 315 is an acrylic adhesive paste that is used for bonding electrical components to heat sinks. Loctite 315 has a high thermal conductivity while maintaining a strong bond between the PCB and heat sink. This will eliminate the need for mechanical fasteners between PCB and heat sink interface.

Appendices:

Appendix A: HC05 Bluetooth Module Data Sheet

HC-05

-Bluetooth to Serial Port Module

Overview

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.
Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH(Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm. Hope it will simplify your overall design/development cycle.

Specifications

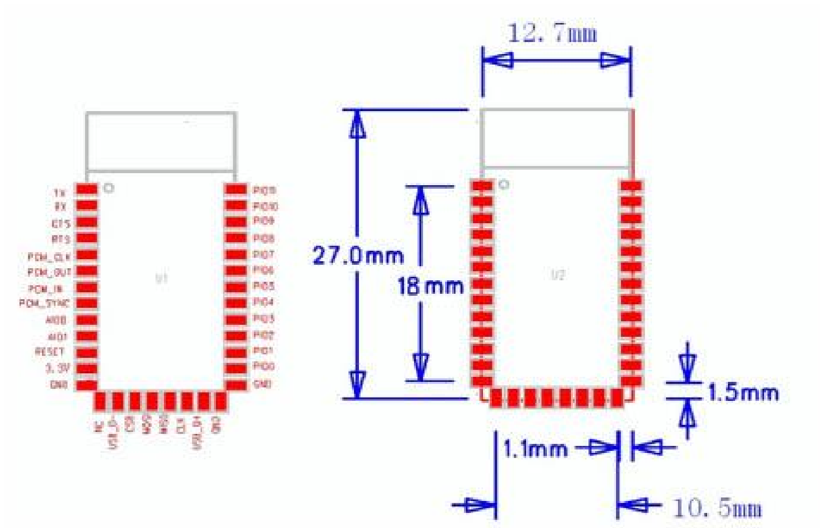
Hardware features

- Typical -80dBm sensitivity
- Up to +4dBm RF transmit power
- Low Power 1.8V Operation ,1.8 to 3.6V I/O
- PIO control
- UART interface with programmable baud rate
- With integrated antenna
- With edge connector

Software features

- Default Baud rate: 38400, Data bits:8, Stop bit:1,Parity:No parity, Data control: has. Supported baud rate: 9600,19200,38400,57600,115200,230400,460800.
- Given a rising pulse in PIO0, device will be disconnected.
- Status instruction port PIO1: low-disconnected, high-connected;
- PIO10 and PIO11 can be connected to red and blue led separately. When master and slave are paired, red and blue led blinks 1time/2s in interval, while disconnected only blue led blinks 2times/s.
- Auto-connect to the last device on power as default.
- Permit pairing device to connect as default.
- Auto-pairing PINCODE:"0000" as default
- Auto-reconnect in 30 min when disconnected as a result of beyond the range of connection.

Hardware



PIN Name	PIN #	Pad type	Description	Note
GND	13 21 22	VSS	Ground pot	
3.3 VCC	12	3.3V	Integrated 3.3V (+) supply with On-chip linear regulator output within 3.15-3.3V	
AIO0	9	Bi-Directional	Programmable input/output line	
AIO1	10	Bi-Directional	Programmable input/output line	
PIO0	23	Bi-Directional RX EN	Programmable input/output line, control output for LNA(if fitted)	
PIO1	24	Bi-Directional TX EN	Programmable input/output line, control output for PA(if fitted)	
PIO2	25	Bi-Directional	Programmable input/output line	
PIO3	26	Bi-Directional	Programmable input/output line	
PIO4	27	Bi-Directional	Programmable input/output line	
PIO5	28	Bi-Directional	Programmable input/output line	
PIO6	29	Bi-Directional	Programmable input/output line	
PIO7	30	Bi-Directional	Programmable input/output line	
PIO8	31	Bi-Directional	Programmable input/output line	
PIO9	32	Bi-Directional	Programmable input/output line	
PIO10	33	Bi-Directional	Programmable input/output line	
PIO11	34	Bi-Directional	Programmable input/output line	

RESETB	11	CMOS input with weak internal pull-up	Reset if low.input debouncede so must be low for >5MS to cause a reset	
UART_RTS	4	**CMOS output, tri-stable with weak internal pull-up**	**UART request to send, active low**	
UART_CTS	3	**CMOS input with weak internal pull-down**	**UART clear to send, active low**	
UART_RX	2	**CMOS input with weak internal pull-down**	**UART Data input**	
UART_TX	1	**CMOS output, Tri-stable with weak internal pull-up**	**UART Data output**	
SPI_MOSI	17	**CMOS input with weak internal pull-down**	**Serial peripheral interface data input**	
SPI_CSB	16	**CMOS input with weak internal pull-up**	**Chip select for serial peripheral interface, active low**	
SPI_CLK	19	**CMOS input with weak internal pull-down**	**Serial peripheral interface clock**	
SPI_MISO	18	**CMOS input with weak internal pull-down**	**Serial peripheral interface data Output**	
USB_-	15	**Bi-Directional**		

USB_+	20	Bi-Directional		
NC	14			
PCM_CLK	5	Bi-Directional	Synchronous PCM data clock	
PCM_OUT	6	CMOS output	Synchronous PCM data output	
PCM_IN	7	CMOS Input	Synchronous PCM data input	
PCM_SYNC	8	Bi-Directional	Synchronous PCM data strobe	

AT command Default:

How to set the mode to server (master):

1. Connect PIO11 to high level.
2. Power on, module into command state.
3. Using baud rate 38400, sent the "AT+ROLE=1\r\n" to module, with "OK\r\n" means setting successes.
4. Connect the PIO11 to low level, repower the module, the module work as server (master).

AT commands: (all end with \r\n)

1. Test command:

Command	Respond	Parameter
AT	OK	-

2. Reset

Command	Respond	Parameter
AT+RESET	OK	-

3. Get firmware version

Command	Respond	Parameter
AT+VERSION?	+VERSION:<Param> OK	Param : firmware version

Example:

AT+VERSION?\r\n
+VERSION:2.0-20100601
OK

4. Restore default

Command	Respond	Parameter
AT+ORGL	OK	-

Default state:

Slave mode, pin code :1234, device name: H-C-2010-06-01 ,Baud 38400bits/s.

5. Get module address

Command	Respond	Parameter
AT+ADDR?	+ADDR:<Param> OK	Param: address of Bluetooth module

Bluetooth address: NAP: UAP : LAP

Example:

AT+ADDR?\r\n

+ADDR:1234:56:abcdef

OK

6. Set/Check module name:

Command	Respond	Parameter
AT+NAME=<Param>	OK	Param: Bluetooth module name (Default :HC-05)
AT+NAME?	+NAME:<Param> OK (/FAIL)	

Example:

AT+NAME=HC-05\r\n   set the module name to "HC-05"

OK

AT+NAME=ITeadStudio\r\n

OK

AT+NAME?\r\n

+NAME: ITeadStudio

OK

7. Get the Bluetooth device name:

Command	Respond	Parameter
AT+RNAME?<Param1>	1. +NAME:<Param2> OK 2. FAIL	Param1,Param 2 : the address of Bluetooth device

Example: (Device address 00:02:72:od:22:24，name：ITead)

AT+RNAME? 0002，72，od2224\r\n

+RNAME:ITead

OK

8. Set/Check module mode:

Command	Respond	Parameter
AT+ROLE=<Param>	OK	Param: 0- Slave
AT+ ROLE?	+ROLE:<Param>	

	OK	1-Master 2-Slave-Loop

9. Set/Check device class

Command	Respond	Parameter
AT+CLASS=<Param>	OK	Param: Device Class
AT+ CLASS?	1. +CLASS:<Param> OK 2. FAIL	

10. Set/Check GIAC (General Inquire Access Code)

Command	Respond	Parameter
AT+IAC=<Param>	1.OK 2. FAIL	Param: GIAC (Default : 9e8b33)
AT+IAC	+IAC:<Param> OK	

Example:
AT+IAC=9e8b3f\r\n
OK
AT+IAC?\r\n
+IAC: 9e8b3f
OK

11. Set/Check – Query access patterns

Command	Respond	Parameter
AT+INQM=<Param>,<Param2>, <Param3>	1.OK 2. FAIL	Param: 0——inquiry_mode_standard 1——inquiry_mode_rssi Param2: Maximum number of Bluetooth devices to respond to Param3: Timeout (1-48 : 1.28s to 61.44s)
AT+ INQM?	+INQM： <Param>,<Param2>, <Param3> OK	

Example:
AT+INQM=1,9,48\r\n
OK
AT+INQM\r\n
+INQM:1, 9, 48
OK

12. Set/Check PIN code:

Command	Respond	Parameter
AT+PSWD=<Param>	OK	Param: PIN code (Default 1234)
AT+ PSWD?	+ PSWD ： <Param> OK	

13. Set/Check serial parameter:

Command	Respond	Parameter
AT+UART=<Param>,<Param2>,<Param3>	OK	Param1: Baud Param2: Stop bit Param3: Parity
AT+ UART?	+UART=<Param>,<Param2>,<Param3> OK	

Example:

AT+UART=115200， 1,2,\r\n

OK

AT+UART?

+UART:115200,1,2

OK

14. Set/Check connect mode:

Command	Respond	Parameter
AT+CMODE=<Param>	OK	Param: 0 - connect fixed address 1 - connect any address 2 - slave-Loop
AT+ CMODE?	+ CMODE:<Param> OK	

15. Set/Check fixed address:

Command	Respond	Parameter
AT+BIND=<Param>	OK	Param: Fixed address (Default 00:00:00:00:00:00)
AT+ BIND?	+ BIND:<Param> OK	

Example:

AT+BIND=1234， 56， abcdef\r\n

OK

AT+BIND?\r\n

+BIND:1234:56:abcdef

OK

16. Set/Check LED I/O

Command	Respond	Parameter
AT+POLAR=<Param1,<Param2>	OK	Param1: 0- PIO8 low drive LED 1- PIO8 high drive LED
AT+ POLAR?	+ POLAR=<Param1>,<Param2> OK	

		Param2: 0- PIO9 low drive LED 1- PIO9 high drive LED

17. Set PIO output

Command	Respond	Parameter
AT+PIO=<Param1>,<Param2>	OK	Param1: PIO number Param2: PIO level 0- low 1- high

Example:

1. PIO10 output high level

AT+PI0=10， 1\r\n

OK

18. Set/Check – scan parameter

Command	Respond	Parameter
AT+IPSCAN=<Param1>,<Param2>,<Param3>,<Param4>	OK	Param1: Query time interval Param2：Query duration Param3：Paging interval Param4：Call duration
AT+IPSCAN?	+IPSCAN:<Param1>,<Param2>,<Param3>,<Param4> OK	

Example:

AT+IPSCAN =1234,500,1200,250\r\n

OK

AT+IPSCAN?

+IPSCAN:1234,500,1200,250

19. Set/Check – SHIFF parameter

Command	Respond	Parameter
AT+SNIFF=<Param1>,<Param2>,<Param3>,<Param4>	OK	Param1: Max time Param2: Min time Param3: Retry time Param4: Time out
AT+ SNIFF?	+SNIFF:<Param1>,<Param2>,<Param3>,<Param4> OK	

20. Set/Check security mode

Command	Respond	Parameter
AT+SENM=<Param1>,<Param2>	1. OK 2. FAIL	Param1: 0——sec_mode0+off
AT+ SENM?	+ SENM:<Param1>,<Param2>	1——sec_mode1+non_se

	OK	cure 2——sec_mode2_service 3——sec_mode3_link 4——sec_mode_unknow n Param2: 0——hci_enc_mode_off 1——hci_enc_mode_pt_t o_pt 2——hci_enc_mode_pt_t o_pt_and_bcast

21. Delete Authenticated Device

Command	Respond	Parameter
AT+PMSAD=<Param>	OK	Param: Authenticated Device Address

Example:
AT+PMSAD =1234,56,abcdef\r\n
OK

22. Delete All Authenticated Device

Command	Respond	Parameter
AT+ RMAAD	OK	-

23. Search Authenticated Device

Command	Respond	Parameter
AT+FSAD=<Param>	1. OK 2. FAIL	Param: Device address

24. Get Authenticated Device Count

Command	Respond	Parameter
AT+ADCN?	+ADCN：<Param> OK	Param: Device Count

25. Most Recently Used Authenticated Device

Command	Respond	Parameter
AT+MRAD?	+ MRAD：<Param> OK	Param: Recently Authenticated Device Address

26. Get the module working state

Command	Respond	Parameter

AT+ STATE?	+ STATE：<Param> OK	Param: “INITIALIZED” “READY” “PAIRABLE” “PAIRED” “INQUIRING” “CONNECTING” “CONNECTED” “DISCONNECTED” “NUKNOW”

27. Initialize the SPP profile lib

Command	Respond	Parameter
AT+INIT	1. OK 2. FAIL	-

28. Inquiry Bluetooth Device

Command	Respond	Parameter
AT+INQ	+INQ: <Param1>, <Param2>, <Param3> .... OK	Param1：Address Param2：Device Class Param3 ： RSSI Signal strength

Example:

AT+INIT\r\n
OK
AT+IAC=9e8b33\r\n
OK
AT+CLASS=0\r\n
AT+INQM=1,9,48\r\n
At+INQ\r\n
+INQ:2:72:D2224,3E0104,FFBC
+INQ:1234:56:0,1F1F,FFC1
+INQ:1234:56:0,1F1F,FFC0
+INQ:1234:56:0,1F1F,FFC1
+INQ:2:72:D2224,3F0104,FFAD
+INQ:1234:56:0,1F1F,FFBE
+INQ:1234:56:0,1F1F,FFC2
+INQ:1234:56:0,1F1F,FFBE
+INQ:2:72:D2224,3F0104,FFBC
OK

28. Cancel Inquiring Bluetooth Device

Command	Respond	Parameter
AT+ INQC	OK	-

29. Equipment Matching

Command	Respond	Parameter
AT+PAIR=<Param1>,<Param2>	1. OK 2. FAIL	Param1：Device Address Param2：Time out

30. Connect Device

Command	Respond	Parameter
AT+LINK=<Param>	1. OK 2. FAIL	Param：Device Address

Example:

AT+FSAD=1234,56,abcdef\r\n

OK

AT+LINK=1234,56,abcdef\r\n

OK

31. Disconnect

Command	Respond	Parameter
AT+DISC	1. +DISC:SUCCESS OK 2. +DISC:LINK_LOSS OK 3. +DISC:NO_SLC OK 4. +DISC:TIMEOUT OK 5. +DISC:ERROR OK	Param：Device Address

32. Energy-saving mode

Command	Respond	Parameter
AT+ENSNIFF=<Param>	OK	Param：Device Address

33. Exerts Energy-saving mode

Command	Respond	Parameter
AT+ EXSNIFF =<Param>	OK	Param：Device Address

Revision History

Rev.	Description	Release date
v1.0	Initial version	7/18/2010

Appendix B: LM317 Current Regulator Data Sheet

LM317 3-Terminal Adjustable Regulator

1 Features

- Output voltage range adjustable from 1.25 V to 37 V
- Output current greater than 1.5 A
- Internal short-circuit current limiting
- Thermal overload protection
- Output safe-area compensation

2 Applications

- ATCA solutions
- DLP: 3D biometrics, hyperspectral imaging, optical networking, and spectroscopy
- DVR and DVS
- Desktop PCs
- Digital signage and still cameras
- ECG electrocardiograms
- EV HEV chargers: levels 1, 2, and 3
- Electronic shelf labels
- Energy harvesting
- Ethernet switches
- Femto base stations
- Fingerprint and iris biometrics
- HVAC: heating, ventilating, and air conditioning
- High-speed data acquisition and generation
- Hydraulic valves
- IP phones: wired and wireless
- Intelligent occupancy sensing
- Motor controls: brushed DC, brushless DC, low-voltage, permanent magnet, and stepper motors
- Point-to-point microwave backhauls
- Power bank solutions
- Power line communication modems
- Power over ethernet (PoE)
- Power quality meters
- Power substation controls
- Private branch exchanges (PBX)
- Programmable logic controllers
- RFID readers
- Refrigerators
- Signal or waveform generators
- Software-defined radios (SDR)
- Washing machines: high-end and low-end
- X-rays: baggage scanners, medical, and dental

3 Description

The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying more than 1.5 A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM317DCY	SOT-223 (4)	6.50 mm × 3.50 mm
LM317KCS	TO-220 (3)	10.16 mm × 9.15 mm
LM317KCT	TO-220 (3)	10.16 mm × 8.59 mm
LM317KTT	TO-263 (3)	10.16 mm × 9.01 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Battery-Charger Circuit

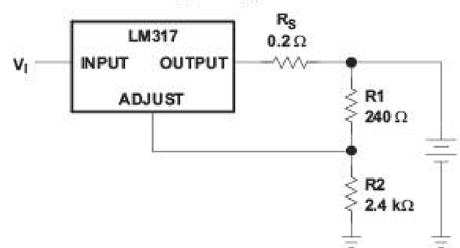


Table of Contents

4 Revision History

Changes from Revision X (September 2016) to Revision Y	Page
• Added *Device Comparison Table*	3
• Changed V_{IN} to I_{OUT} in *Load Transient Response* figures	7
• Added missing caption to second y-axis in second *Load Transient Response* figure	7
• Changed V_{OUT} and output impedance equations in *Battery-Charger Circuit* section	14

Changes from Revision W (January 2015) to Revision X	Page
• Changed body size dimensions for KCS TO-220 Package on *Device information* table	1
• Changed body size dimensions for KTT TO-263 Package on *Device information* table	1
• Changed V_O Output Voltage max value from 7 to 37 on *Recommended Operating Conditions* table	5
• Added min value to I_O Output Current in *Recommended Operating Conditions* table	5
• Changed values in the Thermal Information table to align with JEDEC standards	5
• Added KCT package data to *Thermal Information* table	5
• Deleted Section 9.3.6 "Adjusting Multiple On-Card Regulators with a Single Control"	14
• Updated Adjustsable 4-A Regulator Circuit graphic	16
• Added *Receiving Notification of Documentation Updates* section and *Community Resources* section	19

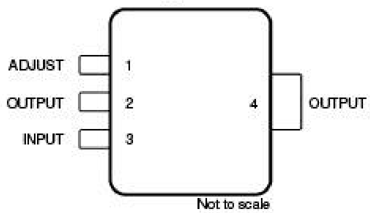
Changes from Revision V (February 2013) to Revision W	Page
• Added *Applications*, *Device Information* table, *Pin Functions* table, *ESD Ratings* table, *Thermal Information* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section.	1
• Deleted *Ordering Information* table.	1

5 Device Comparison Table

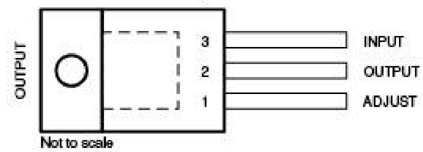
I_{OUT}	PARAMETER	LM317	LM317-N	LM317A	LM317HV	UNIT
1.5 A	Input voltage range	4.25 - 40	4.25 - 40	4.25 - 40	4.25 - 60	V
	Load regulation accuracy	1.5	1.5	1	1.5	%
	PSRR (120 Hz)	64	80	80	65	dB
	Recommended operating temperature	0 to 125	0 to 125	–40 to 125	0 to 125	°C
	TO-220 (NDE) T_{JA}	23.5	23.2	23.3	23	°C/W
	TO-200 (KCT) T_{JA}	37.9	N/A	N/A		°C/W
	TO-252 T_{JA}	N/A	54	54		°C/W
	TO-263 T_{JA}	38	41	N/A		°C/W
	SOT-223 T_{JA}	66.8	59.6	59.6		°C/W
	TO-92 T_{JA}	N/A	186	186		°C/W
0.5 A		LM317M				
	Input voltage range	3.75 - 40				V
	Load regulation accuracy	1.5				%
	PSRR (120 Hz)	80				dB
	Recommended operating temperature	-40 - 125				°C
	SOT-223 T_{JA}	60.2				°C/W
	TO-252 T_{JA}	56.9				°C/W
0.1 A		LM317L	LM317L-N			
	Input voltage range	3.75 - 40	4.25 - 40			V
	Load regulation accuracy	1	1.5			%
	PSRR (120 Hz)	62	80			dB
	Recommended operating temperature	–40 to 125	–40 to 125			°C
	SOT-23 T_{JA}	167.8	N/A			°C/W
	SO-8 T_{JA}	N/A	165			°C/W
	DSBGA T_{JA}	N/A	290			°C/W
	TO-92 T_{JA}	N/A	180			°C/W

6 Pin Configuration and Functions

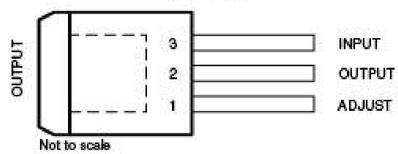
DCY Package
3-Pin SOT-223
Top View



KCS or KCT Package
3-Pin TO-220
Top View



KTT Package
3-Pin TO-263
Top View



Pin Functions

PIN			I/O	DESCRIPTION
NAME	TO-263, TO-220	SOT-223		
ADJUST	1	1	I	Output voltage adjustment pin. Connect to a resistor divider to set V_O
INPUT	3	3	I	Supply input pin
OUTPUT	2	2, 4	O	Voltage output pin

7 Specifications

7.1 Absolute Maximum Ratings

over virtual junction temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
$V_I - V_O$	Input-to-output differential voltage		40	V
T_J	Operating virtual junction temperature		150	°C
	Lead temperature 1,6 mm (1/16 in) from case for 10 s		260	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

7.2 ESD Ratings

			MAX	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	2500	V
		Charged device model (CDM), per JEDEC specification JESD22-C101(2)	1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

		MIN	MAX	UNIT
V_O	Output voltage	1.25	37	V
$V_I - V_O$	Input-to-output differential voltage	3	40	V
I_O	Output current	0.01	1.5	A
T_J	Operating virtual junction temperature	0	125	°C

7.4 Thermal Information

THERMAL METRIC(1)		LM317 DCY (SOT-223) 4 PINS	LM317 KCS (TO-220) 3 PINS	LM317 KCT (TO-220) 3 PINS	LM317 KTT (TO-263) 3 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	66.8	23.5	37.9	38.0	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	43.2	15.9	51.1	36.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	16.9	7.9	23.2	18.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	3.6	3.0	13.0	6.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	16.8	7.8	22.8	17.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	NA	0.1	4.2	1.1	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC package thermal metrics* application report.

7.5 Electrical Characteristics

over recommended ranges of operating virtual junction temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS[1]			MIN	TYP	MAX	UNIT
Line regulation[2]	$V_I - V_O$ = 3 V to 40 V		T_J = 25°C		0.01	0.04	%/V
			T_J = 0°C to 125°C		0.02	0.07	
Load regulation	I_O = 10 mA to 1500 mA	C_{ADJ}[3] = 10 µF, T_J = 25°C	$V_O \le 5$ V			25	mV
			$V_O \ge 5$ V		0.1	0.5	$\%V_O$
		T_J = 0°C to 125°C	$V_O \le 5$ V		20	70	mV
			$V_O \ge 5$ V		0.3	1.5	$\%V_O$
Thermal regulation	20-ms pulse,	T_J = 25°C			0.03	0.07	$\%V_O$/W
ADJUST terminal current					50	100	µA
Change in ADJUST terminal current	$V_I - V_O$ = 2.5 V to 40 V, $P_D \le 20$ W, I_O = 10 mA to 1500 mA				0.2	5	µA
Reference voltage	$V_I - V_O$ = 3 V to 40 V, $P_D \le 20$ W, I_O = 10 mA to 1500 mA			1.2	1.25	1.3	V
Output-voltage temperature stability	T_J = 0°C to 125°C				0.7		$\%V_O$
Minimum load current to maintain regulation	$V_I - V_O$ = 40 V				3.5	10	mA
Maximum output current	$V_I - V_O \le 15$ V,	$P_D < P_{MAX}$[4]		1.5	2.2		A
	$V_I - V_O \le 40$ V,	$P_D < P_{MAX}$[4],	T_J = 25°C	0.15	0.4		
RMS output noise voltage (% of V_O)	f = 10 Hz to 10 kHz,	T_J = 25°C			0.003		$\%V_O$
Ripple rejection	V_O = 10 V,	f = 120 Hz	C_{ADJ} = 0 µF[3]		57		dB
			C_{ADJ} = 10 µF[3]	62	64		
Long-term stability	T_J = 25°C				0.3	1	%/1k hr

(1) Unless otherwise noted, the following test conditions apply: $|V_I - V_O|$ = 5 V and I_{OMAX} = 1.5 A, T_J = 0°C to 125°C. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible.
(2) Line regulation is expressed here as the percentage change in output voltage per 1-V change at the input.
(3) C_{ADJ} is connected between the ADJUST terminal and GND.
(4) Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A) / \theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

7.6 Typical Characteristics

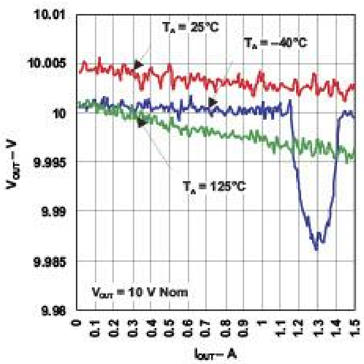


Figure 1. Load Regulation

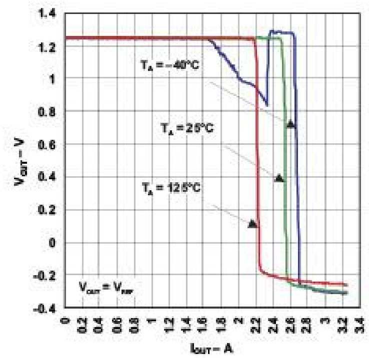


Figure 2. Load Regulation

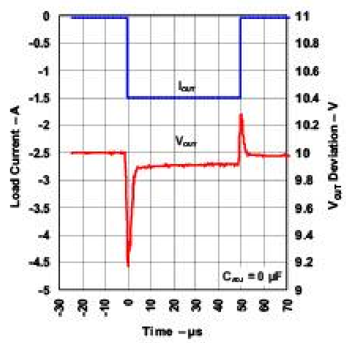


Figure 3. Load Transient Response

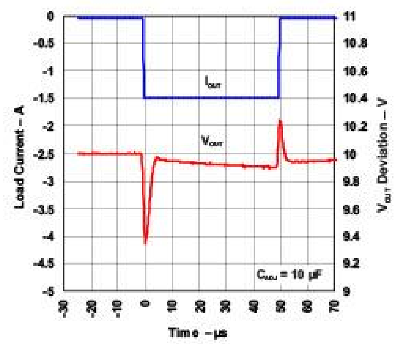


Figure 4. Load Transient Response

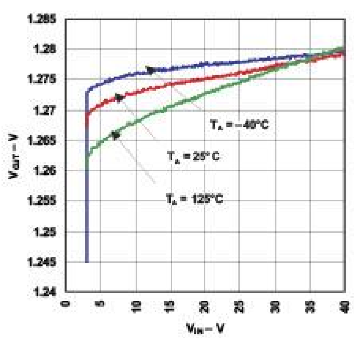


Figure 5. Line Regulation

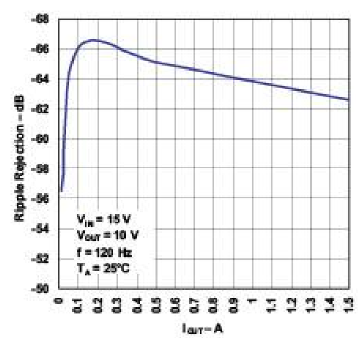


Figure 6. Ripple Rejection vs Output Current

Typical Characteristics (continued)

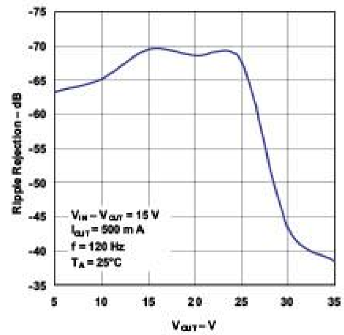


Figure 7. Ripple Rejection vs Output Voltage

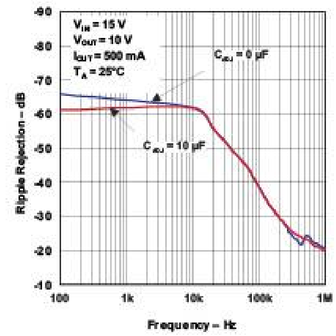


Figure 8. Ripple Rejection vs Frequency

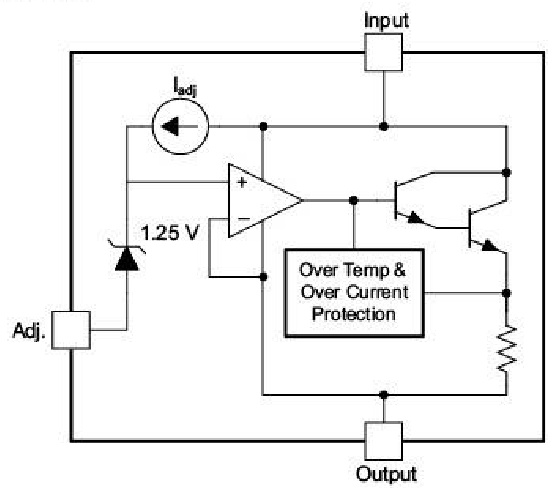
8 Detailed Description

8.1 Overview

The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying up to 1.5 A over an output-voltage range of 1.25 V to 37 V. It requires only two external resistors to set the output voltage. The device features a typical line regulation of 0.01% and typical load regulation of 0.1%. It includes current limiting, thermal overload protection, and safe operating area protection. Overload protection remains functional even if the ADJUST terminal is disconnected.

The LM317 device is versatile in its applications, including uses in programmable output regulation and local on-card regulation. Or, by connecting a fixed resistor between the ADJUST and OUTPUT terminals, the LM317 device can function as a precision current regulator. An optional output capacitor can be added to improve transient response. The ADJUST terminal can be bypassed to achieve very high ripple-rejection ratios, which are difficult to achieve with standard three-terminal regulators.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 NPN Darlington Output Drive

NPN Darlington output topology provides naturally low output impedance and an output capacitor is optional. 3-V headroom is recommended ($V_I - V_O$) to support maximum current and lowest temperature.

8.3.2 Overload Block

Over-current and over-temperature shutdown protects the device against overload or damage from operating in excessive heat.

8.3.3 Programmable Feedback

Op amp with 1.25-V offset input at the ADJUST terminal provides easy output voltage or current (not both) programming. For current regulation applications, a single resistor whose resistance value is 1.25 V/I_O and power rating is greater than $(1.25\ V)^2/R$ should be used. For voltage regulation applications, two resistors set the output voltage.

8.4 Device Functional Modes

8.4.1 Normal Operation

The device OUTPUT pin will source current necessary to make OUTPUT pin 1.25 V greater than ADJUST terminal to provide output regulation.

8.4.2 Operation With Low Input Voltage

The device requires up to 3-V headroom (V_I – V_O) to operate in regulation. The device may drop out and OUTPUT voltage will be INPUT voltage minus drop out voltage with less headroom.

8.4.3 Operation at Light Loads

The device passes its bias current to the OUTPUT pin. The load or feedback must consume this minimum current for regulation or the output may be too high. See the *Electrical Characteristics* table for the minimum load current needed to maintain regulation.

8.4.4 Operation In Self Protection

When an overload occurs the device shuts down Darlington NPN output stage or reduces the output current to prevent device damage. The device will automatically reset from the overload. The output may be reduced or alternate between on and off until the overload is removed.

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

The flexibility of the LM317 allows it to be configured to take on many different functions in DC power applications.

9.2 Typical Application

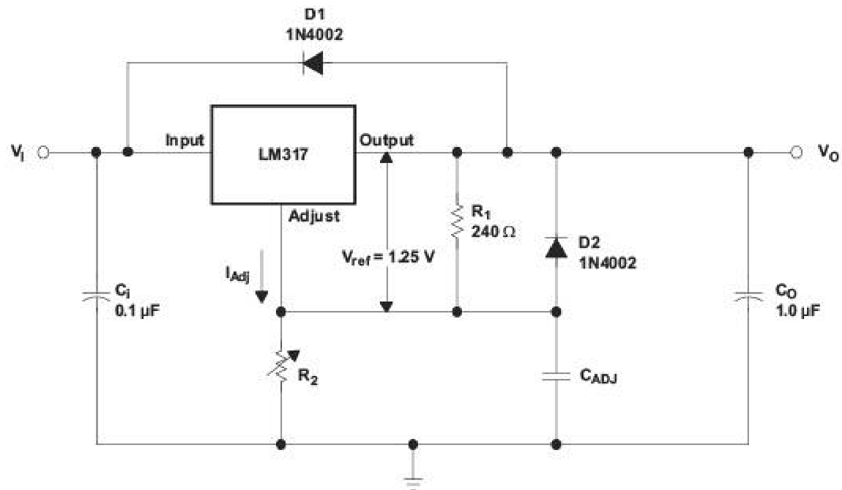


Figure 9. Adjustable Voltage Regulator

9.2.1 Design Requirements

- R1 and R2 are required to set the output voltage.
- C_{ADJ} is recommended to improve ripple rejection. It prevents amplification of the ripple as the output voltage is adjusted higher.
- C_i is recommended, particularly if the regulator is not in close proximity to the power-supply filter capacitors. A 0.1-µF or 1-µF ceramic or tantalum capacitor provides sufficient bypassing for most applications, especially when adjustment and output capacitors are used.
- C_O improves transient response, but is not needed for stability.
- Protection diode D2 is recommended if C_{ADJ} is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator.
- Protection diode D1 is recommended if C_O is used. The diode provides a low-impedance discharge path to prevent the capacitor from discharging into the output of the regulator.

9.2.2 Detailed Design Procedure

V_O is calculated as shown in Equation 1. I_{ADJ} is typically 50 µA and negligible in most applications.

$$V_O = V_{REF}\,(1 + R2 / R1) + (I_{ADJ} \times R2) \quad (1)$$

Typical Application (continued)

9.2.3 Application Curves

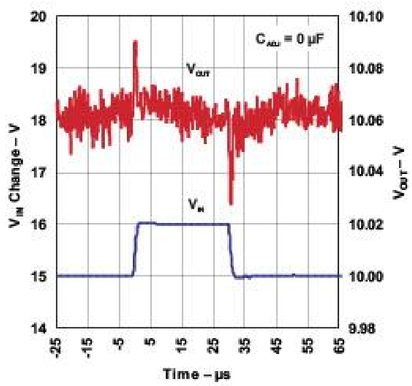


Figure 10. Line-Transient Response

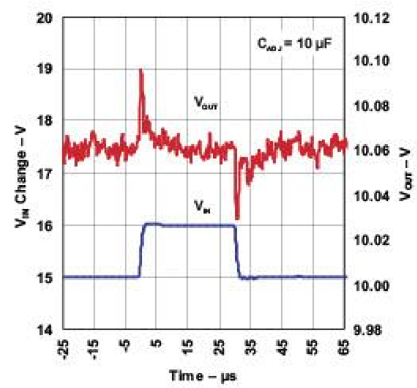


Figure 11. Line-Transient Response

9.3 System Examples

9.3.1 0-V to 30-V Regulator Circuit

Here, the voltage is determined by $V_{OUT} = V_{REF}\left(1 + \frac{R_2 + R_3}{R_1}\right) - 10\,V$

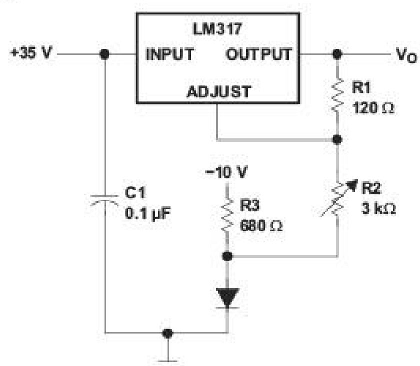


Figure 12. 0-V to 30-V Regulator Circuit

System Examples (continued)

9.3.2 Adjustable Regulator Circuit With Improved Ripple Rejection

C2 helps to stabilize the voltage at the adjustment pin, which helps reject noise. Diode D1 exists to discharge C2 in case the output is shorted to ground.

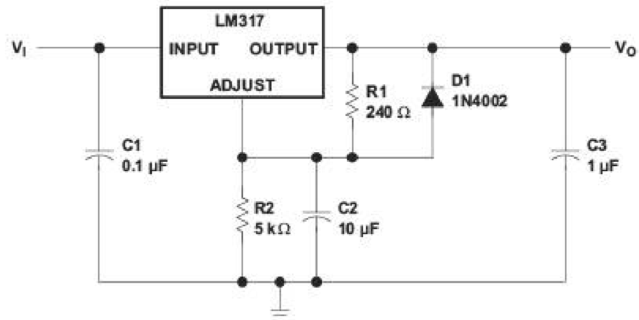


Figure 13. Adjustable Regulator Circuit with Improved Ripple Rejection

9.3.3 Precision Current-Limiter Circuit

This application limits the output current to the I_{LIMIT} in the diagram.

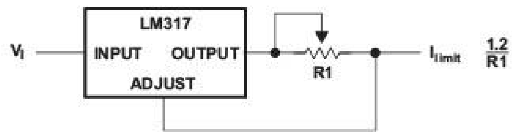


Figure 14. Precision Current-Limiter Circuit

9.3.4 Tracking Preregulator Circuit

This application keeps a constant voltage across the second LM317 in the circuit.

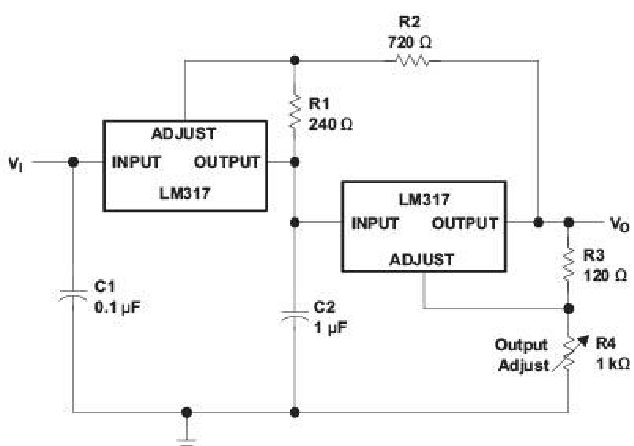


Figure 15. Tracking Preregulator Circuit

System Examples (continued)

9.3.5 1.25-V to 20-V Regulator Circuit With Minimum Program Current

Because the value of V_{REF} is constant, the value of R1 determines the amount of current that flows through R1 and R2. The size of R2 determines the IR drop from ADJUSTMENT to GND. Higher values of R2 translate to higher V_{OUT}.

$$V_{OUT} = V_{REF}\left(1 + \frac{R_2 + R_3}{R_1}\right) - 10\,V \tag{2}$$

$$(R1 + R2)\min = V_{Olreg(min)} \tag{3}$$

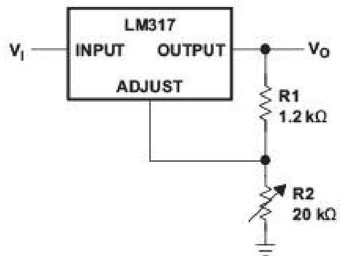


Figure 16. 1.25-V to 20-V Regulator Circuit With Minimum Program Current

9.3.6 Battery-Charger Circuit

The series resistor limits the current output of the LM317, minimizing damage to the battery cell.

$$V_{OUT} = 1.25\,V \times \left(1 + \frac{R2}{R1}\right) \tag{4}$$

$$I_{OUT}(short) = \frac{1.25V}{RS} \tag{5}$$

$$\text{Output Impedance} = RS \times \left(1 + \frac{R2}{R1}\right) \tag{6}$$

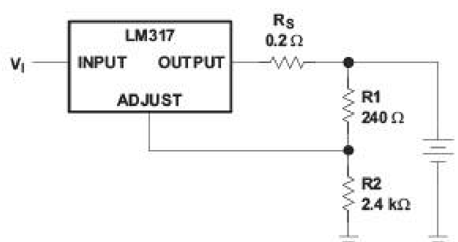


Figure 17. Battery-Charger Circuit

System Examples (continued)

9.3.7 50-mA Constant-Current Battery-Charger Circuit

The current limit operation mode can be used to trickle charge a battery at a fixed current. I_{CHG} = 1.25 V ÷ 24 Ω. V_I should be greater than V_{BAT} + 4.25 V. (1.25 V [V_{REF}] + 3 V [headroom])

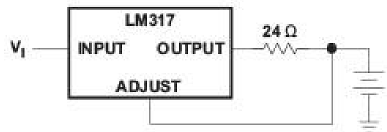


Figure 18. 50-mA Constant-Current Battery-Charger Circuit

9.3.8 Slow Turn-On 15-V Regulator Circuit

The capacitor C1, in combination with the PNP transistor, helps the circuit to slowly start supplying voltage. In the beginning, the capacitor is not charged. Therefore output voltage starts at V_{C1}+ V_{BE} + 1.25 V = 0 V + 0.65 V + 1.25 V = 1.9 V. As the capacitor voltage rises, V_{OUT} rises at the same rate. When the output voltage reaches the value determined by R1 and R2, the PNP will be turned off.

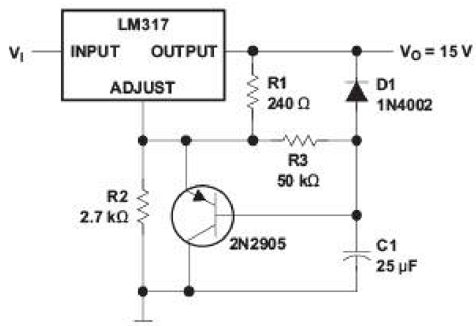


Figure 19. Slow Turn-On 15-V Regulator Circuit

9.3.9 AC Voltage-Regulator Circuit

These two LM317s can regulate both the positive and negative swings of a sinusoidal AC input.

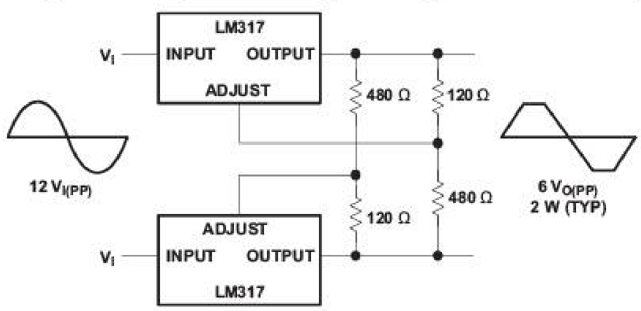


Figure 20. AC Voltage-Regulator Circuit

System Examples (continued)

9.3.10 Current-Limited 6-V Charger Circuit

As the charge current increases, the voltage at the bottom resistor increases until the NPN starts sinking current from the adjustment pin. The voltage at the adjustment pin drops, and consequently the output voltage decreases until the NPN stops conducting.

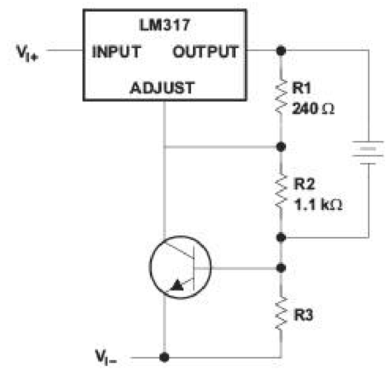


Figure 21. Current-Limited 6-V Charger Circuit

9.3.11 Adjustable 4-A Regulator Circuit

This application keeps the output current at 4 A while having the ability to adjust the output voltage using the adjustable (1.5 kΩ in schematic) resistor.

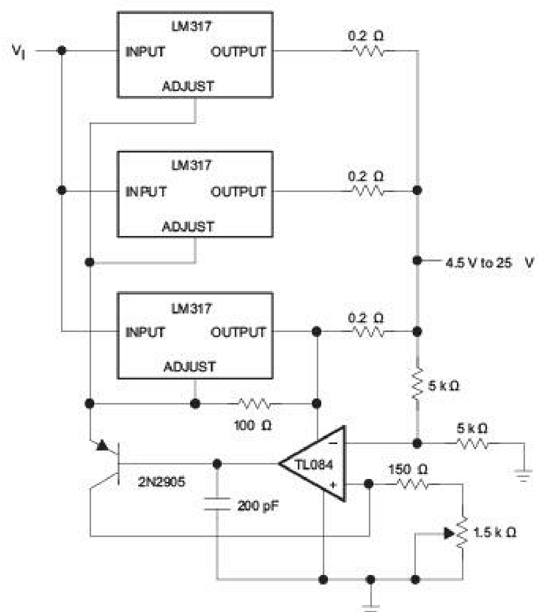


Figure 22. Adjustable 4-A Regulator Circuit

System Examples (continued)

9.3.12 High-Current Adjustable Regulator Circuit

The NPNs at the top of the schematic allow higher currents at V_{OUT} than the LM317 can provide, while still keeping the output voltage at levels determined by the adjustment pin resistor divider of the LM317.

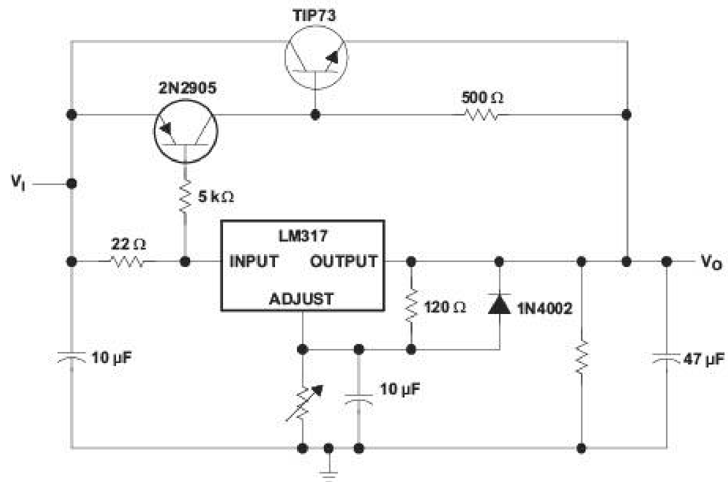


Figure 23. High-Current Adjustable Regulator Circuit

10 Power Supply Recommendations

The LM317 is designed to operate from an input voltage supply range between 1.25 V to 37 V greater than the output voltage. If the device is more than six inches from the input filter capacitors, an input bypass capacitor, 0.1 µF or greater, of any type is needed for stability.

11 Layout

11.1 Layout Guidelines

- TI recommends that the input terminal be bypassed to ground with a bypass capacitor.
- The optimum placement is closest to the input terminal of the device and the system GND. Take care to minimize the loop area formed by the bypass-capacitor connection, the input terminal, and the system GND.
- For operation at full rated load, TI recommends to use wide trace lengths to eliminate I × R drop and heat dissipation.

11.2 Layout Example

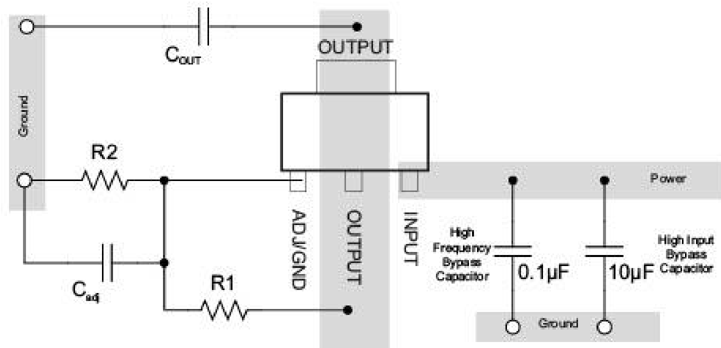


Figure 24. Layout Example

12 Device and Documentation Support

12.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

12.2 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

12.3 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.4 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

12.5 Glossary

SLYZ022 — *TI Glossary*.
This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM317DCY	ACTIVE	SOT-223	DCY	4	80	RoHS & Green	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317DCYG3	ACTIVE	SOT-223	DCY	4	80	RoHS & Green	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317DCYR	ACTIVE	SOT-223	DCY	4	2500	RoHS & Green	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317DCYRG3	ACTIVE	SOT-223	DCY	4	2500	RoHS & Green	SN	Level-2-260C-1 YEAR	0 to 125	L3	Samples
LM317KCS	ACTIVE	TO-220	KCS	3	50	RoHS & Green	SN	N / A for Pkg Type	0 to 125	LM317	Samples
LM317KCSE3	ACTIVE	TO-220	KCS	3	50	RoHS & Green	SN	N / A for Pkg Type	0 to 125	LM317	Samples
LM317KCT	ACTIVE	TO-220	KCT	3	50	RoHS & Non-Green	SN	N / A for Pkg Type	0 to 125	LM317	Samples
LM317KTTR	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS & Green	SN	Level-3-245C-168 HR	0 to 125	LM317	Samples
LM317KTTRG3	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS & Green	SN	Level-3-245C-168 HR	0 to 125	LM317	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

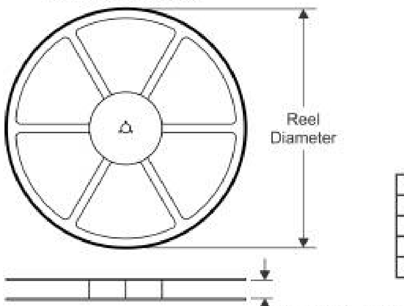
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

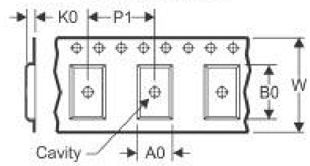
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

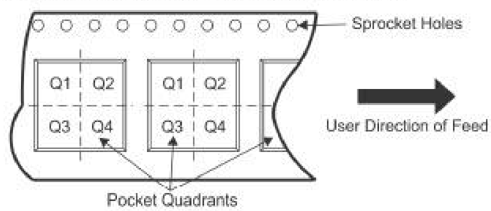


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

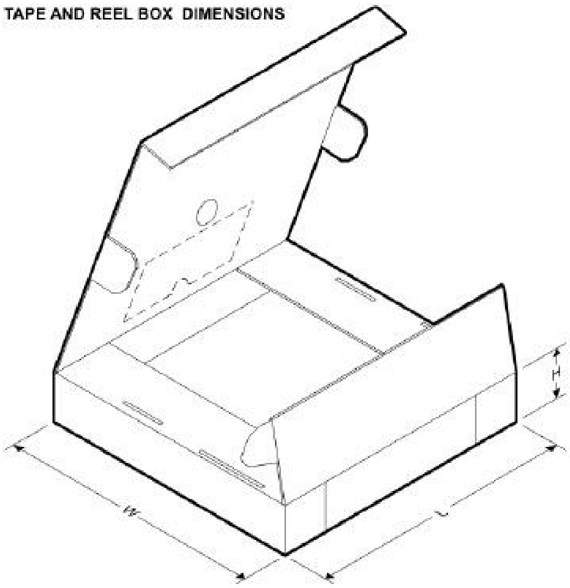
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM317DCYR	SOT-223	DCY	4	2500	330.0	12.4	7.05	7.4	1.9	8.0	12.0	Q3
LM317DCYR	SOT-223	DCY	4	2500	330.0	12.4	6.55	7.25	1.9	8.0	12.0	Q3
LM317DCYR	SOT-223	DCY	4	2500	330.0	12.4	7.0	7.42	2.0	8.0	12.0	Q3
LM317KTTR	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.8	16.1	4.9	16.0	24.0	Q2

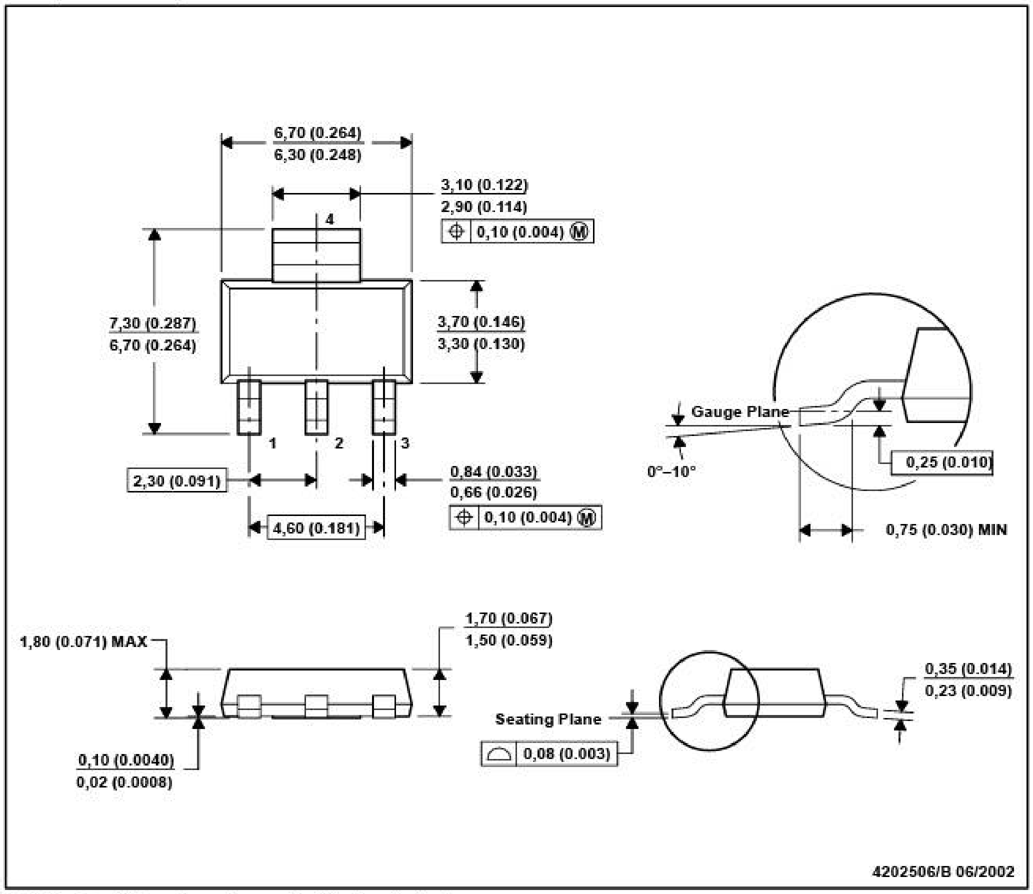
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

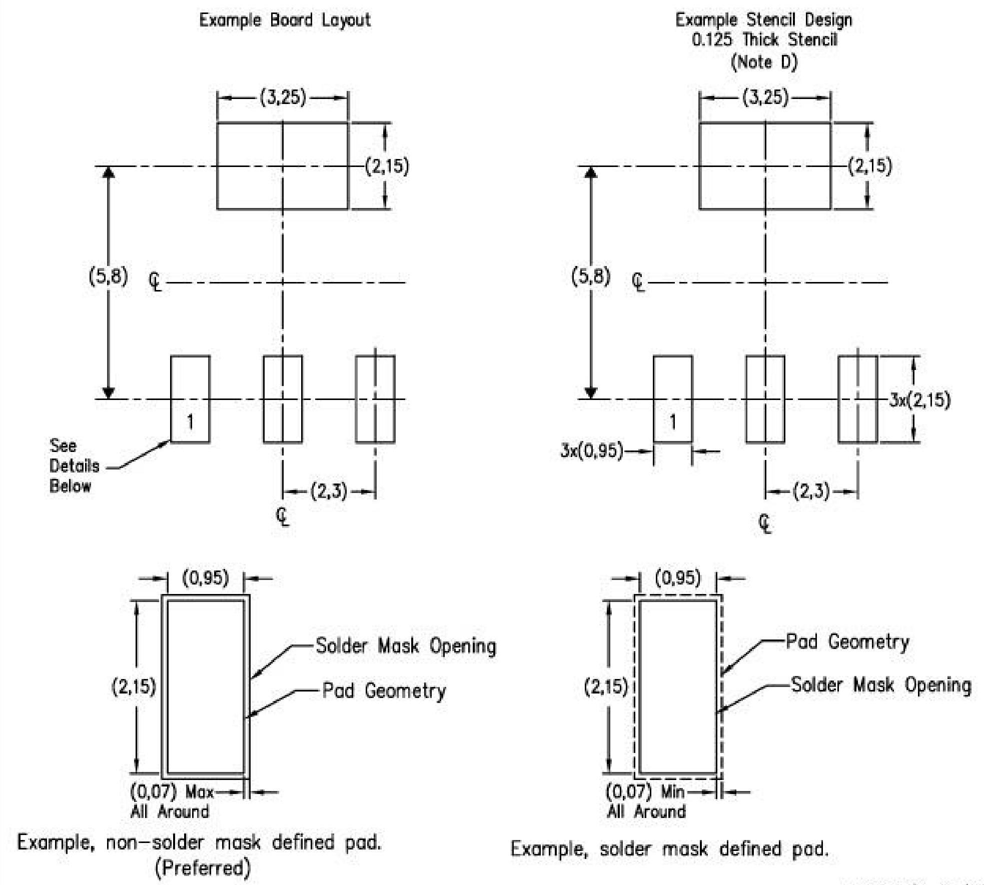
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM317DCYR	SOT-223	DCY	4	2500	340.0	340.0	38.0
LM317DCYR	SOT-223	DCY	4	2500	336.0	336.0	48.0
LM317DCYR	SOT-223	DCY	4	2500	350.0	334.0	47.0
LM317KTTR	DDPAK/TO-263	KTT	3	500	350.0	334.0	47.0

DCY (R-PDSO-G4) **PLASTIC SMALL-OUTLINE**



NOTES: A. All linear dimensions are in millimeters (inches).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC TO-261 Variation AA.

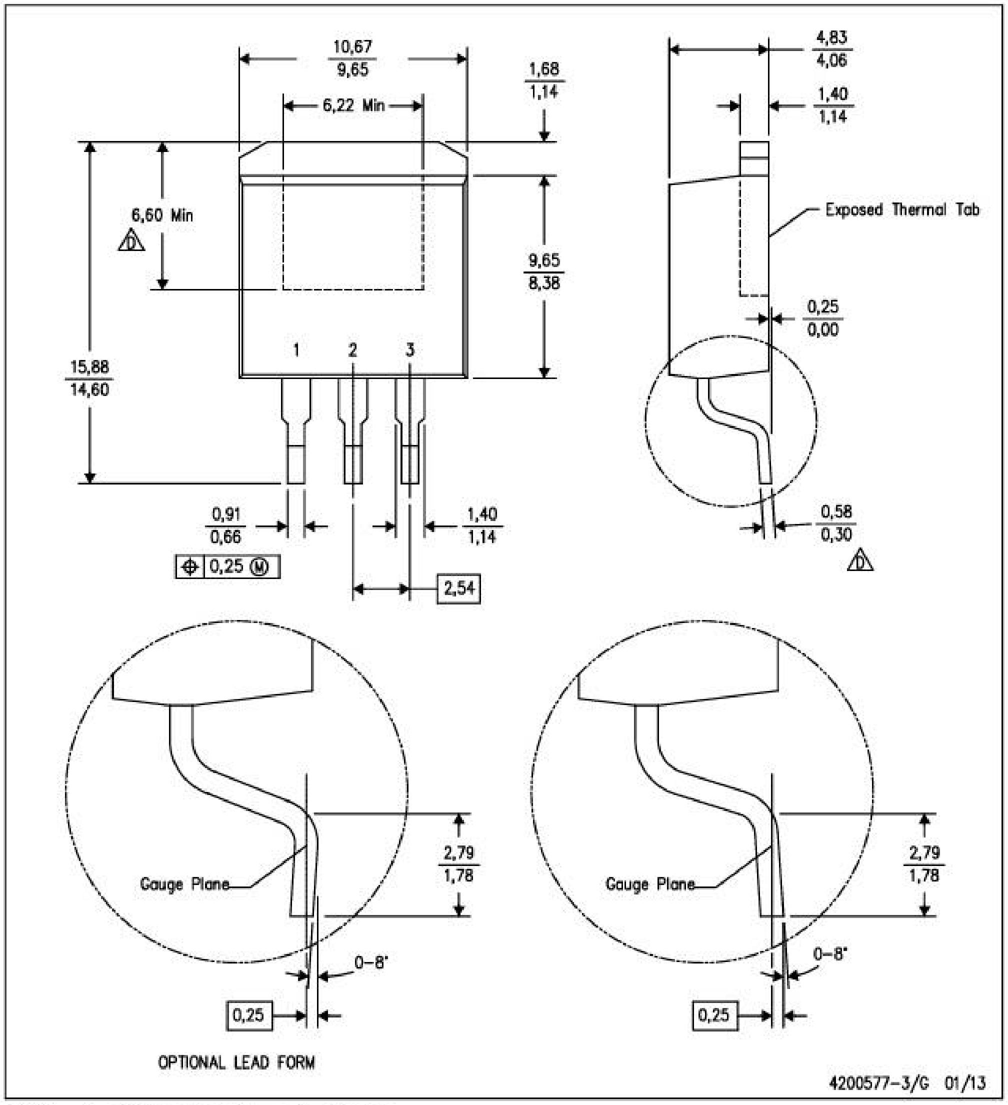
DCY (R-PDSO-G4) PLASTIC SMALL OUTLINE



4210278/C 07/13

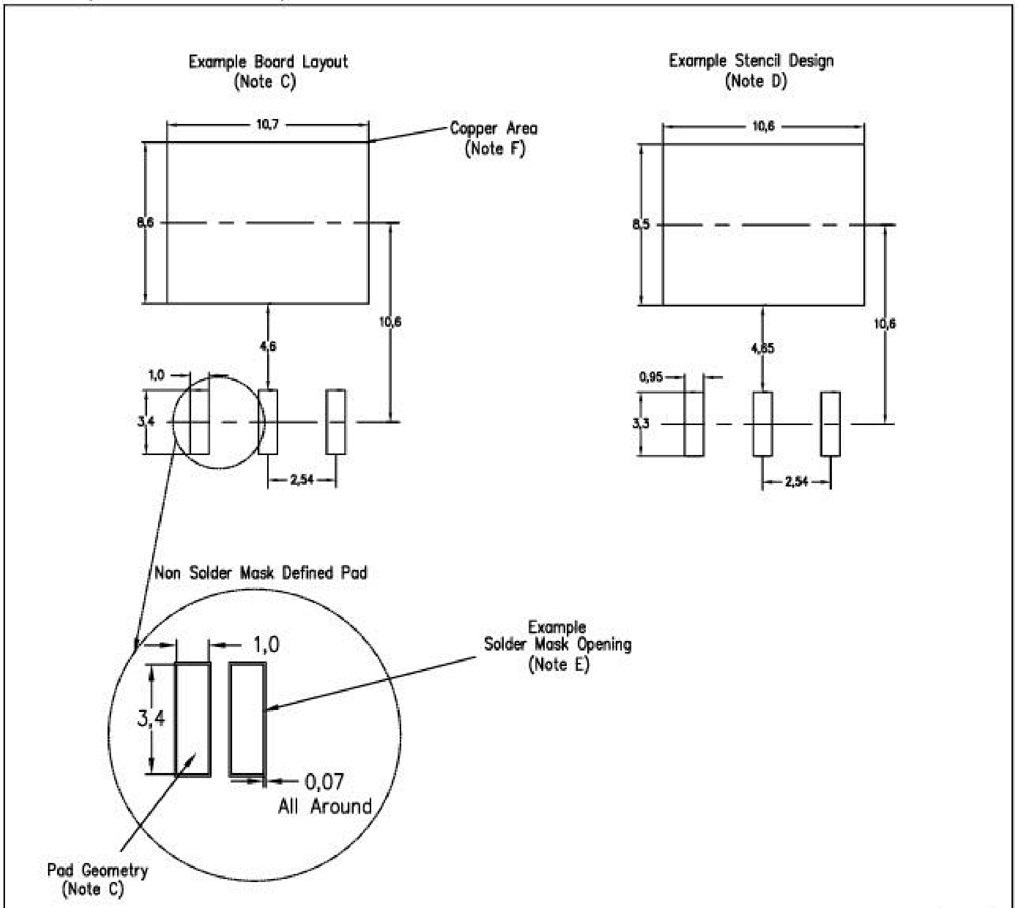
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil recommendations. Refer to IPC 7525 for stencil design considerations.

KTT (R–PSFM–G3) PLASTIC FLANGE–MOUNT PACKAGE



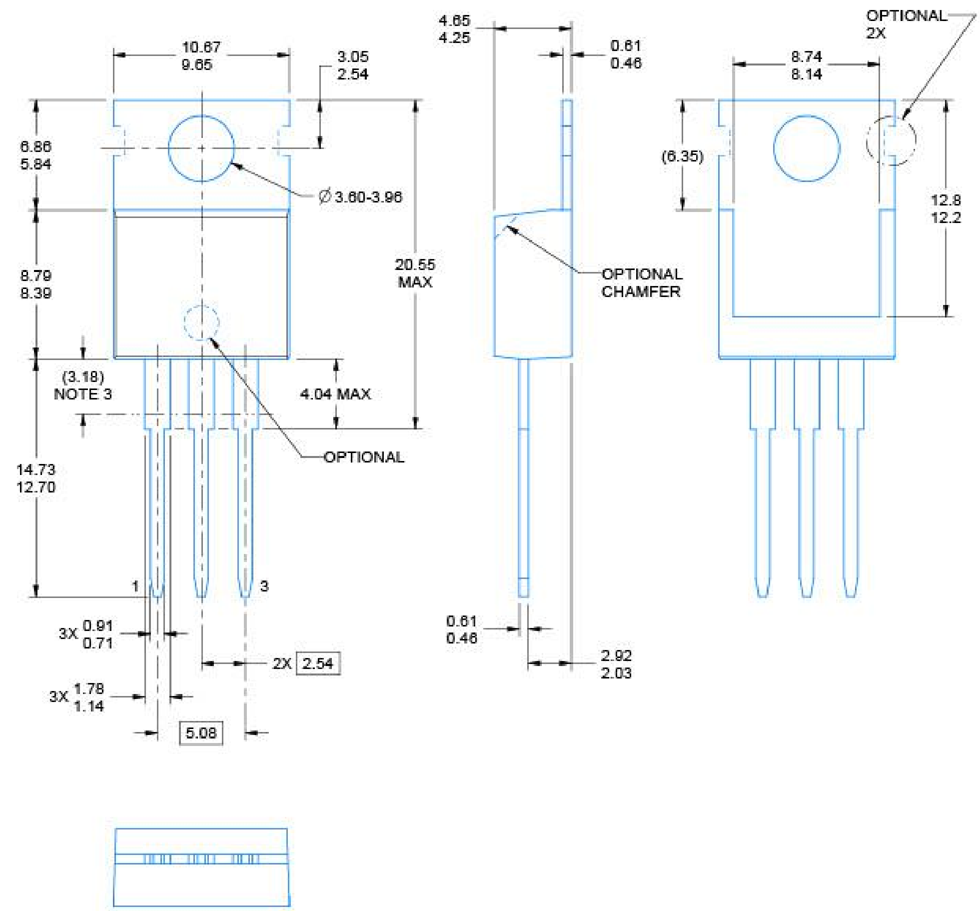
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash or protrusion not to exceed 0.005 (0,13) per side.
D. Falls within JEDEC TO–263 variation AA, except minimum lead thickness and minimum exposed pad length.

KTT (R–PSFM–G3) PLASTIC FLANGE–MOUNT PACKAGE



4208208–2/C 08/12

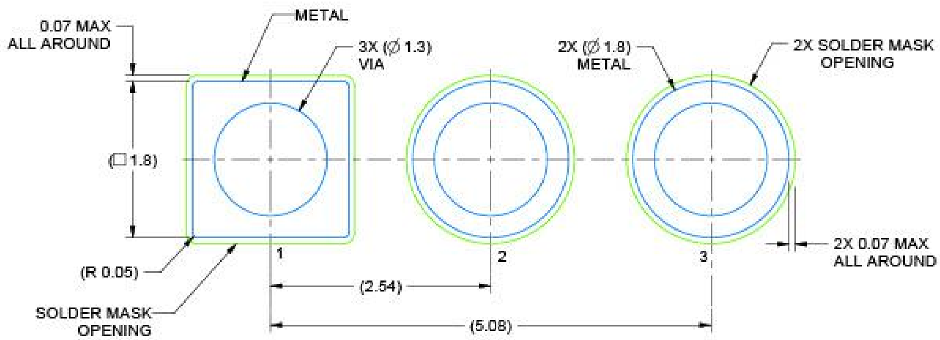
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–SM–782 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
F. This package is designed to be soldered to a thermal pad on the board. Refer to the Product Datasheet for specific thermal information, via requirements, and recommended thermal pad size. For thermal pad sizes larger than shown a solder mask defined pad is recommended in order to maintain the solderable pad geometry while increasing copper area.



4223034/B 08/2018

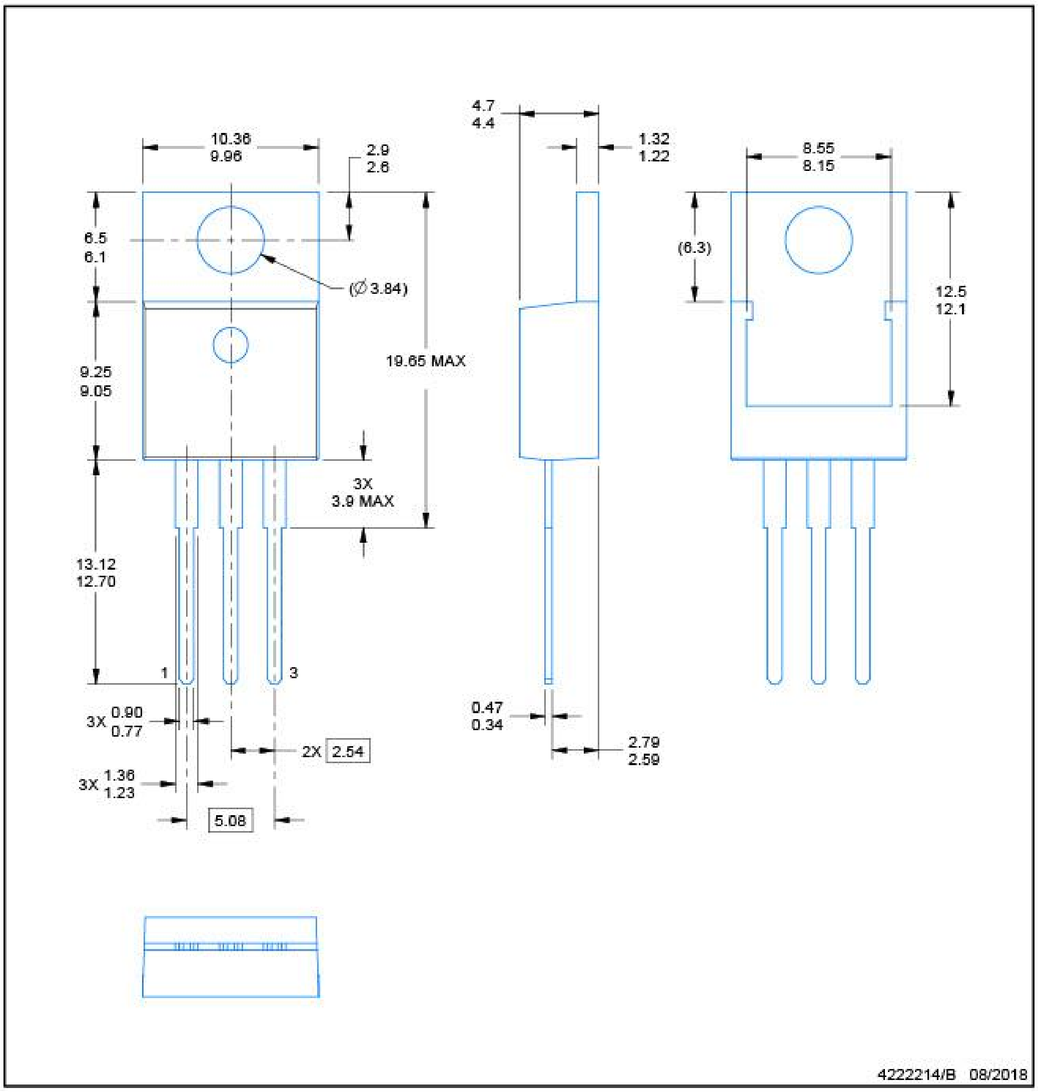
NOTES:

1. Dimensions are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Lead dimensions are not controlled within this area.
4. Reference JEDEC registration TO-220.



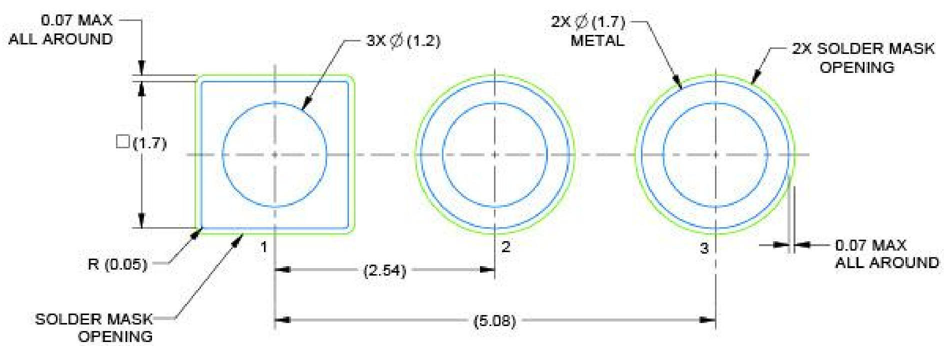
LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE:15X

4223034/B 08/2018



NOTES:

1. Dimensions are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-220.



LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE:15X

4222214/B 08/2018

IMPORTANT NOTICE AND DISCLAIMER

Appendix C: RS5-1.7-1% Resistor Data Sheet

Wirewound Resistors, Industrial, Precision Power, Silicone Coated, Axial Lead

FEATURES

- High temperature coating (> 350 °C)
- Complete welded construction
- Meets applicable requirements of MIL-PRF-26
- Available in non-inductive styles (type NS) with Ayrton-Perry winding for lowest reactive components
- Excellent stability in operation (typical resistance shift < 0.5 %)
- MIL-PRF-26 qualified, type RW resistors can be found at: www.vishay.com/doc?30281
- Material categorization: for definitions of compliance please see www.vishay.com/doc?99912

Pb-free Available
e3
RoHS* Available
HALOGEN FREE Available
GREEN (5-2008) Available

DESIGN SUPPORT TOOLS

click logo to get started

3D Models Available

Note
* This datasheet provides information about parts that are RoHS-compliant and / or parts that are non RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information / tables in this datasheet for details

STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	HIST. MODEL	POWER RATING (1) $P_{25\,°C}$ W U ± 0.05 % to ± 5 %	POWER RATING (1) $P_{25\,°C}$ W V ± 3 % to ± 10 %	RESISTANCE RANGE Ω ± 0.05 %	RESISTANCE RANGE Ω ± 0.1 %	RESISTANCE RANGE Ω ± 0.25 %	RESISTANCE RANGE Ω ± 0.5 %, ± 1 %	RESISTANCE RANGE Ω ± 3 %, ± 5 %, ± 10 %	WEIGHT (typical) g
RS1/4	RS-1/4	0.4	-	1 to 1K	0.499 to 1K	0.499 to 3.4K	0.1 to 3.4K	0.1 to 3.4K	0.21
RS1/2	RS-1/2	0.75	-	1 to 1.3K	0.499 to 1.3K	0.499 to 4.9K	0.1 to 4.9K	0.1 to 4.9K	0.23
RS01A	RS-1A	1.0	-	1 to 2.74K	0.499 to 2.74K	0.499 to 10.4K	0.1 to 10.4K	0.1 to 10.4K	0.34
RS01A...300	RS-1A-300	1.0	-	-	0.499 to 2.74K	0.499 to 10.4K	0.1 to 10.4K	-	0.34
RS01M	RS-1M	1.0	-	1 to 1.32K	0.499 to 1.67K	0.499 to 6.85K	0.1 to 6.85K	0.1 to 6.85K	0.30
RS002	RS-2	4.0	5.5	0.499 to 12.7K	0.499 to 12.7K	0.1 to 47.1K	0.1 to 47.1K	0.1 to 47.1K	2.10
RS02M	RS-2M	3.0	-	0.499 to 4.49K	0.499 to 4.49K	0.1 to 18.74K	0.1 to 18.74K	0.1 to 18.74K	0.65
RS02B	RS-2B	3.0	3.75	0.499 to 6.5K	0.499 to 6.5K	0.1 to 24.5K	0.1 to 24.5K	0.1 to 24.5K	0.70
RS02B...300	RS-2B-300	3.0	-	-	0.499 to 6.5K	0.1 to 24.5K	0.1 to 24.5K	-	0.70
RS02C	RS-2C	2.5	3.25	0.499 to 8.6K	0.499 to 8.6K	0.1 to 32.3K	0.1 to 32.3K	0.1 to 32.3K	1.6
RS02C...17	RS-2C-17	2.5	3.25	0.499 to 8.6K	0.499 to 8.6K	0.1 to 32.3K	0.1 to 32.3K	0.1 to 32.3K	1.6
RS02C...23	RS-2C-23	-	3.25	-	-	-	-	0.1 to 32.3K	1.6
RS005	RS-5	5.0	6.5	0.499 to 25.7K	0.499 to 25.7K	0.1 to 95.2K	0.1 to 95.2K	0.1 to 95.2K	4.2
RS005...69	RS-5-69	5.0	-	-	0.499 to 25.7K	0.1 to 95.2K	0.1 to 95.2K	0.1 to 95.2K	4.2
RS005...70	RS-5-70	-	6.5	-	-	-	-	0.1 to 95.2K	4.2
RS007	RS-7	7.0	9.0	0.499 to 41.4K	0.499 to 41.4K	0.1 to 154K	0.1 to 154K	0.1 to 154K	4.7
RS010	RS-10	10.0	13.0	0.499 to 73.4K	0.499 to 73.4K	0.1 to 273K	0.1 to 273K	0.1 to 273K	9.0
RS010...38	RS-10-38	10.0	-	-	0.499 to 73.4K	0.1 to 273K	0.1 to 273K	0.1 to 273K	9.0
RS010...39	RS-10-39	-	13.0	-	-	-	-	0.1 to 273K	9.0

Notes
- Models not available as lead (Pb)-free: RS01A...300, RS02B...300, RS02C...23, RS005...69, RS005...70, RS010...38, RS010...39.
- Shaded area indicates most popular models.

(1) Vishay Dale RS models have two power ratings depending on operation temperature and stability requirements. Models not available for characteristic V are: RS1/4, RS1/2, RS01A, RS01A...300, RS01M, RS02M, RS02B...300, RS005...69, and RS010...38.

GLOBAL PART NUMBER INFORMATION

Global Part Numbering example: RS02C10K00FS7017

R	S	0	2	C	1	0	K	0	0	F	S	7	0	1	7	

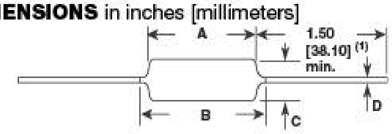
GLOBAL MODEL (5 digits)	RESISTANCE VALUE (5 digits)	TOLERANCE CODE (1 digit)	PACKAGING (3 digits)	SPECIAL (up to 3 digits)
(see Standard Electrical Specifications Global Model column for options)	**R** = decimal **K** = thousand **15R00** = 15 Ω **10K00** = 10 kΩ	**A** = 0.05 % **B** = 0.1 % **C** = 0.25 % **D** = 0.5 % **F** = 1.0 % **H** = 3.0 % **J** = 5.0 % **K** = 10.0 %	**E70** = lead (Pb)-free, tape / reel (smaller than RS005) **E73** = lead (Pb)-free, tape / reel (RS005 and larger) **E12** = lead (Pb)-free, bulk **S70** = tin / lead, tape / reel (smaller than RS005) **S73** = tin / lead, tape / reel (RS005 and larger) **B12** = tin / lead, bulk	(dash number) from **1 to 999** as applicable

Historical Part Numbering example: RS-2C-17 10 kΩ 1 % S70

RS-2C-17	10 kΩ	1 %	S70
HISTORICAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	PACKAGING

For technical questions, contact: ww2aresistors@vishay.com

DIMENSIONS in inches [millimeters]



Note

(1) On some standard reel pack methods, the leads may be trimmed to a shorter length than shown

MATERIAL SPECIFICATIONS

Element: copper-nickel alloy or nickel-chrome alloy, depending on resistance value

Core: ceramic, steatite or alumina, depending on physical size

Coating: special high temperature silicone

Standard Terminals: 100 % Sn, or 60/40 Sn/Pb coated Copperweld®

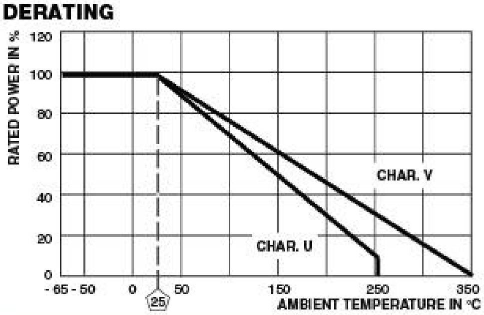
End Caps: stainless steel

Part Marking: DALE, model, wattage (1), value, tolerance, date code

Note

(1) Wattage marked on part will be "U" characteristic

DERATING



GLOBAL MODEL	DIMENSIONS in inches [millimeters]			
	A	B (1) (max.)	C	D
RS1/4	0.250 ± 0.031 [6.35 ± 0.787]	0.281 [7.14]	0.085 ± 0.020 [2.16 ± 0.508]	0.020 ± 0.002 [0.508 ± 0.051]
RS1/2	0.312 ± 0.016 [7.92 ± 0.406]	0.328 [8.33]	0.078 + 0.016 - 0.031 [1.98 + 0.406 - 0.787]	0.020 ± 0.002 [0.508 ± 0.051]
RS01A RS01A...300	0.406 ± 0.031 [10.31 ± 0.787]	0.437 [11.10]	0.094 ± 0.031 [2.39 ± 0.787]	0.020 ± 0.002 [0.508 ± 0.051]
RS01M	0.270 ± 0.031 [6.86 ± 0.787]	0.311 [7.90]	0.110 ± 0.015 [2.79 ± 0.381]	0.020 ± 0.002 [0.508 ± 0.051]
RS002	0.625 ± 0.062 [15.88 ± 1.57]	0.765 [19.43]	0.250 ± 0.031 [6.35 ± 0.787]	0.040 ± 0.002 [1.02 ± 0.051]
RS02M	0.500 ± 0.062 [12.70 ± 1.57]	0.562 [14.27]	0.185 ± 0.031 [4.70 ± 0.787]	0.032 ± 0.002 [0.813 ± 0.051]
RS02B RS02B...300	0.560 ± 0.062 [14.22 ± 1.57]	0.622 [15.80]	0.187 ± 0.031 [4.75 ± 0.787]	0.032 ± 0.002 [0.813 ± 0.051]
RS02C	0.500 ± 0.062 [12.70 ± 1.57]	0.593 [15.06]	0.218 ± 0.031 [5.54 ± 0.787]	0.040 ± 0.002 [1.02 ± 0.051]
RS02C...17 RS02C...23	0.500 ± 0.062 [12.70 ± 1.57]	0.593 [15.06]	0.218 ± 0.031 [5.54 ± 0.787]	0.032 ± 0.002 [0.813 ± 0.051]
RS005 RS005...69 RS005...70	0.875 ± 0.062 [22.23 ± 1.57]	1.0 [25.4]	0.312 ± 0.031 [7.92 ± 0.787]	0.040 ± 0.002 [1.02 ± 0.051]
RS007	1.22 ± 0.062 [30.99 ± 1.57]	1.28 [32.51]	0.312 ± 0.031 [7.92 ± 0.787]	0.040 ± 0.002 [1.02 ± 0.051]
RS010 RS010...39	1.78 ± 0.062 [45.21 ± 1.57]	1.87 [47.50]	0.375 ± 0.031 [9.53 ± 0.787]	0.040 ± 0.002 [1.02 ± 0.051]
RS010...38	1.78 ± 0.062 [45.21 ± 1.57]	1.84 [46.74]	0.375 ± 0.031 [9.53 ± 0.787]	0.040 ± 0.002 [1.02 ± 0.051]

Note

(1) B (max.) dimension is clean lead to clean lead

NS NON-INDUCTIVE

Models of equivalent physical and electrical specifications are available with non-inductive (Ayrton-Perry) winding. They are identified by substituting the letter N for R in the model number (NS005, for example).

Two conditions apply:

1. For NS models, divide maximum resistance values by two
2. Body O.D. on NS02C may exceed that of the RS02C by 0.010"

TECHNICAL SPECIFICATIONS

PARAMETER	UNIT	RS RESISTOR CHARACTERISTICS
Temperature Coefficient	ppm/°C	± 20 for 10 Ω and above, ± 50 for 1 Ω to 9.9 Ω, ± 90 for 0.5 Ω to 0.99 Ω
Maximum Working Voltage	V	$(P \times R)^{1/2}$
Insulation Resistance	Ω	1000 MΩ minimum dry, 100 MΩ minimum after moisture test
Operating Temperature Range	°C	Characterisitic U = -65 to +250, characteristic V = -65 to +350

PERFORMANCE

TEST	CONDITIONS OF TEST	TEST LIMITS	
		CHARACTERISTIC U	CHARACTERISTIC V
Thermal Shock	Rated power applied until thermally stable, then a minimum of 15 min at -55 °C	± (0.2 % + 0.05 Ω) ΔR	± (2.0 % + 0.05 Ω) ΔR
Short Time Overload	5x rated power (3.75 W and smaller), 10 x rated power (4 W and larger) for 5 s	± (0.2 % + 0.05 Ω) ΔR	± (2.0 % + 0.05 Ω) ΔR
Dielectric Withstanding Voltage	500 V_{RMS} min. for RS1/4 thru RS01A, 1000 V_{RMS} for all others, duration of 1 min	± (0.1 % + 0.05 Ω) ΔR	± (0.1 % + 0.05 Ω) ΔR
Low Temperature Storage	-65 °C for 24 h	± (0.2 % + 0.05 Ω) ΔR	± (2.0 % + 0.05 Ω) ΔR
High Temperature Exposure	250 h at: U = +250 °C, V = +350 °C	± (0.5 % + 0.05 Ω) ΔR	± (2.0 % + 0.05 Ω) ΔR
Moisture Resistance	MIL-STD-202 Method 106, 7b not applicable	± (0.2 % + 0.05 Ω) ΔR	± (2.0 % + 0.05 Ω) ΔR
Shock, Specified Pulse	MIL-STD-202 Method 213, 100 *g*'s for 6 ms, 10 shocks	± (0.1 % + 0.05 Ω) ΔR	± (0.2 % + 0.05 Ω) ΔR
Vibration, High Frequency	Frequency varied 10 Hz to 2000 Hz, 20 *g* peak, 2 directions 6 h each	± (0.1 % + 0.05 Ω) ΔR	± (0.2 % + 0.05 Ω) ΔR
Load Life	2000 h at rated power, +25 °C, 1.5 h "ON", 0.5 h "OFF"	± (0.5 % + 0.05 Ω) ΔR	± (3.0 % + 0.05 Ω) ΔR
Terminal Strength	Pull test 5 s to 10 s, 5 lb (RS1/4 thru RS01A), 10 lb for all others; torsion test - 3 alternating directions, 360° each	± (0.1 % + 0.05 Ω) ΔR	± (1.0 % + 0.05 Ω) ΔR

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Appendix D: 100K Ohm 3W 5% Metal Oxide Film Resistor Data Sheet

ROYALOHM

Metal Oxide Film Fixed Resistors

Performance Specification

Temperature Coefficient	±350PPM/°C
Short Time Overload	Normal size: ±(1.0% + 0.05Ω)Max, with no evidence of mechanical damage. Small size: ±(2.0% + 0.05Ω)Max, with no evidence of mechanical damage.
Dielectric Withstanding Voltage	No evidence of flashover, mechanical damage, arcing or insulation breakdown.
Pulse Overload	Normal size: ±(2.0% + 0.05Ω)Max, with no evidence of mechanical damage. Small size: ±(5.0% + 0.05Ω)Max, with no evidence of mechanical damage.
Terminal Strength	No evidence of mechanical damage.
Resistance to Soldering Heat	±(1.0% + 0.05Ω)Max, with no evidence of mechanical damage.
Solderability	Min. 95% coverage.
Resistance to Solvent	No deterioration of protective coating and markings.
Temperature Cycling	±(2.0% + 0.05Ω)Max, with no evidence of mechanical damage.
Humidity (Steady state)	±(2.0% + 0.05Ω)Max, with no evidence of mechanical damage.
Load Life in Humidity	<100KΩ : ±(5.0% + 0.05Ω)Max ≥100KΩ : ±(10.0% + 0.05Ω)Max
Load Life	<100KΩ : ±(5.0% + 0.05Ω)Max ≥100KΩ : ±(10.0% + 0.05Ω)Max
Non-Flame	No evidence of flaming or arcing.

Ordering Procedure: Ex.: MOR 1/2W, +/-5%, 100Ω, T/B-1000

M O R 0 W 2 J 0 1 0 1 A 1 0

Type:
MOR = Metal Oxide Film

Feature:
0 = Standard
I = Non-Inductive

Wattage:
Normal size
W4 = 1/4W
W2 = 1/2W
1W = 1W
2W = 2W
3W = 3W
5W = 5W
7W = 7W
8W = 8W
9W = 9W

Small size
S2 = 1/2W-S
1S = 1W-S
2S = 2W-S
3S = 3W-S
4S = 4W-S
5S = 5W-S

Extra small size
5U = 5W-SS

Tolerance:
G = ±2%
J = ±5%
K = ±10%

Resistance Value:
- E-24 series:
  1st digit is "0"
  2nd & 3rd digits are the significant figures of the resistance
  4th indicates the number of zeros:
  "J" ~ 0.1, "K" ~ 0.01
  Ex.: 4.7Ω , ~ 47J, 4.7KΩ ~ 472
- E-96 series:
  1st to 3rd digits are the significant figures of the resistance and the 4th digit indicates the number of zeros.
  Ex.: 1.33 KΩ = 1331

Packing Type:
A = Tape/Box
T = Tape/Reel
B = Bulk/Box
P = Tape/Box of PT-26mm

Packing Qty:
1 = 1,000 pcs. 2 = 2,000 pcs.
5 = 5,000 pcs. A = 500 pcs.
B = 2,500 pcs. 0 = Bulk/Box

Additional Information:
0 = PT-52mm, PT-26mm, Standard lead wire for Bulk/Box
8 = PT-58mm
9 = PT-64mm
7 = Lead wire (H=38mm)
A = PT-83mm
C = PT-73mm
D = PT-71mm

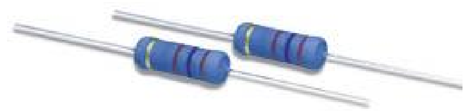
RoHS Compliant

ROYALOHM

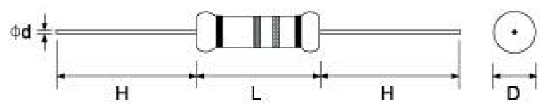
Metal Oxide Film Fixed Resistors

Features

- High safety standard, high purity ceramic core
- Excellent non-flame coating, non-inductivetype available
- Stableperformance indiverse environment, meet EIAJ-RC2655A requirements
- Too low or too highohmic value can be supplied on a case to case basis



Standard : 2% ,5% ,10% -- E - 24 series

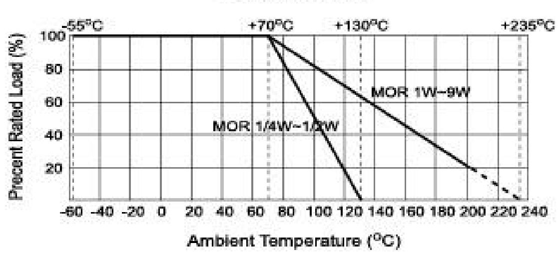


Part No.	Style	Power Rating at 70°C	Dimension (mm)					Max Working Voltage	Max Overload Voltage	Dielectric Withstanding Voltage	Resistance Range	Std Packing Qty
			D Max	L Max	H±3	d±0.05	PT					
Normal Size												
MOR0W4	MOR 25	1/4W(0.25W)	2.5	7.5	28	0.54	52	250V	400V	250V	0.3Ω~50KΩ	5,000
MOR0W2	MOR 50	1/2W (0.50W)	3.5	10.0	28	0.54	52	250V	400V	250V	0.3Ω~50KΩ	1,000
MOR01W	MOR 100	1W	5.0	12.0	25	0.70	52	350V	600V	350V	0.3Ω~50KΩ	1,000
MOR02W	MOR 200	2W	5.5	16.0	28	0.70	64	350V	600V	350V	0.3Ω~50KΩ	1,000
MOR03W	MOR 300	3W	6.5	17.5	28	0.75	64	500V	800V	500V	5Ω~100KΩ	500
MOR05W	MOR 500	5W	8.5	26.0	38	0.75	B/B	750V	1,000V	750V	5Ω~150KΩ	1,000
MOR07W	MOR 700	7W	8.5	32.0	38	0.75	B/B	750V	1,000V	750V	20Ω~150KΩ	1,600
MOR08W	MOR 800	8W	8.5	41.0	38	0.75	B/B	750V	1,000V	750V	30Ω~200KΩ	1,600
MOR09W	MOR 900	9W	8.5	54.0	38	0.75	B/B	750V	1,000V	750V	50Ω~200KΩ	1,800
Small Size												
MOR0S2	MOR-50-S	1/2W (0.50W)	2.5	7.5	28	0.54	52	250V	400V	250V	0.3Ω~50KΩ	5,000
MOR01S	MOR-100-S	1W	3.5	10.0	28	0.54	52	350V	600V	350V	0.3Ω~50KΩ	1,000
MOR02S	MOR-200-S	2W	5.0	12.0	25	0.70	52	350V	600V	350V	0.3Ω~50KΩ	1,000
MOR03S	MOR-300-S	3W	5.5	16.0	28	0.70	64	350V	600V	350V	0.3Ω~50KΩ	1,000
MOR04S	MOR-400-S	4W	6.5	17.5	28	0.75	64	500V	800V	500V	5Ω~100KΩ	500
MOR05S	MOR-500-S	5W	8.0	25.0	38	0.75	B/B	500V	800V	500V	5Ω~150KΩ	1,000
Extra Small Size												
MOR05U	MOR-500-SS	5W	6.5	17.5	28	0.75	64	500V	800V	500V	5Ω~100KΩ	500

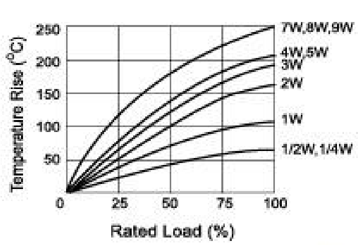
Note:

- Standard gray base color for normal size product, sea blue color for small size and extra small size product
- Standard Non-flammable coating
- Non-Inductive type available on a case to case basis

Derating Curve



Heat Rise Chart



RoHS Compliant

Appendix E: SN-HP1W-1550 Emitter Data Sheet

Specification

规 格 书

Client Name

客户名称：

Client P/N

客户品号：

Product P/N

产品型号：SN-HP1W-1550

Sending Date

送样日期：

Client approval 客户审核			Shining approval 我司审核		
Approval 核准	Audit 确认	Confirmation 制作	Approval 核准	Audit 确认	Confirmation 制作
□ Qualified 接受	□ Disqualified 不接受		DATE: 日期:		

注：此规格书以中英文方式书写, 若有冲突以中文版本为准文本.

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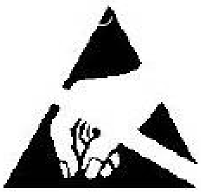


ATTENTION
OBSERVE PRECAUTIONS
FOR HANDLING
ELECTROSTATIC
DISCHARGE
SENSITIVE
DEVICES

产品特征

发光角度：120°

高可靠性

低电压

无铅回流焊

符合 RoHS 包装：

每盘 50pcs

防潮等级：MSL1

Features

The product size(mm): below

Viewing Angl：120°

High reliability

Low forward voltage

Peak wavelength λp=1550nm

Pb-free reflow soldering

application RoHS compliant、

Package:50pcs/tray

Moisture Sensitive Level： Level 1

产品运用

CCB 摄像机

监视系统

红外相机

机器视觉系统

Applications

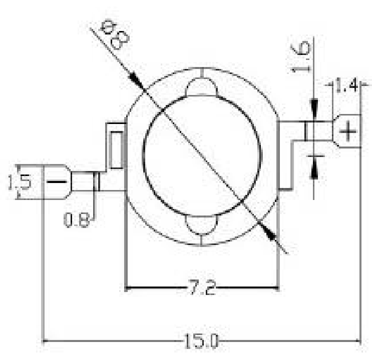
CCB cameras

Surveillance systems

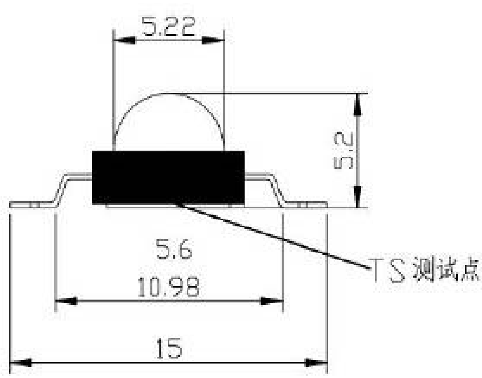
Infrared Illumination for cameras

Machine vision systems

Package Dimensions 封装尺寸



Recommended Soldering 推荐焊接



Notes 注意:

1. All dimension units are millimeters.所有尺寸单位均为毫米.
2. All dimension tolerance is ±0.2mm unless otherwise noted.所有尺寸误差是±0.2 毫米除非另有说明。

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Typical Optical/ Electrical Characteristics @T_a=25℃ 典型的光学/电气特性在 Ta=25°C

Symbol 符号	Item 名称	Min. 最低	Typ. 典型	Max. 最高	Units 单位	Test Conditions 测试条件
IV	Luminous Intensity 发光强度	—	—	—	mcd	IF=350mA
Φe	Radiation Power 辐射功率	20 50	—	50 120	mw	IF=350mA IF=700mA
VF	Forward Voltage [1]正向电压	1.0	—	1.5	v	IF=700mA
λd	Wave length 主波长	—	—	—	nm	IF=700mA
λp	PeakWavelength 峰值波长		1550		nm	IF=700mA
2θ-1/2	50% power angle 发光角度	—	120	140	deg	IF=700mA
IR	Reverse Current 反向电流	—	—	20	uA	VR = 5V

Notes 注:

1.Tolerance of measurement of forward voltage±0.1V、peak Wavelength±2.0nm、Radiation Power ±5%

测量正向电压误差为±0.1、波长误差为 2.0nm、辐射功率误差为±5%。

Absolute Maximum Ratings 绝对最大额定值在 TA=25°C

名称 Item	Symbol 符号	Absolute Maximum Rating 绝对最大额定值	Units 单位
Power dissipation[1]功率	Pd	1	W
正向电流 DC Forward Current[1]	I_F	700	mA
Reverse Voltage[1] 反向电压	V_R	5	V
Operating Temperature 工作温度范围	Topr	-20 ~ +85 ℃	
Storage Temperature 储存温度范围	Tstg	-40 ~ +100 ℃	
Junction Temperature 结温	T_j	100 ℃	

Note:

1.1/10 Duty Cycle,0.1ms Pulse Width.1 / 10 占空比，0.1ms 脉冲宽度。

2.The temperature of Aluminum PCB do not exceed 55℃.基板温度不超过 55℃。

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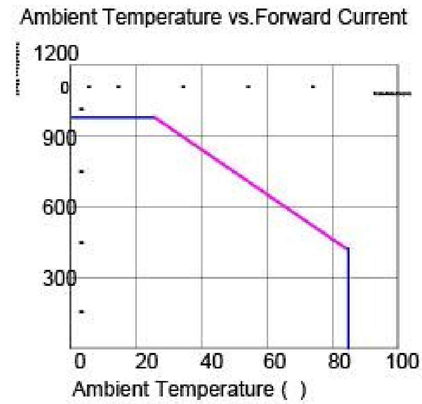
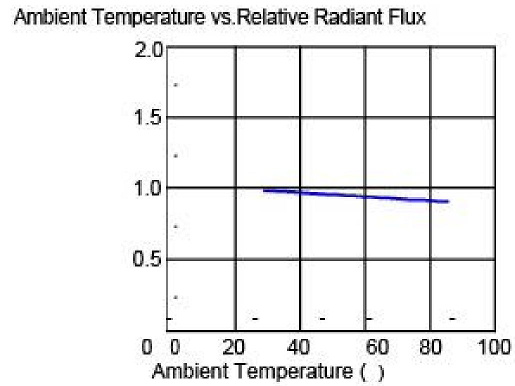
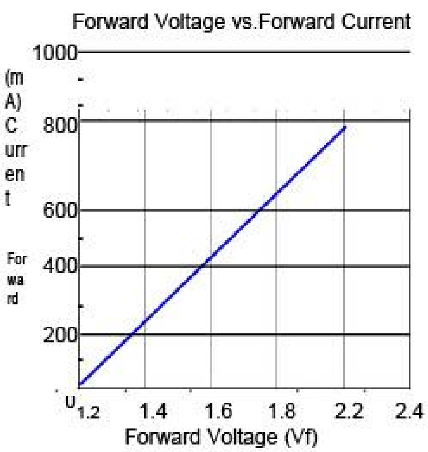
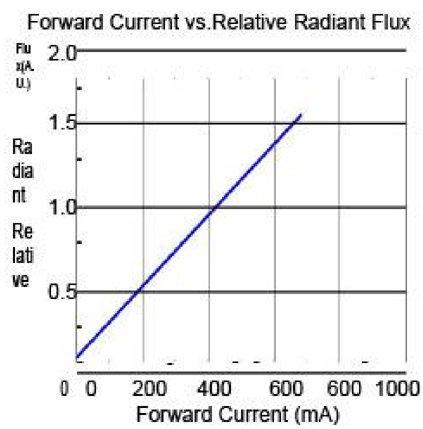
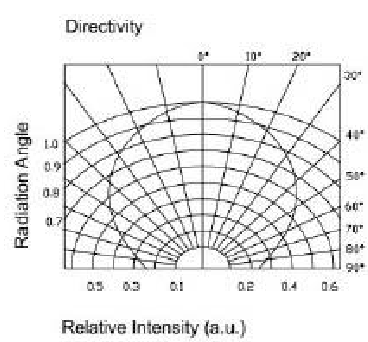
Typical Optical/Electrical Characteristics Curves 典型光学/电性特征曲线 (T_a=25℃ Unless Otherwise Noted)（T_a=25℃ 除非另有注释）











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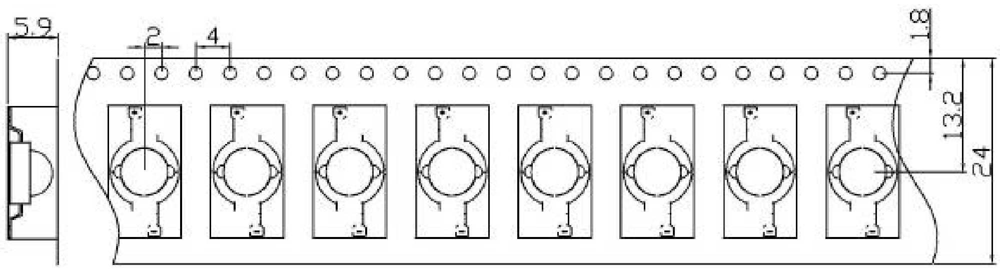
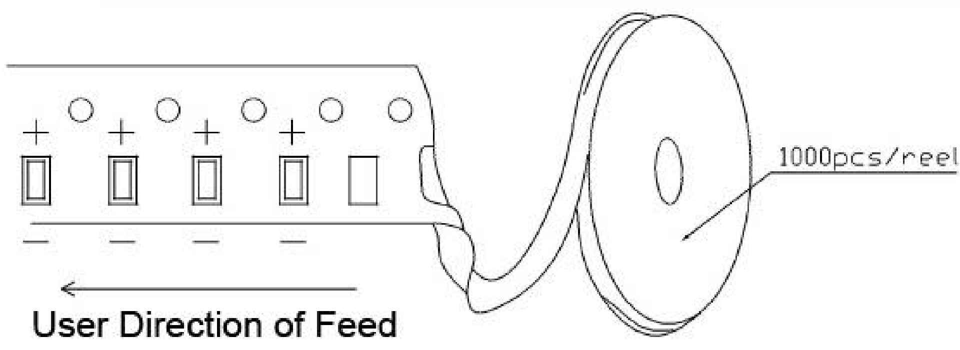
包装规格 Packaging Specifications

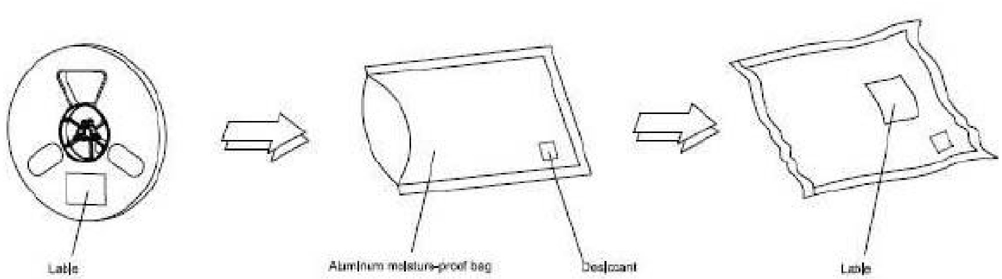
1. 载体尺寸 Carrier Tape Dimensions

Tape by reel (suitable for automatic machine) 卷轴包装（适用于自动贴片机）





Moisture resistant packaging 防潮包装



备注 Note: 标注公差为±0.1 毫米，单位：毫米。The tolerances unless mentioned ±0.1mm. Unit : mm

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Acceptance Test Procedure

Test Equipment:
The test equipment will consist of:
-Pyroelectric Radiometer
-Voltmeter
-Oscilloscope
-Germanium Detector
-IR Camera
-Power Supply

Test Facility:
This project will require an outdoor, open testing environment with a range of different ground settings and heights. (Dirt, Grass, Rocky, Concrete).

For testing the power and field of view of the emitter, we will need access to a lab with a detector that can profile the intensity distribution of the emitters when housed in the mechanical packaging.

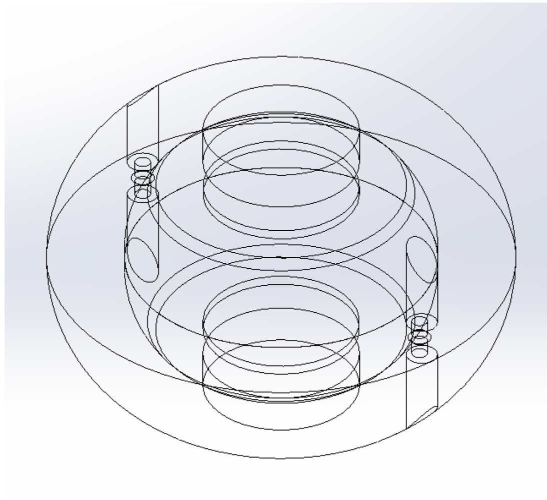
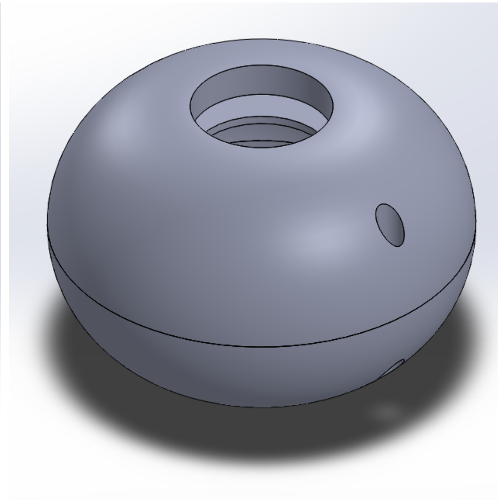
Final Acceptance Test Date:
Final system acceptance testing is planned for 4/27/21 in time for the FAR.

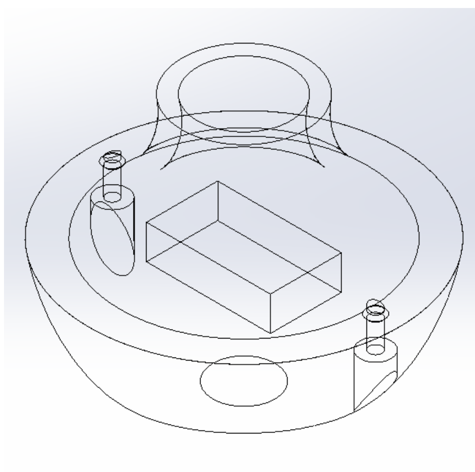
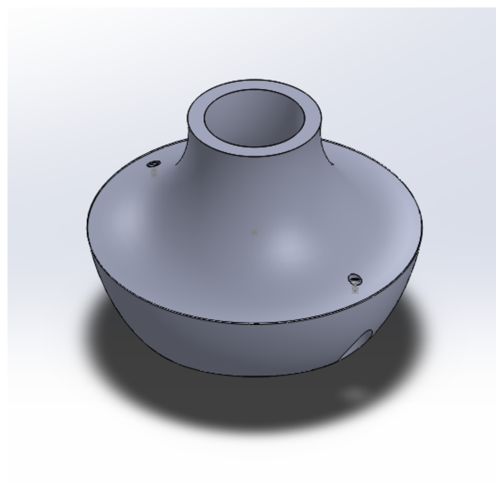
Overall Plan:
Five STrOBe System level tests (Operation Function, Radiant Power, Output Power Variance, Output Angle, and Modulation), and one Microcontroller Subassembly test are planned to verify requirements at the system level. Additionally, two Optics Subassembly tests are included for confidence that the system level acceptance can be performed.

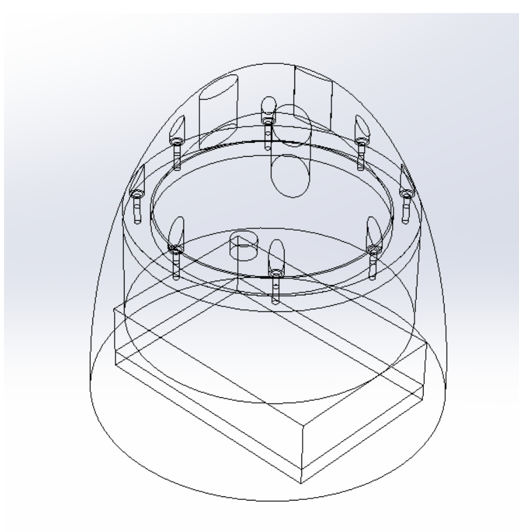
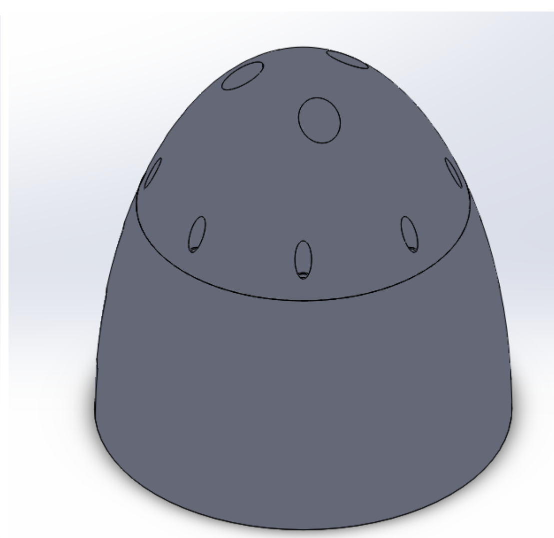
Test Procedures:
Operation Function Test (4.1.2)
Device will be initially powered on and connected to a remote control.
The remote control will be an android phone.
Will stay powered on for 30 mins.
Radiant Power Test (4.1.4)
A pyroelectric radiometer with an ND (neutral density) filter will be used to make sure the power is at least 150mW with a 20% variance. A germanium detector will also be used in the same manner to verify the results.

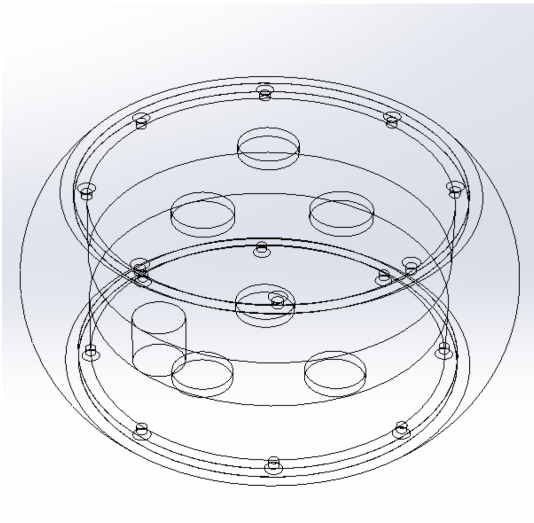
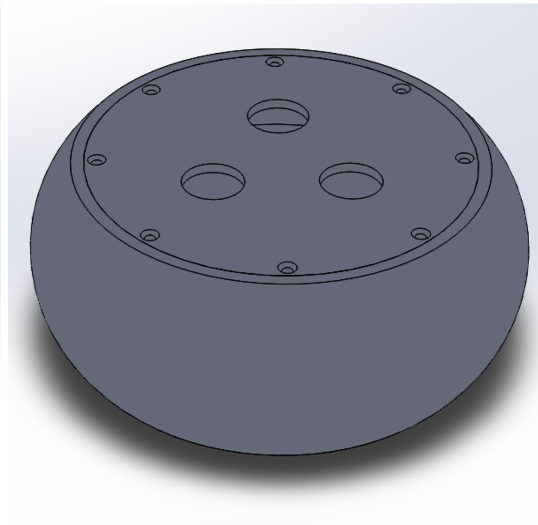
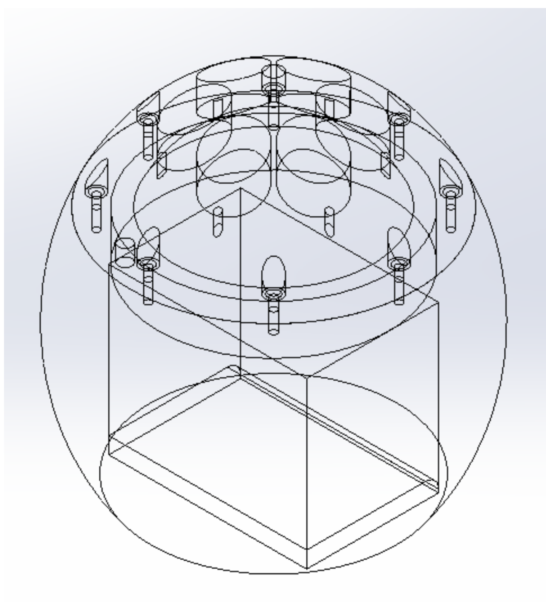
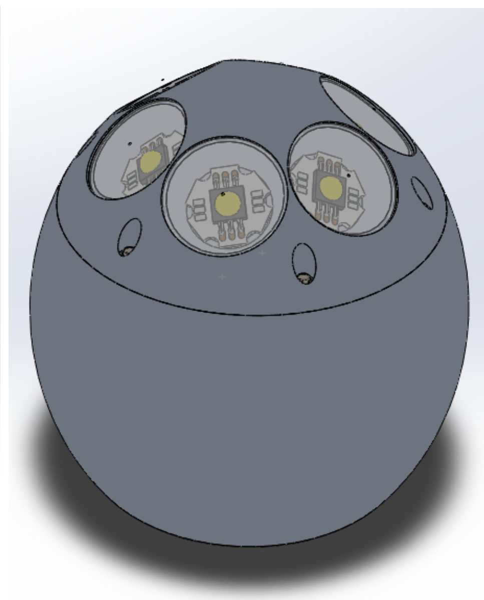
Output Power Test (4.1.5)
A radiometer will be used to measure output power across FFOV.
Output Angle Test (4.1.6)
Angular sweep will be made with the radiometer around emitters to test angle requirement.
Modulation Test (4.1.8)
A radiometer will be attached to an Oscilloscope in order to monitor duty cycle.
Deployment Test (4.2.3)
Drop test in various environments and analyze behavior
Grass, gravel, dirt, concrete, pavement, and uneven surfaces, etc.

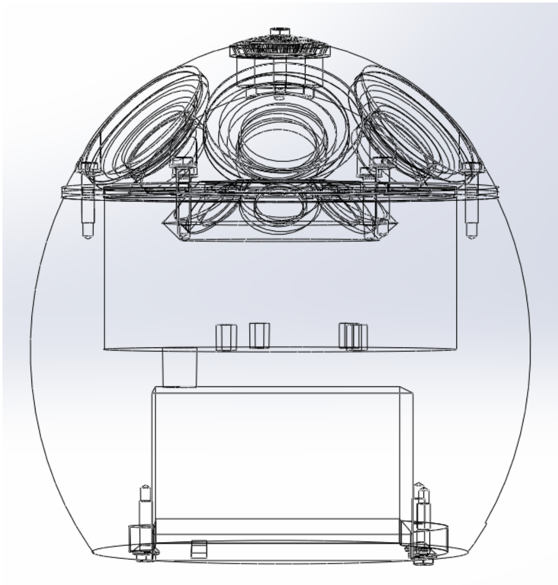
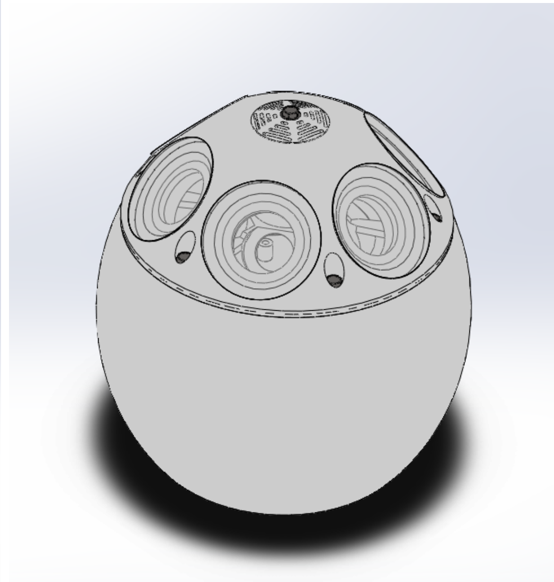
Models / Analysis

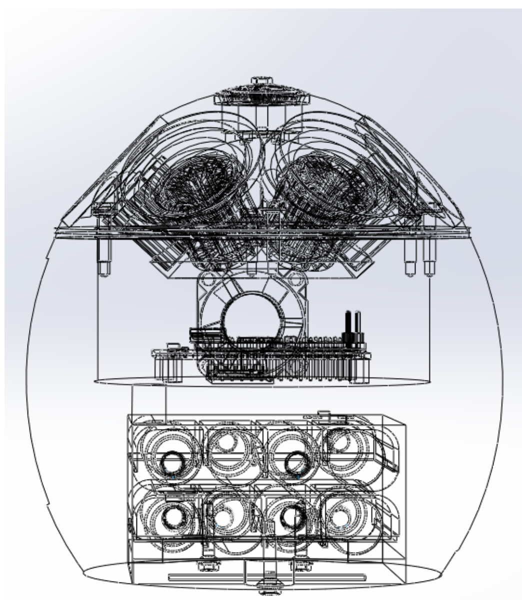
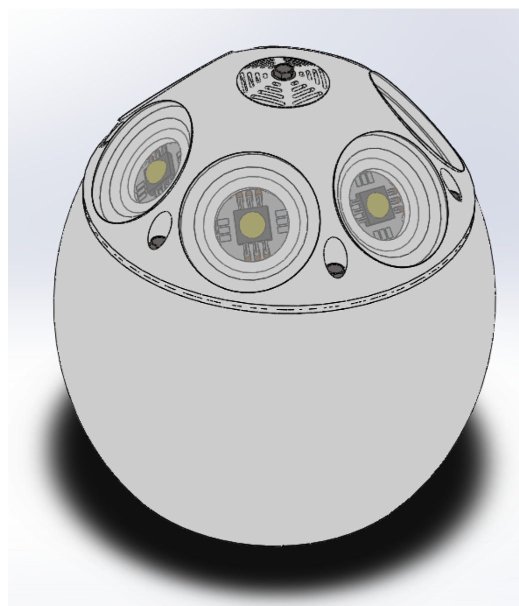



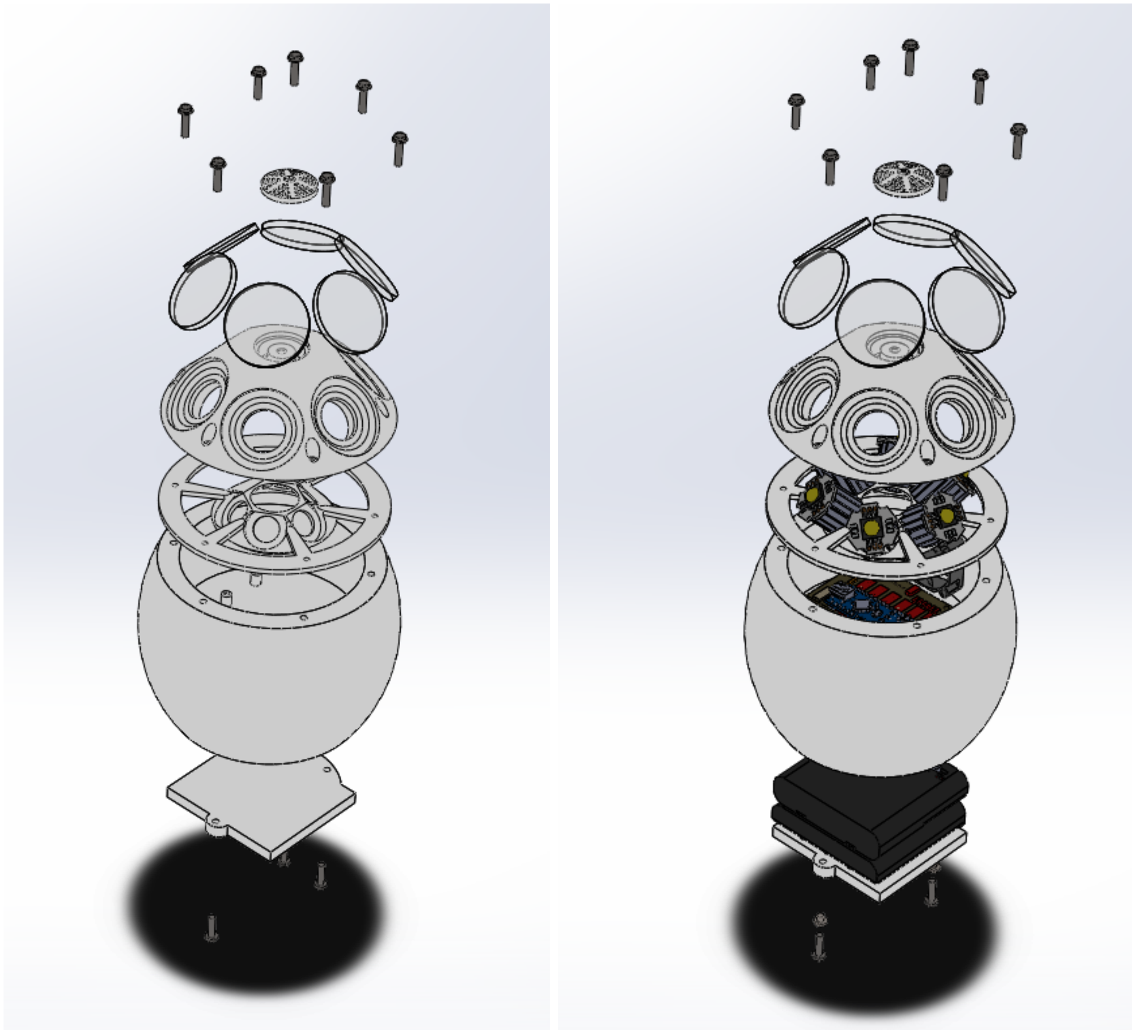



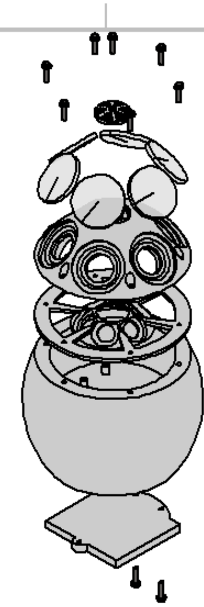





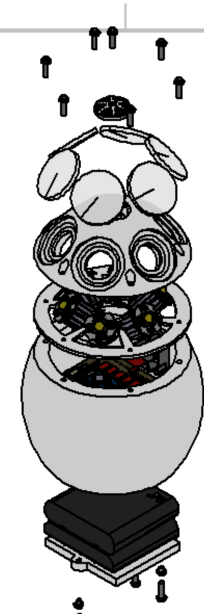


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Bottom Housing	3D Printed Base (PETG)	1
2	Top Housing & Cover	3D Printed Top (PETG)	1
3	TopVent Cover	Vent Cover (PETG)	1
4	Bottom Housing Cover	Battery Housing Cover (PETG)	1
5	Emitter Windows	Plexiglass Windows	6
6	IN-HWMS 0.125-40x0.5x0.5-N	SCREWS	10
7	Mounting Bracket	Mounting Bracket with Holders (PETG)	1



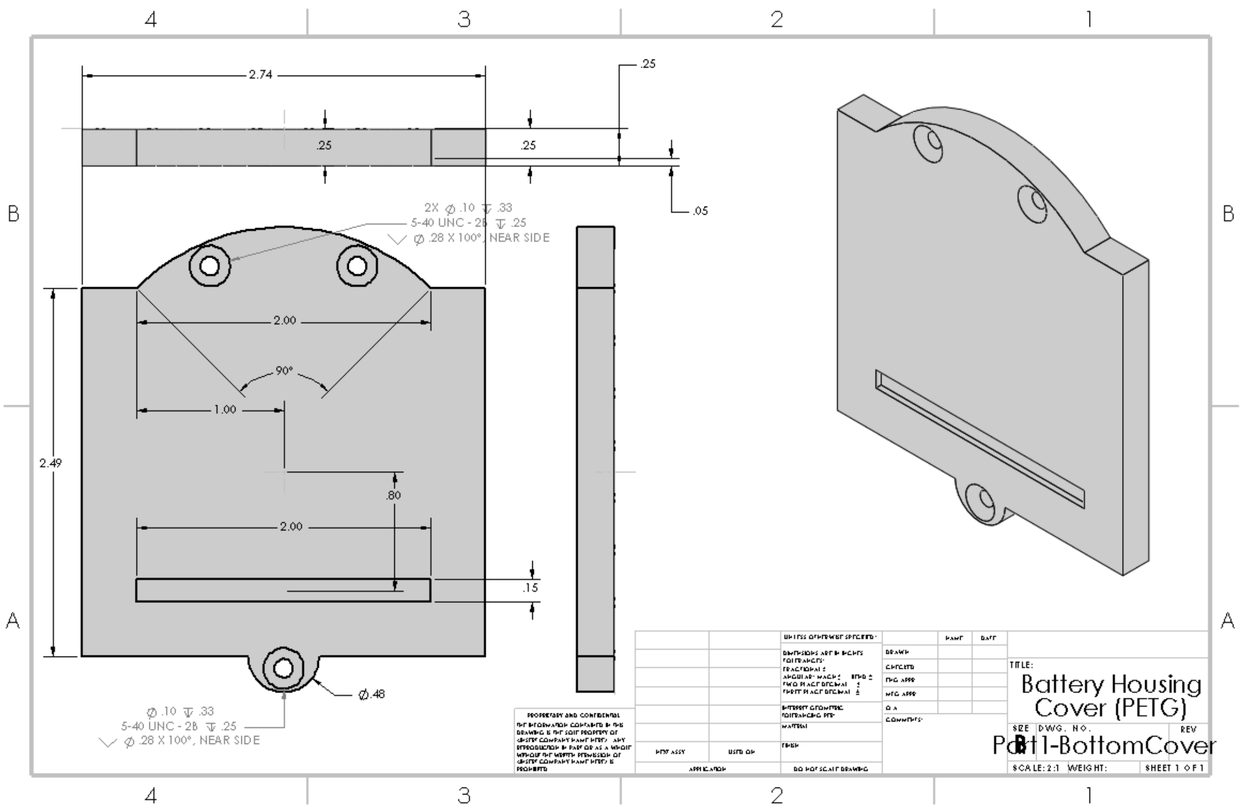
MechanicalPartsList-ISR

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	BOTTOM HOUSING	3D PRINTED BASE (PETG)	1
2	TOP HOUSING & COVER	3D PRINTED TOP (PETG)	1
3	TOPVENT COVER	VENT COVER (PETG)	1
4	BOTTOM HOUSING COVER	BATTERY HOUSING COVER (PETG)	1
5	EMITTER WINDOWS	PLEXIGLASS WINDOWS	6
6	IN-HWMS 0.125-40X0.5X0.5-N	SCREWS	10
7	MOUNTING BRACKET	MOUNTING BRACKET WITH HOLDERS (PETG)	1
8	EMITTERMODULE	EMITTER + STAR PCB + HEATSINK	6
9	HC05	BT MODULE	1
10	CPU FAN V2.STEP	INTERNAL FAN FOR COOLING	1
11	BATTERYPACKFULL	BATTERY PACK WITH 4 BATTERIES	2
12	IN-HWMS 0.125-40X0.125X0.125-N	SCREWS	3
13	NANOV3 V4.STEP	NANO MICROCONTROLLER	1
14	PCB_FINAL.STEP	CUSTOM PCB FOR WIRING AND CONTROL	1

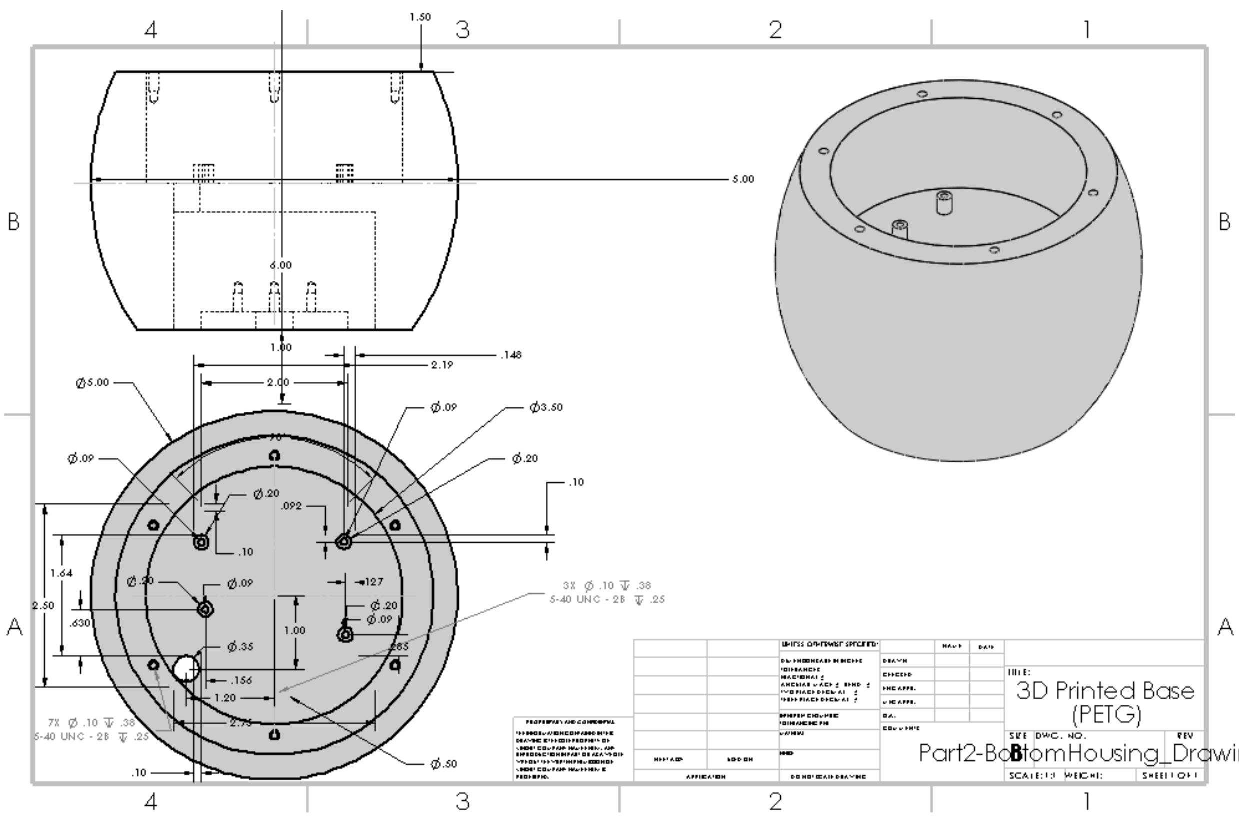


PartsList_ISR

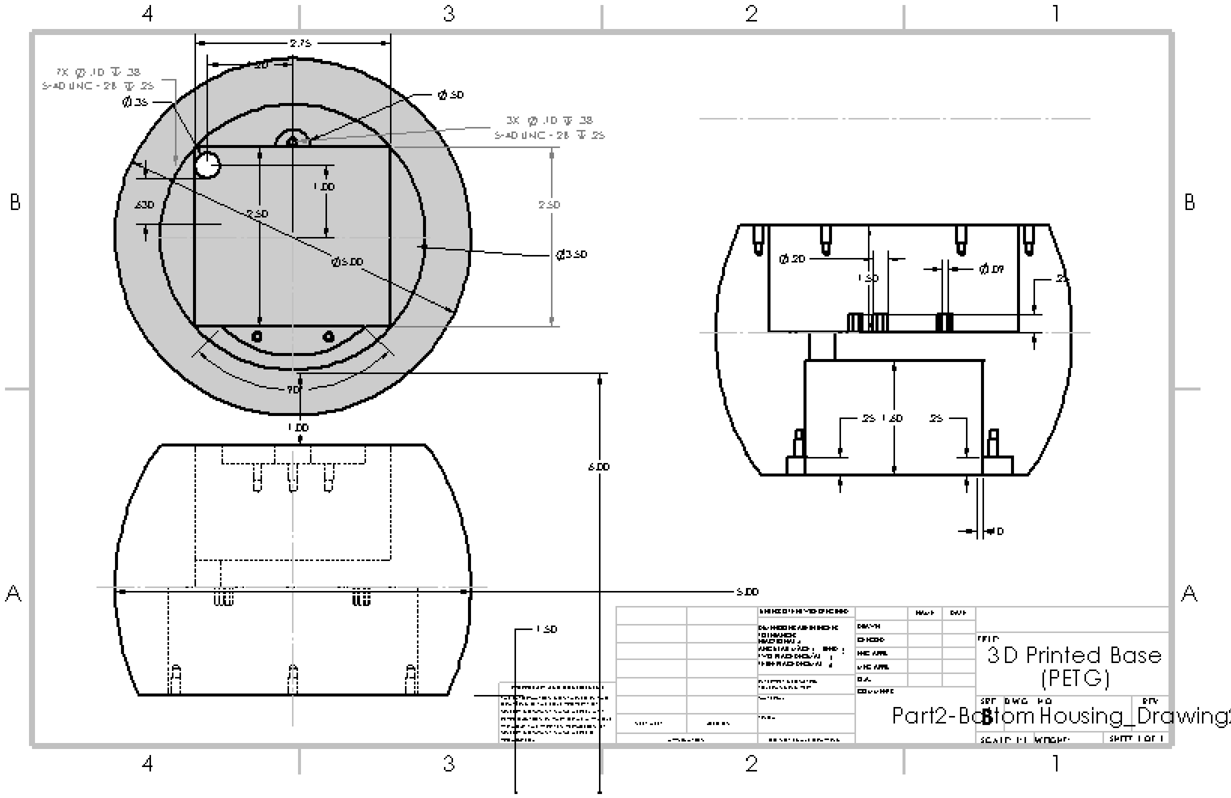
Final Part Drawings



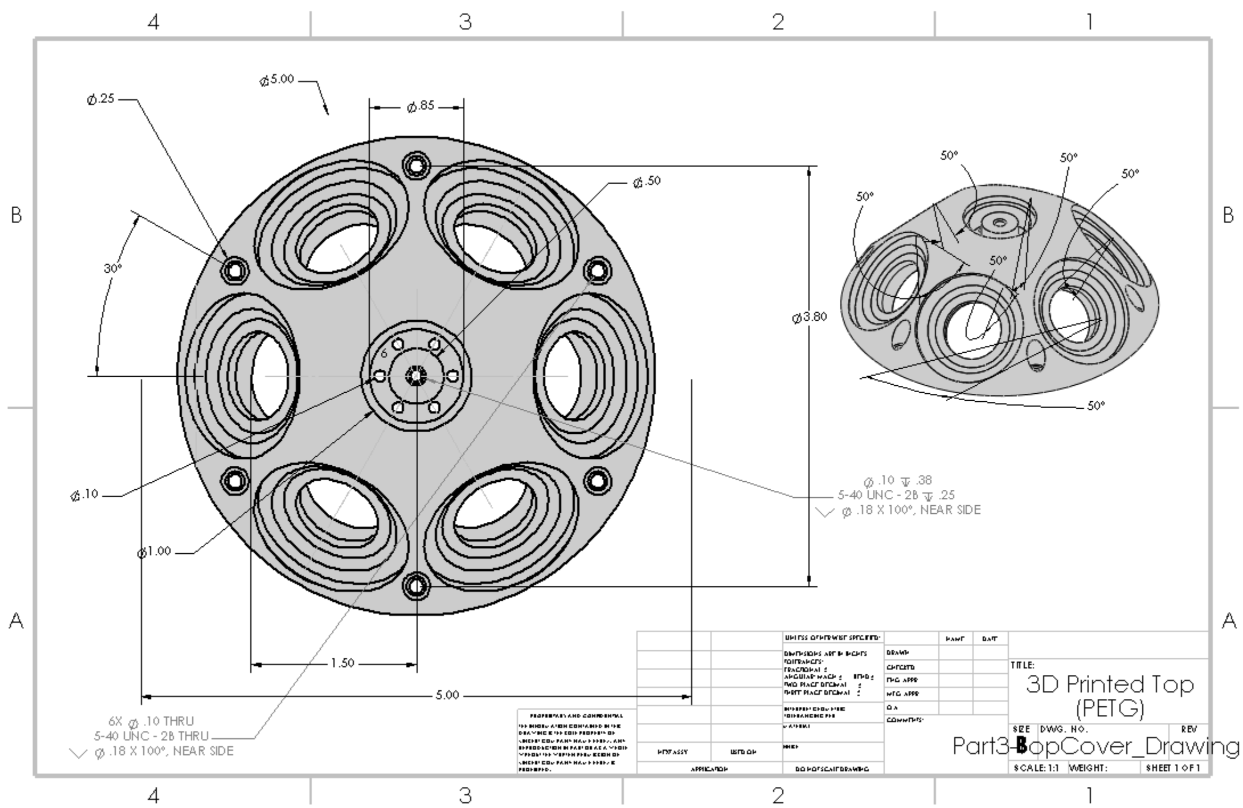
2.74
.25
.25
.25
.05
2X ⌀ .10 ↧ .33
5-40 UNC - 2B ↧ .25
⌵ ⌀ .28 X 100°, NEAR SIDE
2.00
90°
1.00
2.49
.80
2.00
.15
⌀.48
⌀ .10 ↧ .33
5-40 UNC - 2B ↧ .25
⌵ ⌀ .28 X 100°, NEAR SIDE
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
PROPRIETARY AND CONFIDENTIAL
APPLICATION
DO NOT SCALE DRAWING
TITLE:
Battery Housing Cover (PETG)
SIZE DWG. NO. REV
B
Part1-BottomCover
SCALE: 2:1 WEIGHT: SHEET 1 OF 1



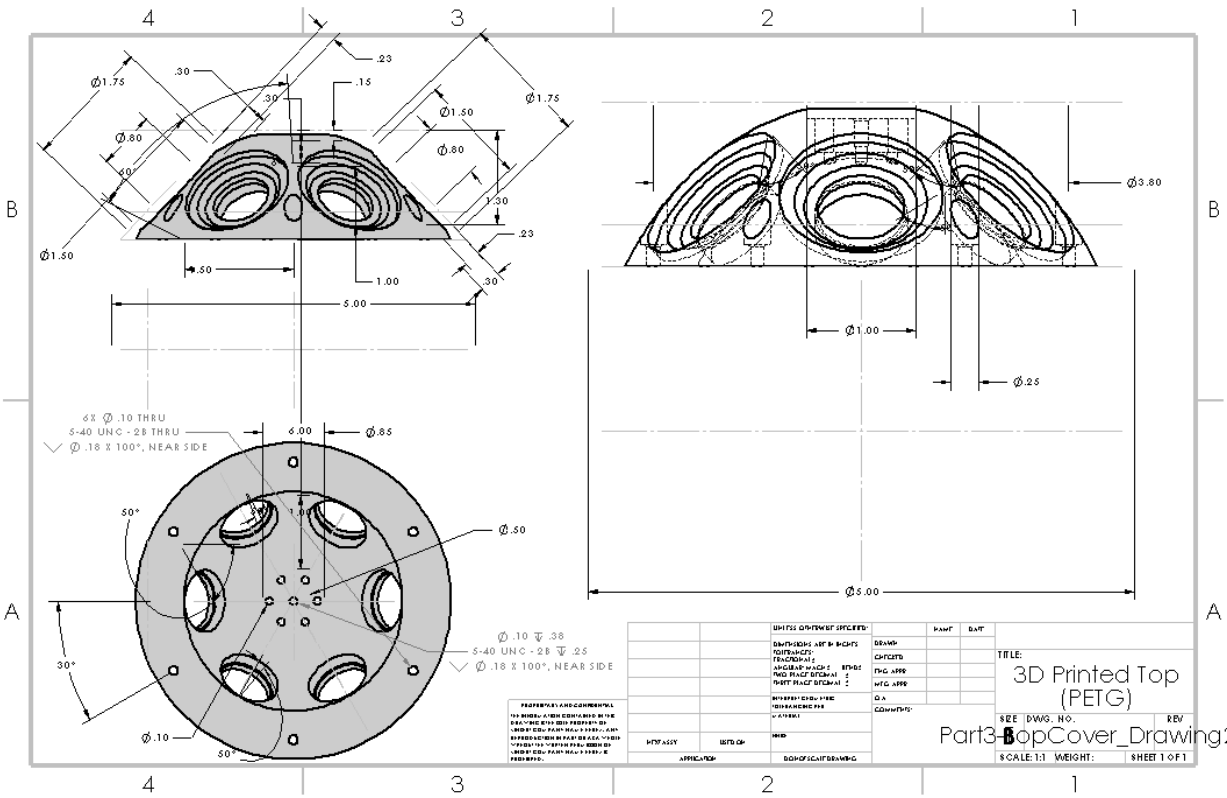
1.50
5.00
6.00
1.00
2.19
.148
2.00
⌀5.00
⌀.09
⌀3.50
⌀.09
⌀.20
⌀.20
.10
.092
.10
1.64
⌀.20
⌀.09
.127
⌀.20
⌀.09
3X ⌀ .10 ↧ .38
5-40 UNC - 2B ↧ .25
2.50
.630
1.00
⌀.35
.285
.156
1.20
7X ⌀ .10 ↧ .38
5-40 UNC - 2B ↧ .25
2.75
⌀.50
.10
UNLESS OTHERWISE SPECIFIED:
TITLE:
3D Printed Base (PETG)
SIZE DWG. NO. REV
B
Part2-BottomHousing_Drawir
SCALE: 1:1 WEIGHT: SHEET 1 OF 1



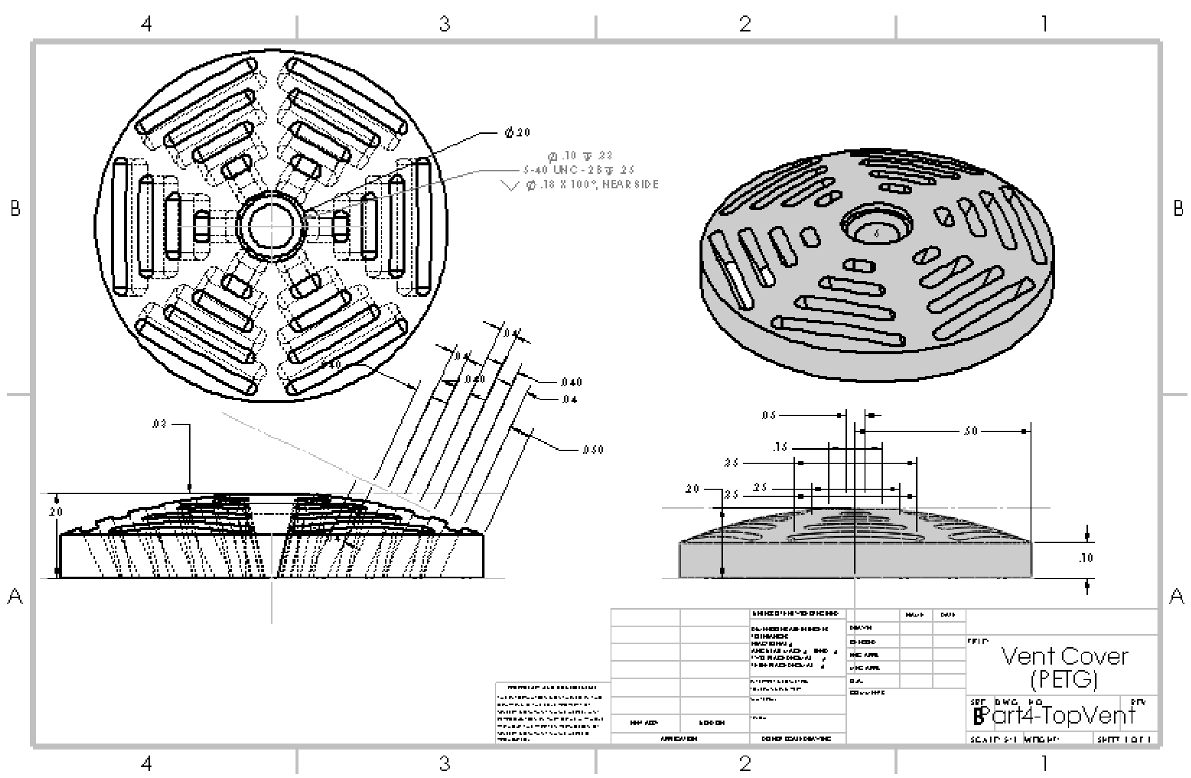
2.75
Ø.50
3X Ø .10 ⊽ .38
5-40 UNC - 2B ⊽ .25
Ø.25
1.00
2.50
Ø5.00
Ø3.50
90°
6.00
5.00
1.50
Ø.20
Ø.07
.25
1.60
3D Printed Base
(PETG)
Part2-Bottom Housing_Drawing2
SCALE: 1:1
SHEET 1 OF 1



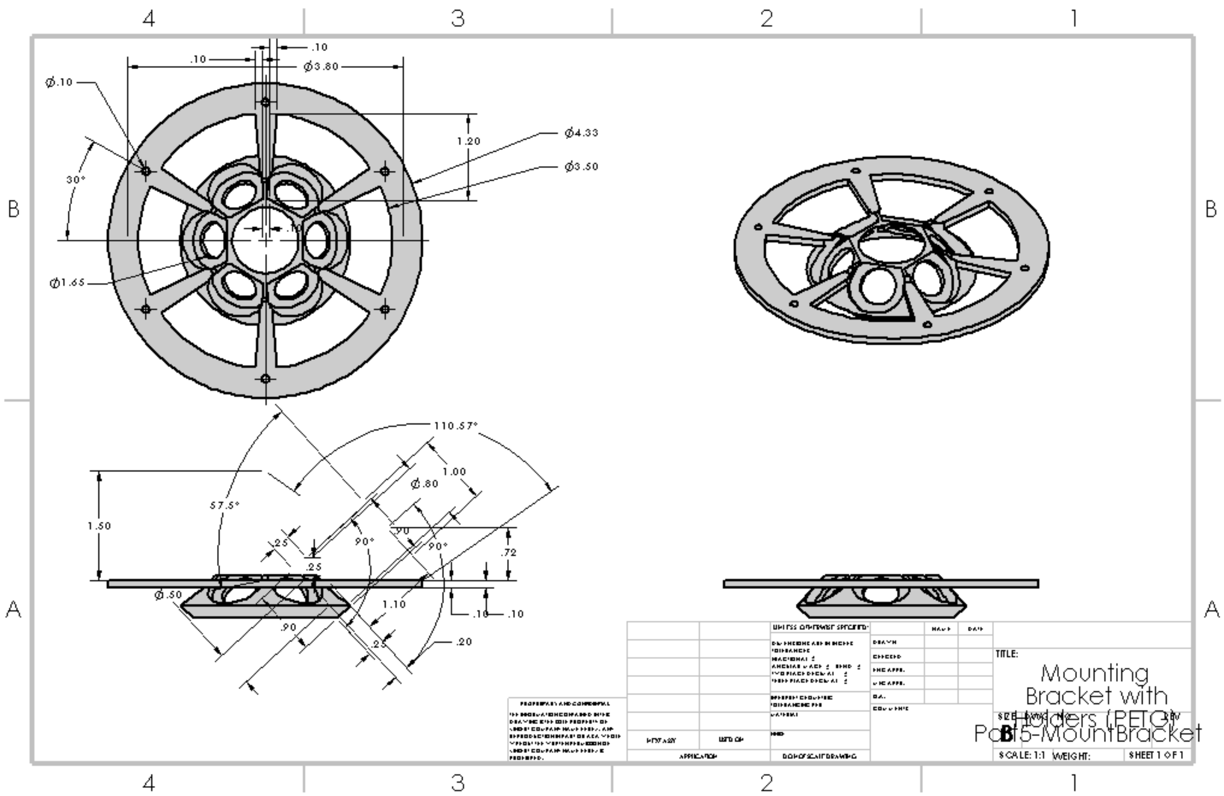
Ø5.00
Ø.25
Ø.85
Ø.50
30°
50°
Ø3.80
Ø.10
Ø1.00
Ø .10 ⊽ .38
5-40 UNC - 2B ⊽ .25
⌵ Ø .18 X 100°, NEAR SIDE
1.50
5.00
6X Ø .10 THRU
5-40 UNC - 2B THRU
⌵ Ø .18 X 100°, NEAR SIDE
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
3D Printed Top
(PETG)
SIZE
DWG. NO.
REV
B
Part3-TopCover_Drawing1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1



3D Printed Top
(PETG)
Part3-TopCover_Drawing2
SCALE: 1:1
SHEET 1 OF 1
6X Ø .10 THRU
5-40 UNC - 2B THRU
Ø .18 X 100°, NEAR SIDE
Ø5.00
Ø1.00
Ø3.80



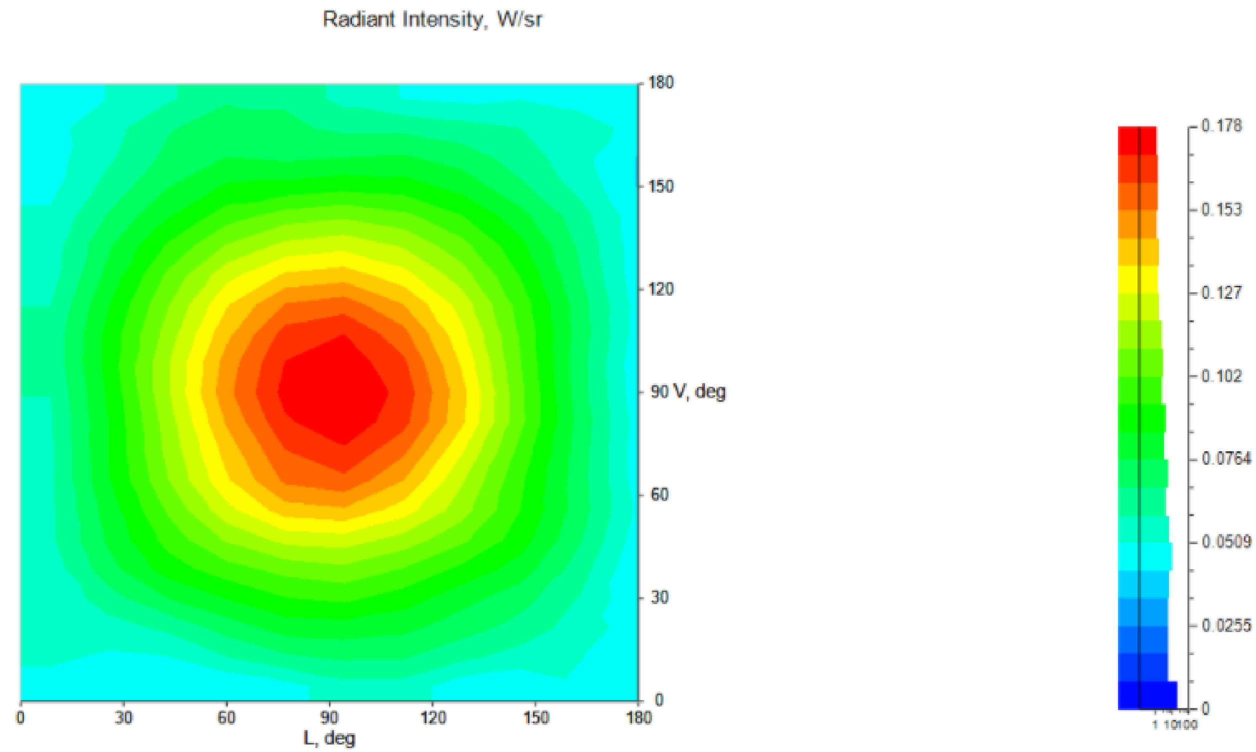
Vent Cover
(PETG)
Part4-TopVent
Ø .10 ↧ .23
5-40 UNC - 2B ↧ .25
Ø .18 X 100°, NEAR SIDE



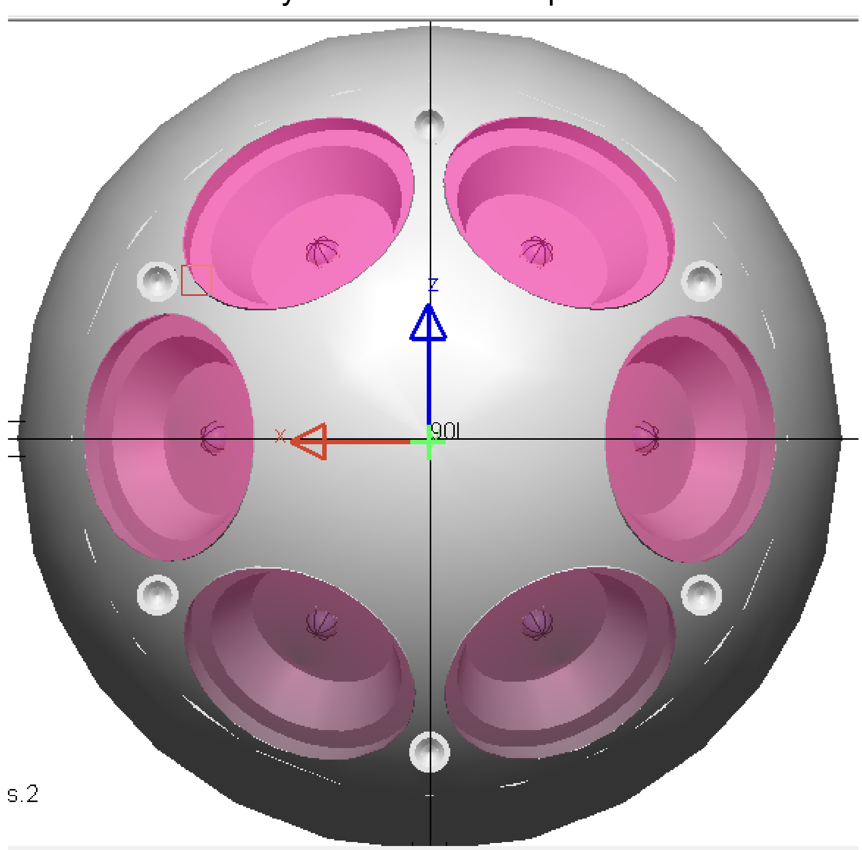
4
3
2
1
B
A
.10
.10
Ø3.80
Ø.10
1.20
Ø4.33
Ø3.50
30°
Ø1.65
110.57°
1.00
Ø.80
57.5°
1.50
.25
90°
.90
90°
.72
.25
Ø.50
1.10
.10
.10
.90
.25
.20
UNLESS OTHERWISE SPECIFIED:
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
TITLE:
Mounting
Bracket with
Holders (PETG)
SIZE
DWG. NO.
REV
B
Part5-MountBracket
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1



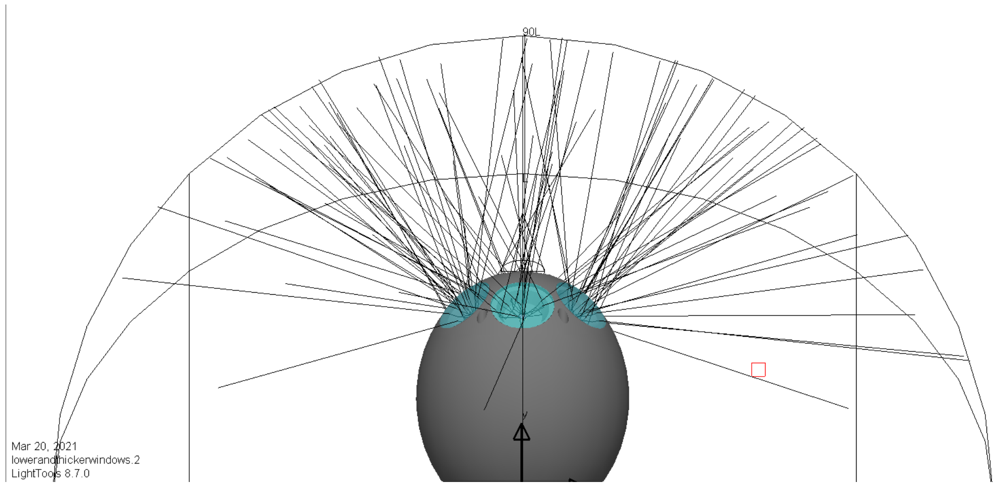

As shown in the three images below, extensive modeling and analysis was done in Lighttools Illumination Design Software. Great care was taken to accurately model the system in every way. According to this model we met all sponsor requirements, but unfortunately our prototype did not meet the model’s optical specifications.



Radiant intensity across the hemisphere field of view



Top down model view



Model view from the side

Acceptance Test Results (Procedure and Data Sheets)

		Verification Method			
		T=Test A=Analysis D=Demonstration I=Inspection			
Requirements	**T**	**A**	**D**	**I**	**PASS / FAIL**
4.1 Performance					
4.1.1 Run Time	X				**PASS**
4.1.2 Operation Function	X				**FAIL**
4.1.3 Operation Control			X		**PASS**
4.1.4 Radiant Power	X	X			**FAIL**
4.1.5 Output Power	X				**FAIL**
4.1.6 Output Angle	X	X			**PASS**
4.1.7 Output Wavelength				X	**PASS**
4.1.8 Modulation	X				**PASS**
4.2 Design Features					
4.2.1 Dimension				X	**PASS**
4.2.2 Shelling				X	**PASS**
4.2.3 Deployment	X		X		**FAIL**
4.2.4 Weight Specification				X	**PASS**
4.2.5 Reuse				X	**PASS**
4.2.6 Temperature	X				**PASS**
4.2.7 Durability			X	X	**FAIL**

Acceptance Test Data Sheet

Requirement under test: 4.1.1			
Analysis Referenced (for verification by T/A): Test			
Name of Test: Run Time			
Unit Under Test (UUT): STrOBe			
Results (Pass / Fail): Pass		Date of Test: 4/26/2021	
Recording of Test Measurement: 30 minutes	Requirement (SRD, with Tolerances): 30 minutes	Test Equipment Error:	Adjusted Test Limit:
Computations, (Include Analyses Results, if any): The strobe lasted over 30 minutes specifically around the 34 minute timestamp.			

Signatures:

Tester Jeremy Dauer, Kayla Filipek

Customer ______________________

Acceptance Test Data Sheet

Requirement under test: 4.1.3

Analysis Referenced (for verification by T/A): Test

Name of Test: Operation Function, Pulse Repetition Rate

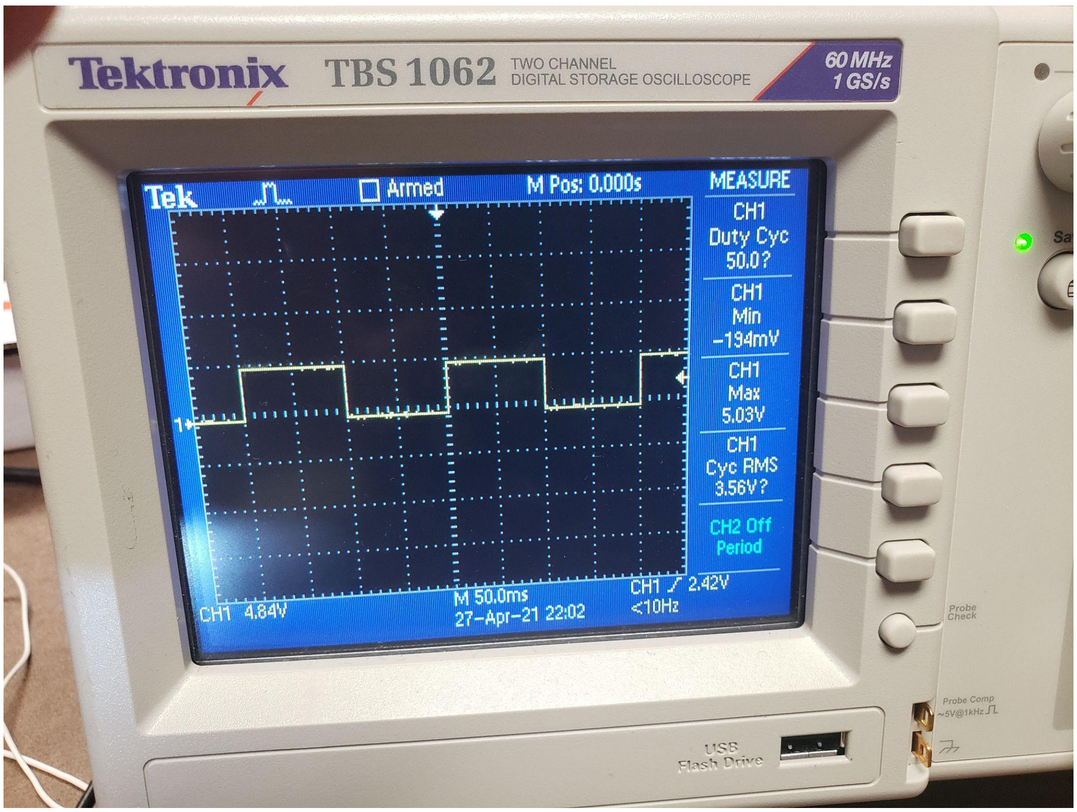
Unit Under Test (UUT):

STrOBe

Results (Pass / Fail): Pass	Date of Test: 4/27/2021

Recording of Test Measurement: 50% duty cycle	Requirement (SRD, with Tolerances): 50% duty cycle	Test Equipment Error:	Adjusted Test Limit:

Computations, (Include Analyses Results, if any):



Signatures:

Tester Lewis Koplon

Customer ____________________

Acceptance Test Data Sheet

Requirement under test: 4.1.4

Analysis Referenced (for verification by T/A): Test

Name of Test: Radiant Power (Variance)

Unit Under Test (UUT):

STrOBe

Results (Pass / Fail):		Date of Test:	
Fail		4/27/2021	
Recording of Test Measurement: 24.6% and 26.6%	Requirement (SRD, with Tolerances): 20%	Test Equipment Error:	Adjusted Test Limit:

Computations, (Include Analyses Results, if any):

2 power measurements were taken across the hemisphere of our 120 degree field of view. Variances were found to be 24.6% and 26.6% with a requirement of 20%.

Signatures:

Tester Jeremy Dauer, Kayla Filipek

Customer ______________________________

Acceptance Test Data Sheet

Requirement under test: 4.1.5

Analysis Referenced (for verification by T/A): Test

Name of Test: Output Power

Unit Under Test (UUT):

STrOBe

Results (Pass / Fail): Fail	Date of Test: 4/27/2021

Recording of Test Measurement: .4mW	Requirement (SRD, with Tolerances): 150mW	Test Equipment Error:	Adjusted Test Limit:
Computations, (Include Analyses Results, if any):			
Signatures: Tester Jeremy Dauer, Kayla Filipek Customer ______________________			

Acceptance Test Data Sheet
Requirement under test: 4.1.6
Analysis Referenced (for verification by T/A): Test
Name of Test: Output Angle

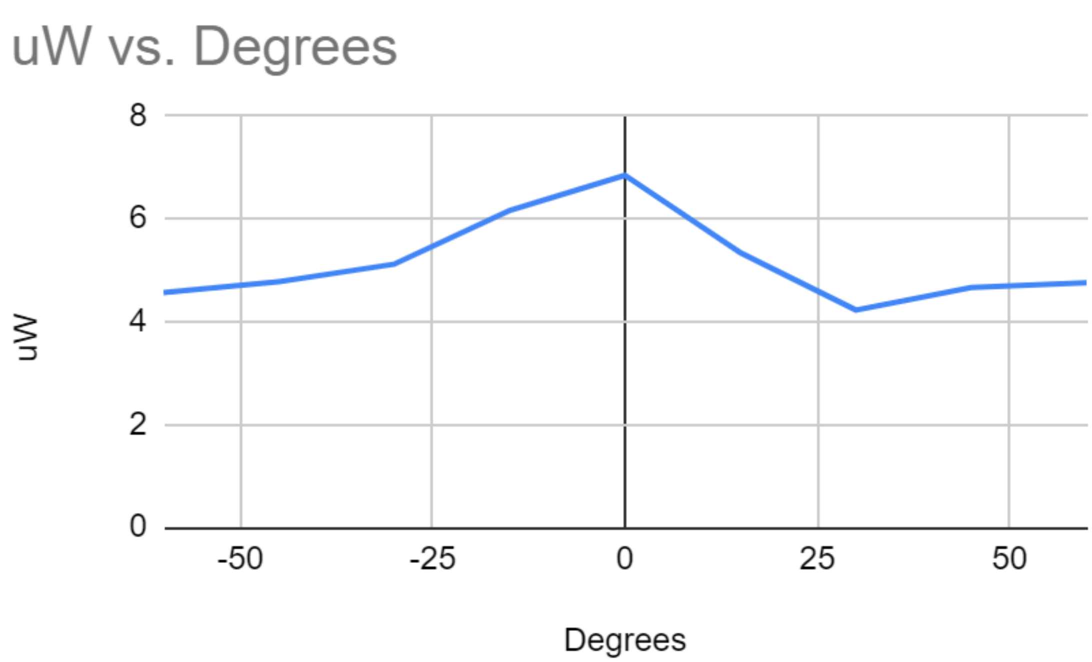
Unit Under Test (UUT):

STrOBe

Results (Pass / Fail): Pass	Date of Test: 4/27/2021

Recording of Test Measurement: 120 degrees	Requirement (SRD, with Tolerances): 120 degrees	Test Equipment Error:	Adjusted Test Limit:

Computations, (Include Analyses Results, if any):



Signatures:

Tester Jeremy Dauer, Kayla Filipek

Customer ____________________

Acceptance Test Data Sheet

Requirement under test: 4.1.8

Analysis Referenced (for verification by T/A): Test

Name of Test: Modulation

Unit Under Test (UUT):

STrOBe

Results (Pass / Fail): Fail	Date of Test: 4/27/2021

Recording of Test Measurement: CW and 5hz frequency	Requirement (SRD, with Tolerances): CW and up to 100hz pulse frequency	Test Equipment Error:	Adjusted Test Limit:
Computations, (Include Analyses Results, if any): With more time the code can be updated to include more frequency cases.			
Signatures: Tester Lewis Koplon Customer ____________________			

Acceptance Test Data Sheet
Requirement under test: 4.2.3
Analysis Referenced (for verification by T/A): Test
Name of Test: Deployment

Unit Under Test (UUT):

STrOBe

Results (Pass / Fail): Fail	Date of Test: 4/27/2021

Recording of Test Measurement: Catastrophic failure, total structural breakdown	Requirement (SRD, with Tolerances): Function normally after being dropped from 6 ft.	Test Equipment Error:	Adjusted Test Limit:

Computations, (Include Analyses Results, if any):

Signatures:

Tester Jeremy Dauer, Kayla Filipek

Customer ______________________________

Acceptance Test Data Sheet

Requirement under test: 4.2.6

Analysis Referenced (for verification by T/A): Test			
Name of Test: Temperature			
Unit Under Test (UUT): STrOBe			
Results (Pass / Fail): Pass		Date of Test: 4/26/2021	
Recording of Test Measurement: 31.16 Celsius	Requirement (SRD, with Tolerances): 100 Celsius	Test Equipment Error:	Adjusted Test Limit:
Computations, (Include Analyses Results, if any):			

Signatures:

Tester Jeremy Dauer, Kayla Filipek

Customer ______________________

Final Budget

Throughout the duration of this project timeline, team 21057 has utilized a total of ~$2,227.29 , from the allocated budget of $4,000.00. The most expensive items purchased were the 1550 nm infrared emitters from Shining LED, China. A total of three purchases were made for these emitters, totaling ~$1,340.19, through Alibaba. All purchased items were ordered from the most convenient supplier, considering cost, reliability, product quality, and lead times. Most purchased items were utilized or are currently in use by a prototype. A few purchases were made with personal funds by team members and were requested for reimbursement from the team's allocated budget.

Date	Vendor	Description	Quantity	Expenses	Date	Vendor	Description	Quantity	Expenses	
11/18/20	Alibaba	1550 nm Diodes	6	$503.02	3/30/21	OSH Park	2 Layer PCB Board	3	$39.10	
1/20/21	Amazon	1/2" 5-40 Screws	100	$14.12	3/30/21	Alibaba	1550 nm Diodes	5	$424.67	
1/27/21	ThorLabs	ND Filter Lens	1	$78.59	4/8/21	Digi-Key	23 AWG Wiring Spool	1	$45.48	
1/28/21	Digi-Key	Current Regulators LM317T	12	$16.61	4/13/21	Amazon	Weldon #4	1	$15.95	
2/3/21	TEDSS	Resistors 1.7 Ohm 5w 1%	6	$41.35	4/13/21	Alibaba	1550 nm Diodes	5	$412.50	
2/5/21	Amazon	Plexiglass 1/8 inch thick	1	$11.95	4/13/21	UA Library	UA 3D Print ABS (Final LED Housing)	1	$88.80	
2/9/21	Amazon	Organizer HC-05 BT 3 Pack	1	$7.90	4/14/21	OSH Park	2 Layer PCB Board Updated	6	$79.50	
2/23/21	Amazon	3-pck Battery Housing	1	$6.07	4/19/21	Amazon	TO-220 Heatsink+Insulator/Mounting	1	$6.99	
3/4/21	Amazon	3 Pack Pro Micro ATmega32U4	1	$13.69	4/19/21	Mouser	Gravitech 2.54MM .1"	10	$19.40	
3/5/21	Amazon	Digital Multimeter	1	$13.02	4/19/21	3D Hubs	Final Housing (PETG)	1	$155.40	
3/11/21	Amazon	Professional Crimping/Multi-Tool	1	$6.99	4/20/21	Digi-Key	Connection RCPT	6	$4.68	
3/11/21	Amazon	Bread Board Jumper Wires	1	$14.53	4/20/21	Digi-Key	Connection Header	6	$4.82	
3/13/21	Mouser	5 Different Resistors for Testing	5	$86.68	4/20/21	Digi-Key	Connection Socket 18-24 AWG	6	$4.66	
3/18/21	UA Library	UA 3D Print (HIPS) P1	1	$54.25	4/26/21	Amazon	TO-220 Heatsink	1	$9.22	
3/24/21	UA Library	UA 3D Print (HIPS) P2	1	$11.50	4/26/21	Amazon	6V Battery Holder Double A (Single Layer)	1	$6.99	TOTAL:
3/26/21	Amazon	Nano Board ATmega328P 3 Pack	1	$13.99	4/26/21	Amazon	6V Battery Holder Double A (Double Layer)	1	$7.58	$2,409.58
3/27/21	Amazon	Thermal Tape	1	$8.69	4/26/21	Mouser	2W 1.8 Ohm 5% Metal Film Resistor	30	$15.46	
3/27/21	Mouser	Low Power Mosfets	10	$21.89	4/26/21	Amazon	TO-220 Heatsink	1	$9.22	LeftOver:
3/29/21	Mouser	15 Pin Female Header	1	$14.29	4/26/21	Amazon	24-Pack Bevigor AA lithium Batteries	1	$26.89	$1,590.42
3/29/21	Digi-Key	MOSFET N-Channel	5	$13.25	5/1/21	Smartsheet	Software Program Charge	1	$48.67	
3/30/21	Digi-Key	Orion 30mm Fan	1	$17.53	5/2/21	Amazon	HiLetGo HC-05 BT Module	1	$13.69	

Lessons Learned

After two semesters of itemizing, designing, building, and testing, team 21057 learned many lessons which the members can utilize in their future professional engineering careers.

The first of which was reaching out for assistance when needed. Time is almost always going to be scarce. Therefore, the team learned that as soon as they ran into problems in their project, they had to request assistance from peers, professors, mentors, and sponsors for advice on how to resolve any issues. During this project there were always enough resources available, but the team had to learn that it was okay not to always immediately understand how to resolve certain issues, so reaching out for assistance was normalized. The second learning outcome the team incorporated was to stay up to date with sponsor(s) for the duration of the project. As the semester progressed, there were certain project requirements which our sponsor wanted us to focus on more than others. Moreover, as the project was coming to an end, we put an emphasis on testing the requirements that mattered most to our sponsor over the requirements which were of lower priority. Additionally, because we were constrained by budget and time, our sponsor recommended using less durable material for testing. This was with the understanding that with time and budget permitting we would have used a more durable material. Issues are always going to arise such as delays in shipping. Therefore, the customer must always be up-to-date on any problems so when the project comes to a close, they understand why certain expectations may not have been met.

The third and fourth project learning outcomes were very similar. The third lesson was for the team to make purchases early and ahead of schedule, and the fourth was to follow-up on orders with the purchasing department. We learned that delivery time is never guaranteed, as we experienced lots of delays in shipping due to the Coronavirus pandemic. Some of our parts took more than two months to arrive and some parts were delivered to the wrong address. This made it vital to double-check the addresses the purchasing department had on file for orders, and it was necessary to stay in contact with the delivery team to ensure that the order was received by the team in time for testing.

The final two project learning outcomes fall hand-in-hand. The first was to meet and communicate often as a team, and the second was to have an agenda for meetings and stick to it. We learned early on in the project that there was always going to be work for us to do as a team because in addition to working with the customer deliverables, we had to ensure that all class assignments were completed to their entirety as well. Often, we would have multiple things due in a week therefore it was beneficial to the team to meet often to work on each of these items. Moving forward with the last learning outcome, it was important to stick to an agenda during team meetings because of how much work needed to be done. By having an agenda, we were able to understand exactly what needed to be done during the meetings which resulted in more productive sessions.

Summary

The STrOBe’s intended use was to mark targets in the field for those equipped with SWIR vision capabilities. The STrOBe had to be a remotely controllable handheld device that emitted in the 15XX wavelength range (the team decided upon 1550 nm). The device was meant to emit over a near hemispherical field of view with less than 20% variance over the field at an output power of 150 mW. The STrOBe was meant to be able to be deployed in a variety of environments by a variety of methods, while landing emitter-side up, even on surfaces with an incline up to 45 degrees. It also needed to be reusable, and have a run time of 30 minutes. Ten out of the fifteen total sponsor-given requirements were satisfied. The satisfied requirements include the remote control abilities, the run time length, field of view, overall size, reusability, dusty cycle, and the device's maximum internal temperature.

The following summarizes the five failed requirements (and their corresponding tests) and suggested improvements to facilitate future success.

Deployment and Durability:

The STrOBe remained fully functional through 12 drops from a height of 6 ft, with 8 of them being on grass and the final 4 being dropped onto dirt. With the 13th drop onto dirt, the STrOBe underwent structural failure and broke into three main pieces: the top portion of the STrOBe detached from the bottom half, one of the plexiglass windows detached from the housing, and the circular mounting bracket that mechanically held the emitters and heat sinks in place broke from the inner part of the top of the housing. It was determined that the main reason for the detachment of the upper section from the bottom section of the housing was that the screws did not properly attach the two portions of housing--instead of biting into the plastic keeping it together, the screw threads damaged the plastic and pulled out. To rectify these problems, the team suggests creating the housing out of machined aluminum, as initially proposed. This would make the housing both more durable and would have better compatibility with screws as an attachment method. To ensure the windows remain attached, a different adhesive with a stronger bond strength should be used. Redesigning the inner mounting bracket as to have thicker (thus, stronger) arms to support the emitters, as well as adding structural reinforcements, would keep this part of the housing from breaking.

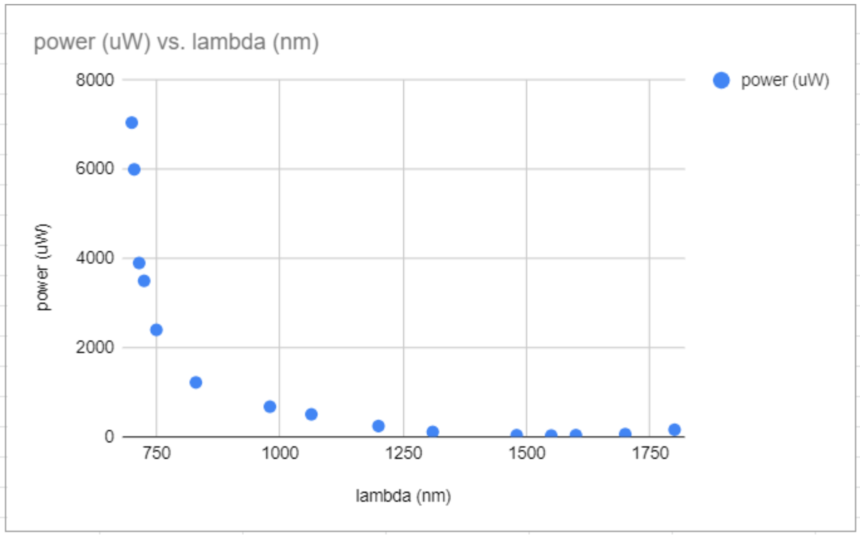
Radiant Power:

The variance of the power over a near hemisphere (ranging from -120 degrees to +120 degrees) was measured over two cross-sections. Across one cross-section the variance was 24.6% and across the other cross-section was 26.6%. This failed to meet the maximum allowable variance specified by the sponsor of 20%.The variance may have been over the acceptable range because the variance was measured using a STrOBe model that had two emitters that were nonfunctional (ie, no longer emitting). To get an accurate representation of the variance across the field, a fully functional STrOBe should be used for testing.

Output Power:

The ideal output power was 150 mW and the output power measured was 0.4 mW. Again, some of this may be due in part to two of the emitters being nonfunctional, but this is still too much of a deviation from the expected value to fully attribute it to that. After further testing of the emitters, it became evident that they were not emitting at the peak wavelength reported by the specification sheet. As you can see in the figure below, the peak emission wavelength was roughly 700 nm and not at 1550 nm as ordered:

lambda (nm)	power (uW)
1550	29
1480	37
1310	110
1200	242
1064	505
980	677
830	1220
700	7050
1700	61
1800	160
1600	38
750	2400
725	3500
715	3900
705	6000



To improve upon this, it is critical to test the emitters early to ensure that the ordered components match their expected specifications. This also emphasizes the importance of ordering components from a reputable supplier.

Operation Function:

While the pulse modulation was working at both continuous wave (CW) and at 5 Hz, there were not enough incremental frequencies between CW and 100 Hz tested to emphatically pass this requirement. Given more time, the code could be updated to include more frequency cases. Since the code was working for CW and 5 Hz (confirmed using an oscilloscope), there is no reason to believe that the proper functionality would not extend to the other frequencies.

As the project is finishing up, the team plans to send out the following deliverables to our sponsor, Elbit Systems of America:

- System Requirements Document
- Technical Data Package (TDP)
- Integrated Development Environment
- Software Code, SDD
- Engineering Notebook -
  Drawings, Schematics, Test Data Sheets, Models, Analyses, etc.
- Prototype Product -
  STrOBe, 2+ MicroControllers
- System Requirements Verification Matrix

- Final Report
- User's Manual

All deliverables will be sent out via fedex and/or UPS by May 14th, 2021.

Appendices

Appendix A: User's Manual

Operating Manual

1. How to Power Prototype on
    a. Download the companion app to a bluetooth compatible device that will be used to control the STrOBe.
    b. Insert batteries into their respective compartment in the base of the housing shortly before powering on the STrOBe.
    c. Enable bluetooth functionality on the operating device (i.e., smart phone) via the settings app and pair said device to the STrOBe. The STrOBe should now be connected to the device.
    d. Repeat to pair the desired number of individual STrOBe units you wish to use/control. The maximum individual STrOBe units that can be supported per app/operating device is three.
    e. To operate the application see section ii.
2. How to operate the app
    a. Download the app, Bluetooth Terminal, from the Google store on your android phone
    b. Open it
    c. Navigate the menu to find the "Make insecure connection"
    d. Connect your phone to the STrOBe by picking which device you had previously found in your bluetooth settings.
    e. The options for STrOBe function that can be adjusted through the app are powering it on and off and adjusting the pulse repetition rate from CW to 100 Hz. Press a and send to turn the STrOBe to continuous wave mode, press b and send to turn the STrOBe to its flicker mode (5hz), and finally press c and send to turn the STrOBe off.
3. How to Power off

a. To turn the STrOBe off press c on the keyboard of the bluetooth terminal application and press send. Doing this will only turn the emitters on, to turn the microcontroller off follow step 2.
b. Remove batteries to increase battery lifetime and prevent the device from idling waiting for a command from the remote.
c. For Reusing the STrOBe
d. The batteries will need to be replaced after each 30 minute runtime.
e. For Reuploading the Code to the Microcontroller
f. To install CH340G drivers which is usually needed for boards sourced not from the Arduino site, this step is unnecessary for boards from the Arduino site:
    i. Download the Driver labeled as Windows CH340 Driver
    ii. Unzip the file
    iii. Run the installer which will be in the unzipped file
    iv. In the Arduino IDE when the CH340 is connected you will see a COM Port in the Tools > Serial Port menu, the COM port will vary per device
g. Next we are going to download the ZIP file from github and download the Arduino IDE as well.
    i. https://github.com/lewisk1899/IRSTrOBe.git
h. When uploading to the board, a usb connection must be facilitated through a Mini-B USB cable.
i. In order to upload it to the arduino, use the arrow key labeled as upload in the Arduino IDE, if the code is uploaded successfully you are ready to operate. If not, please check your CH340G drivers.

Maintenance Manual

4. What to do if prototype loses power
    a. Replace the batteries.
    b. What to do if an emitter is not working
    c. Identify which emitter (or emitters) are no longer functional. Each of the emitters can be replaced individually, as they are supported by their own branch of electronics and their functionality does not affect the other emitters.
    d. Unscrew the top of the housing from the bottom.
    e. Remove whichever emitter/heat sink combinations are no longer working. This may require using a soldering iron and solder sucker to remove the wires from the burnt-out emitter(s).
    f. Solder the new emitter/heatsink combinations in place wherever the old ones were removed.

g. Ensure they are held in place properly using the inner supports that mechanically hold the emitters in place.
h. Place the top of the housing back on the bottom of the housing and screw into place.

5. What to do if the app is not working
    a. Ensure the user is within a 15 foot range to allow for a stable bluetooth connection between the STrOBe and controller.
    b. How to replace all 12 batteries
    c. Unscrew the battery panel on bottom of device
    d. Remove the battery housings from the bottom of the STrOBe, being careful not to tear any wires.
    e. Remove spent batteries.
    f. Replace with fresh batteries.
    g. Screw the battery panel back onto the device.

Procedures for Optimum Performance:

h. Avoid dropping the device from a height greater than 6 feet above the target surface.
i. Avoid dropping the device onto an incline with a slope greater than 45 degrees.
j. Avoid contact with water, as this can damage the internal electronics.
k. Avoid prolonged exposure to sunlight or extreme temperatures, as this can cause the device to overheat and cause damage to the emitters and/or microcontroller.
l. While the STrOBe is eyesafe, avoid prolonged eye exposure to emitters. Do not stare at the emitters for more than 30 minutes.
m. Use the STrOBe only for its intended use.