KGCoE MSD — Technical Review Agenda

Azamat Boranbayev   Nick Liotta   Mike Miranda   Sigitas Rimkus
Alex Usachev

P11543: Variable LED Hemispherical Imager

Meeting Purpose: Detailed design review of P11543 – Variable LED Hemispherical Imager. The objectives of this are to present and receive feedback from others about our final design and bill of materials.

Meeting Date: February 9, 2011

Meeting Location: 78-2150

Meeting Time: 3:00 - 5:00 PM

Project #	Project Name	Project Track	Project Family
11543	Variable LED Hemispherical Imager	Printing and Imaging Systems	N/A
Start Term	**Team Guide**	**Project Sponsor**	**Doc. Rev.**
20102	Prof. Hanzlik	Dr. Wyble and Dr. Gu	1.1

1 Project Description

1.1 Project Background

The many forms of LEDs are the emerging technology for illumination. Fundamental evaluation and quantification of image appearance as a function of illumination spectrum, intensity, and incident angles require a tunable light source. An illumination cavity consisting of a 1 meter diameter hemisphere is required. The design of the hemisphere will enable repeatable positioning of LED clusters. The hemisphere will be broken into 5 degree increments for both latitude and longitude. The LED cluster will consist of 1-7 LEDs mounted in a repeatable manner to maximize additivity of output. Customer required at least two (2) LED clusters to be operational at any point in time. Additionally, each of the seven LEDs within the cluster should be addressable for intensity and on-off time control. This means up to 14 independent addressable LED outputs. Customer interface should be some user friendly PC window for initial setup and running.

1.2 Objectives and Scope

This project consists of three main objectives:

- Design a hemisphere containing mounting points for multiple LED clusters.
- Design clusters of LEDs in order to project light in the visible spectrum, as well as in the IR and UV spectrums.
- Design a computer-based control system in order to selectively address each LED within a particular cluster.

1.3 Deliverables

A fully functional 1-meter hemispherical LED based illumination system with user manual and all supporting documentation.

1.3.1 Deliverables by Discipline

Electrical and Computer Engineering

- Control system operating 14 LEDs independently for intensity and on-off time.
- Provide user friendly PC window type interface.
- Work with mechanical team to provide a harnessing solution from the hemisphere to the control electronics and the PC.
- Conduct testing of electrical subsystems.

Mechanical Engineering

- Design and development of a 1-meter hemisphere that can mount and locate the LED clusters.
- Development, design, and delivery of a cluster module that holds LEDs in the required geometrical relationship and enables easy movement to other positions of the cluster within the hemisphere.
- Development, design, and delivery of reliable electrical connections and quick disconnect and removal.

1.4 Core Team Members

- Azamat Boranbayev (ME)
- Nick Liotta (EE)
- Mike Miranda (EE)
- Sigitas Rimkus (ME)
- Alex Usachev (CE)

2 Document Outline

This report contains the following items and documents in the order listed below.

- Customer Needs
- Engineering Specifications
- Project Timeline
- Risk Assessment

- LED Cluster Assembly
  - LED Cluster
  - PCB Housing
- LED Control
- Hemisphere

3 Component Overview

3.1 LED Cluster Assembly

The LED cluster will be constructed in order to provide a PCB mounting point for all the LEDs on top of a cylindrical shell which will interface with the geodesic hemisphere. The LEDs will be user replaceable through PCB through-hole connectors and all wire strain relief will be provided by the internal geometry of the cluster housing. All control signal wires will be routed through the housing out to a CPC connector. Cable will be used to provide an interface between the LED control mechanism and the LED cluster.

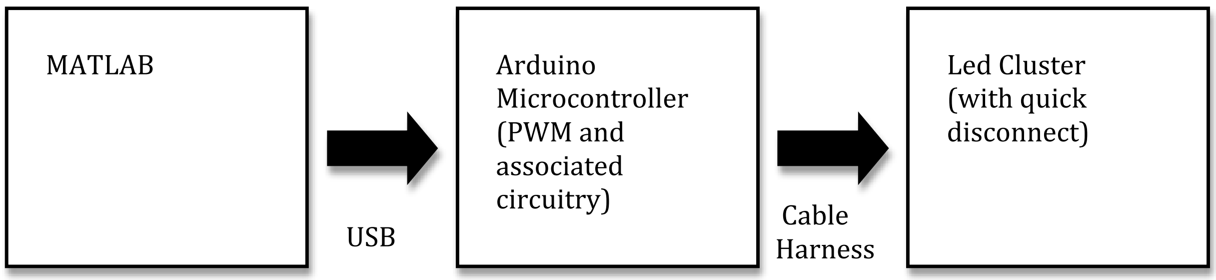
3.2 LED Control

The microcontroller being used in the Arduino Duelminelove. It interfaces with MATLAB to control each LED in the cluster with an 8-bit output allowing the user to alter the intensity of a desired LED as needed. There is one microcontroller used per cluster, providing 6 PWM outputs and one digital output to each cluster. The microcontrollers are stored in a "black-box" which will house communication and power cables, as well as provide easy access to each microcontroller if the need for troubleshooting arises.

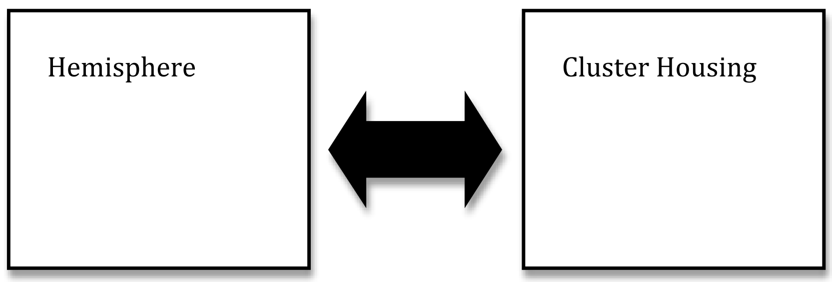
3.3 Hemisphere

The hemisphere is the interface point for the LED cluster assembly. It is used to direct light from the LED cluster onto a designated sample area from various locations. The LED cluster is attached to the hemisphere through the use of magnets embedded into the based of each cluster.

Software/Hardware Design



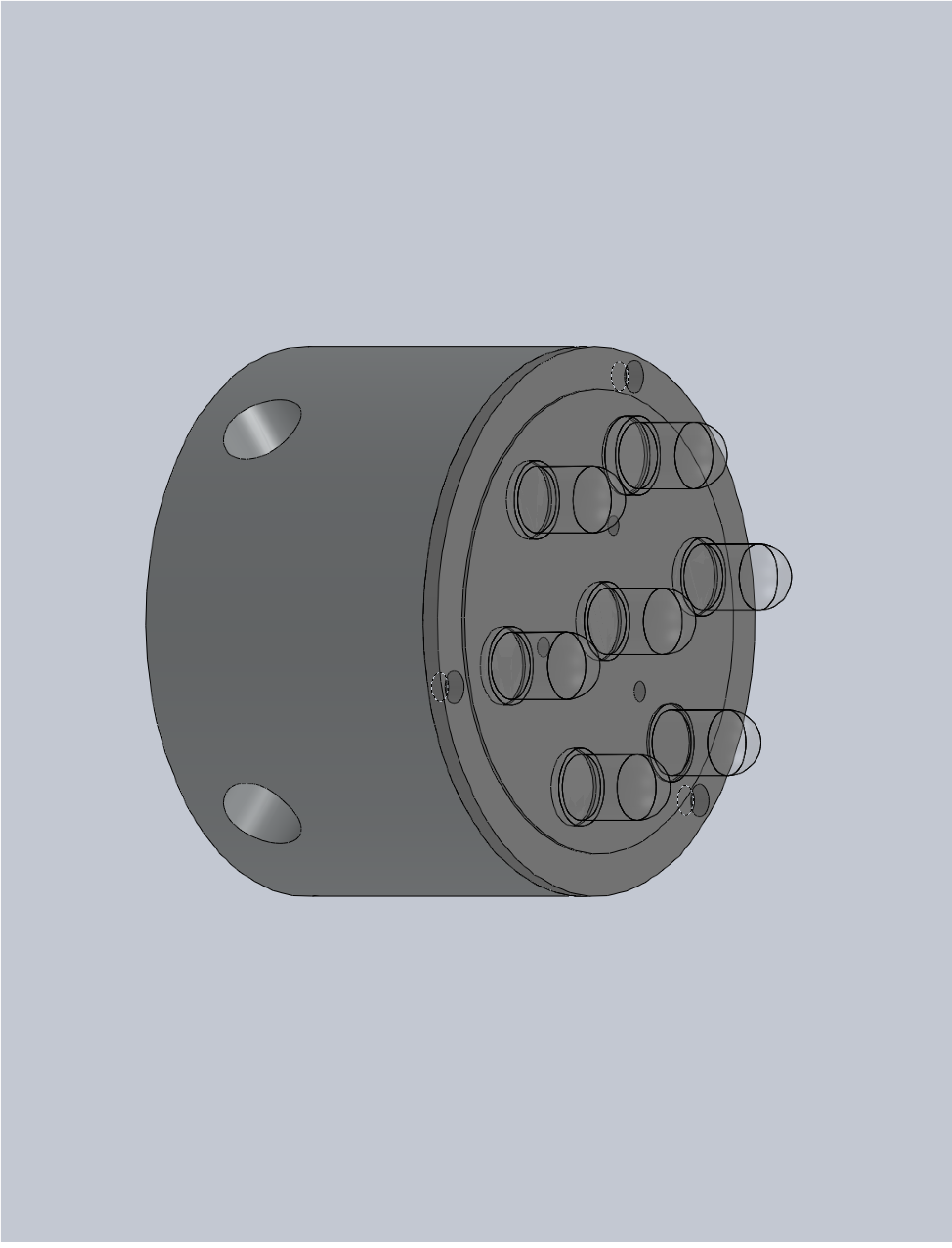
Mechanical Design



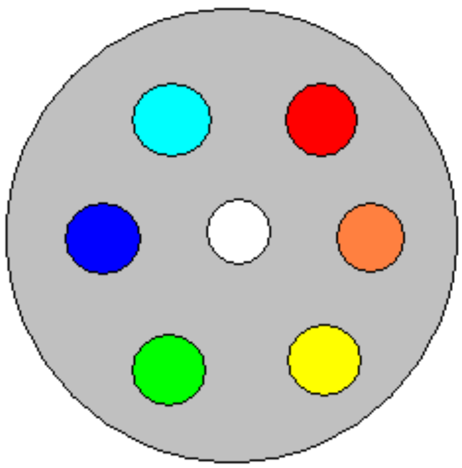
Revision #	3		
Customer Need #	**Importance**	**Description**	**Comments/Status**
		LED Controls	
CN1	5	Control individual intensities of LEDs	PWM
CN2	3	8-bit control	
CN3	3	Serial commands for each LED	
CN4	3	MATLAB software interface	Does not want GUI
CN5	1	No power constraints	
		LED Cluster	
CN6	5	At least 2 clusters of 7 LEDs	Possibility of expansion
CN7	5	Individually addressable LEDs	Adjustable brightness
CN8	5	Cover entire visible light (possibly UV and IR as well)	Visible spectrum more important
CN9	2	Cluster housing	Minimize potential damage to electronics
CN10	5	LED cluster must illuminate sample area	
CN11	4	Individually replaceable LEDs	Avoid need of having to replace entire cluster
CN12	3	Quick, reliable disconnect	
CN13	4	Cluster uniformly illuminates target area	
		Hemisphere	
CN14	5	Dome geometry needs to be a hemisphere	
CN15	5	Repeatable alignment of cluster mounting locations	
CN16	4	Mounting locations identified and labeled	
CN17	2	Minimal weight	Ensure system portability

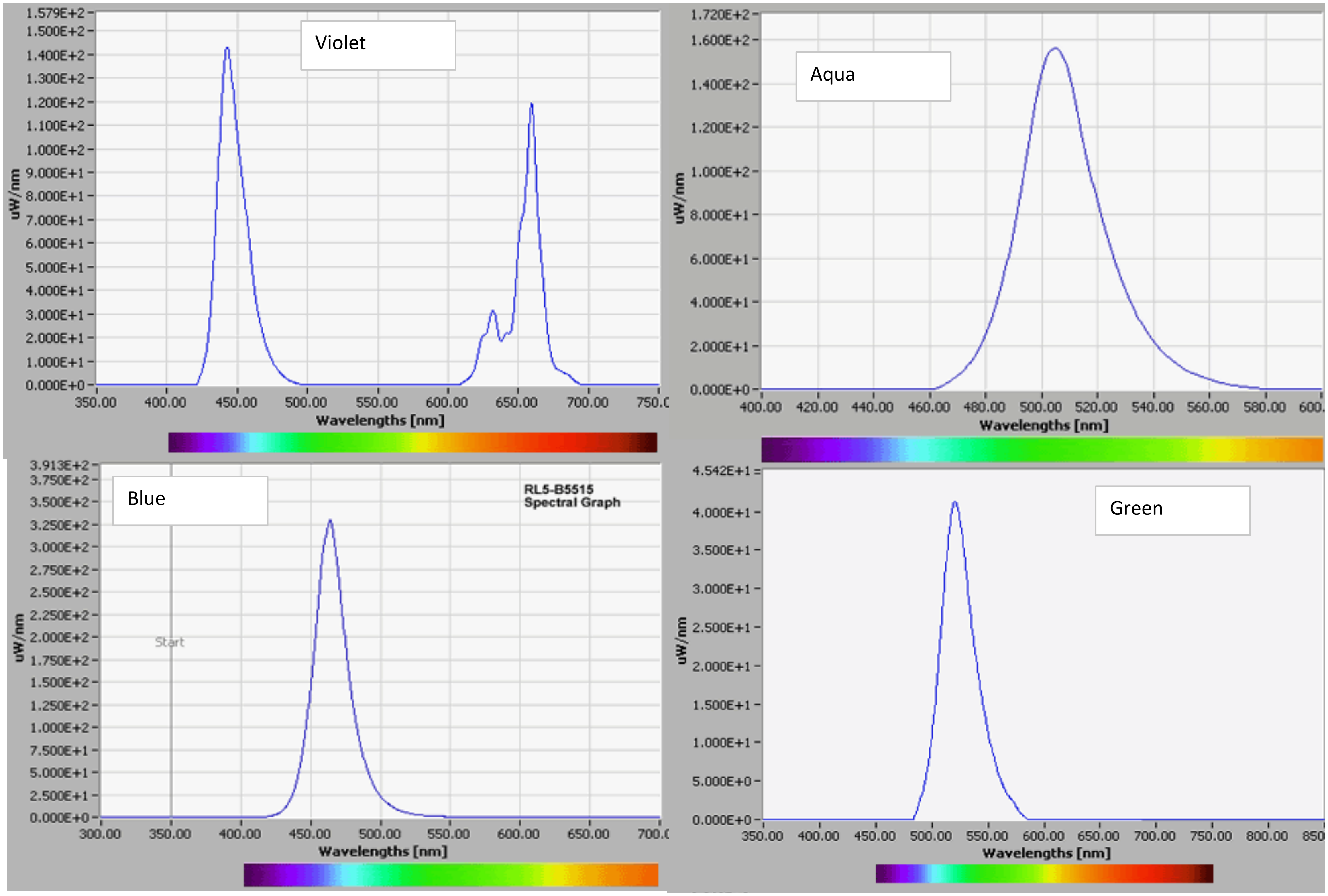
Importance: Scale of 1-5 (1 = preference only, 5 = must have)

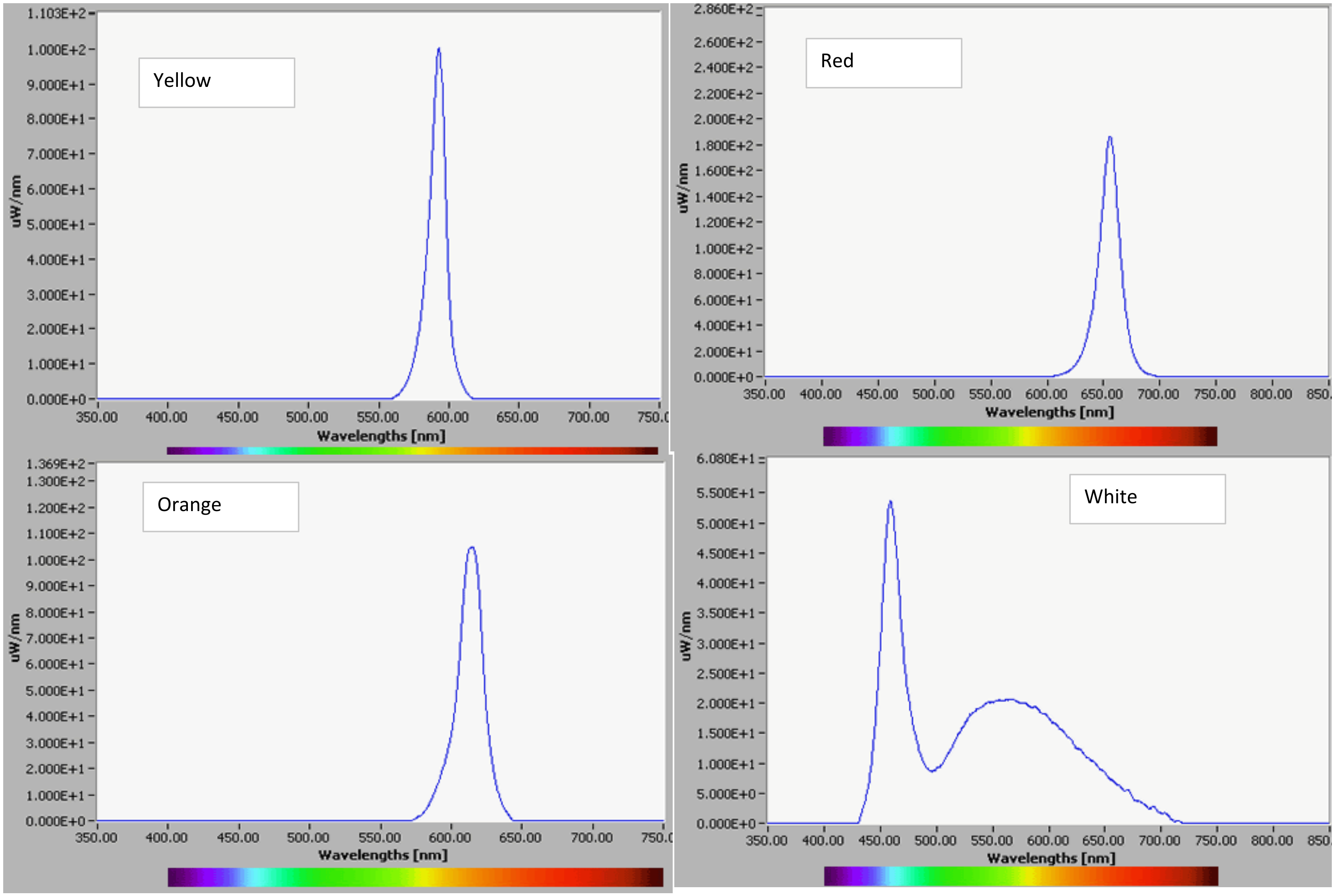
Revision #	3						
Engineering Spec #	**Importance**	**Customer Need #**	**Specification (description)**	**Unit of Measure**	**Marginal Value**	**Ideal Value**	**Comments/Status**
			LED				
1	5	CN7	Individual addressability	Binary	Yes	Yes	Using pulse-width modulation
2	5	CN1/CN3	Individual intensity control	bit	8	8	
3	5	CN6	Amount per cluster	#	7	7	If using UV or IR cluster, 6 can be used since 7th output will be digital
4	5	CN11	Individual disconnect time	sec		<30	
5	4	CN11	Individual replaceability	Binary		Yes	
6	4	CN10	Cone angle	deg	15-20	<18	
7	4	CN10	Casing	mm		5	T1-3/4
8	4	CN10	Individual drive current	mA	15-25	20	
			LED Cluster				
9	5	CN8	Spectral range covered	nm	415-690	400-650	Gaps may appear, especially within the green spectrum
10	5	CN10	Illumination of sample area	Binary		Yes	
11	3	CN9	Casing	Binary		Yes	
12	3	CN13	Casing diameter	cm		<5.1	
13	3	CN6	Amount	#	2	>2	
14	2	CN12	Disconnect time	sec		<30	
15	4	CN13	Uniform illumination	Binary		Yes	Methods still in debate
			Microprocessor				
16	5	CN2	Separate PWM output for each LED	Binary	Yes	Yes	Center LED will be digital, most likely to be white
17	4	CN5	Input voltage	V	6 - 20	7 - 12	
18	3	CN4	USB connection	Binary	Yes	Yes	Arduino microprocessor comes with USB port
19	3	CN4	MATLAB compatibility	Binary	Yes	Yes	No GUI
20	1	CN5	Power constraints	Binary		No	
			Hemisphere				
21	5	CN14	Diameter	m		1	
22	5	CN15/CN16	Measurable location of each node	Binary		Yes	
23	4	CN15/CN16	Number of cluster mounting locations	#		324	~10 degree separation of nodes for longitude and latitude
24	1	CN17	Weight	kg		<14	Light enough to be hand portable

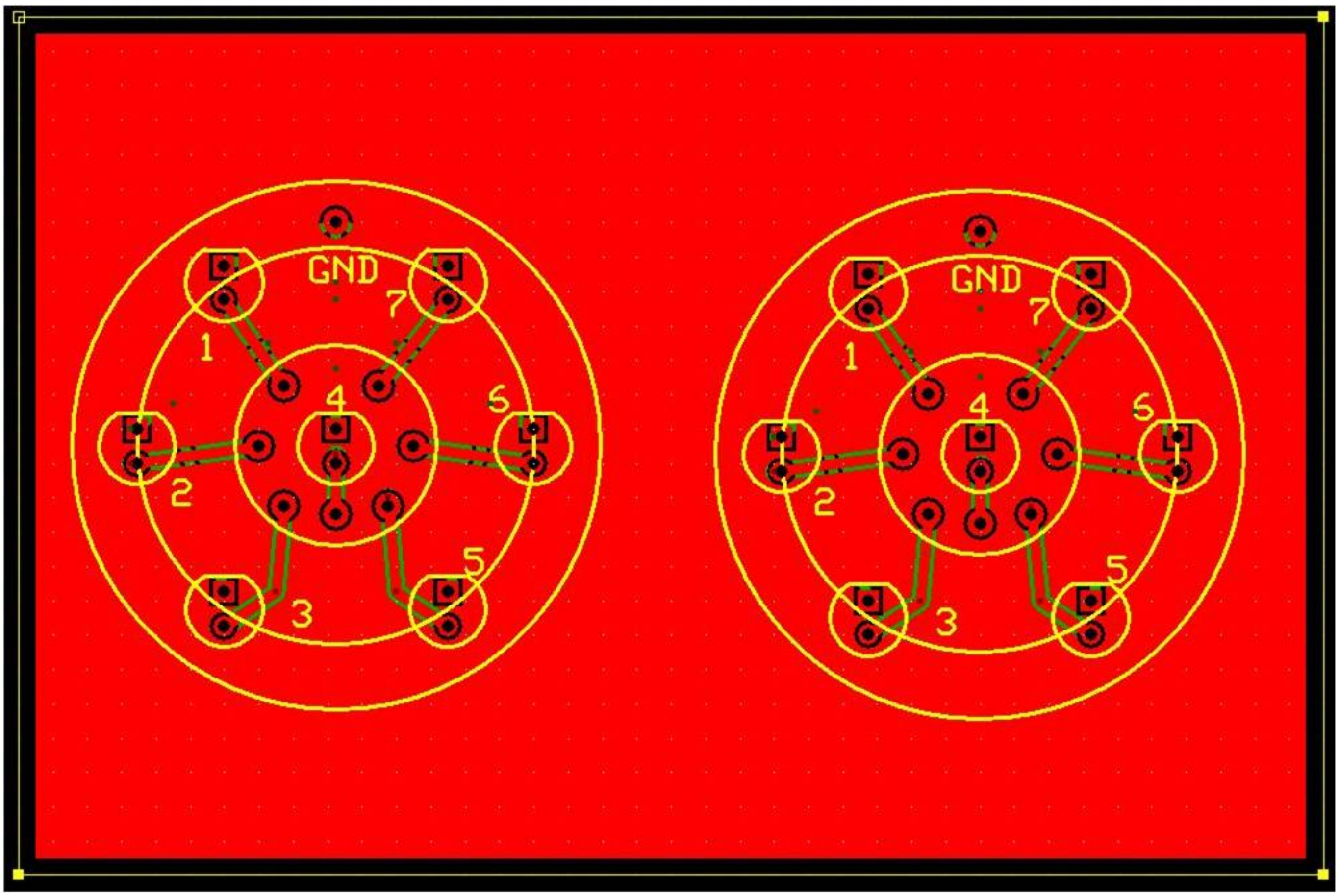


Color	Dominant Wave Length (nm)	Cone Angle	Range	Intensity (mc	Current
UV	380	15		30mW	
Violet	420	15	415-490	1000	20mA
Blue	467	15	420-490	5500	20mA
Aqua	505	18	480-540	9000	20mA
Green	525	20	490-570	8000	20mA
Yellow	590	15	575-610	5600	20mA
Orange	605	15	570-640	5000	20mA
Red	644	15	630-690	5000	20mA
White	x=.29 y=.29	15		18000	20mA




Violet
Aqua
Blue
Green
RL5-B5515
Spectral Graph
Start
uW/nm
Wavelengths [nm]


Yellow
Red
Orange
White
uW/nm
Wavelengths [nm]



GND
1
7
4
6
2
5
3
GND
1
7
4
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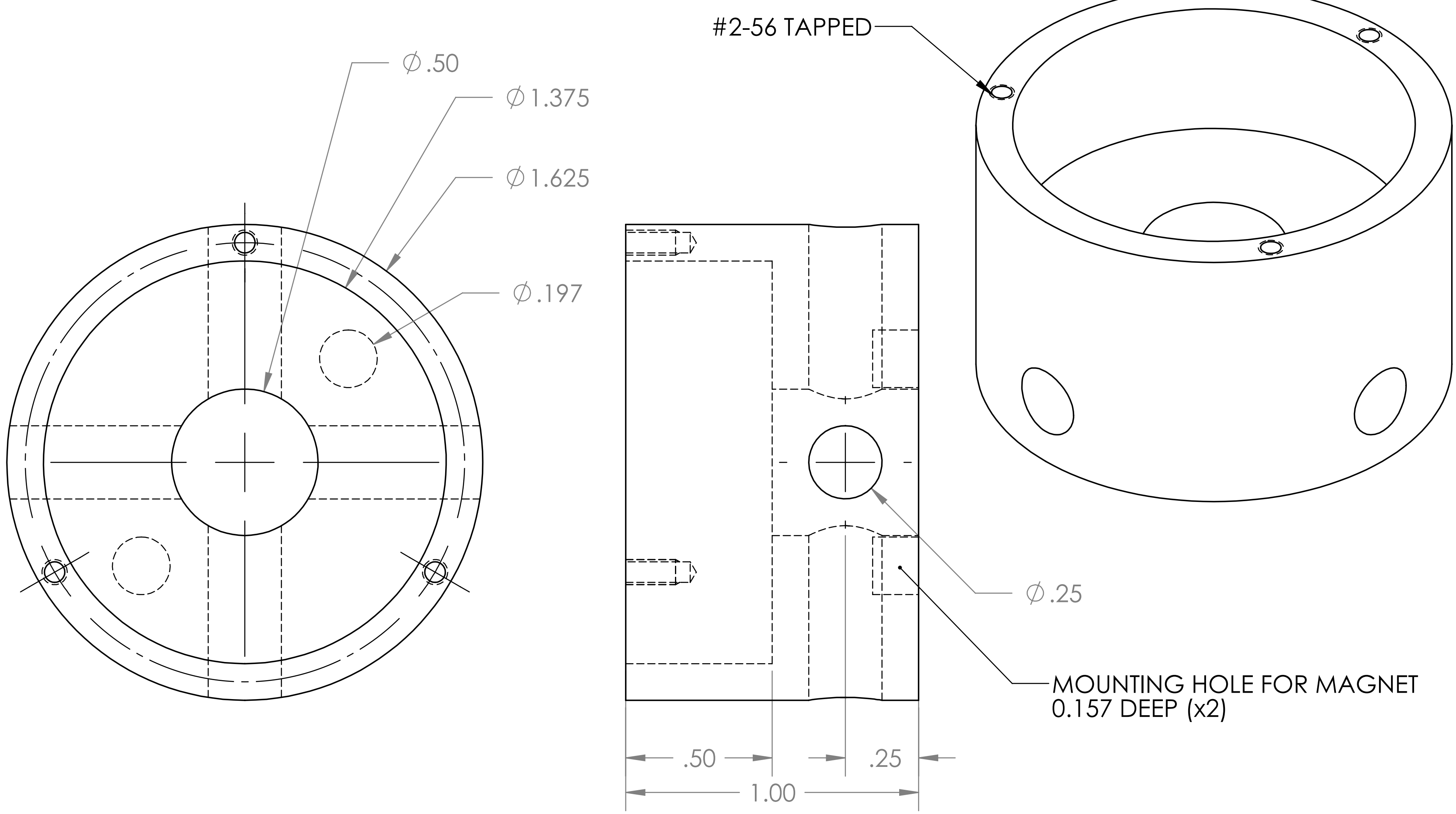
2
5
3



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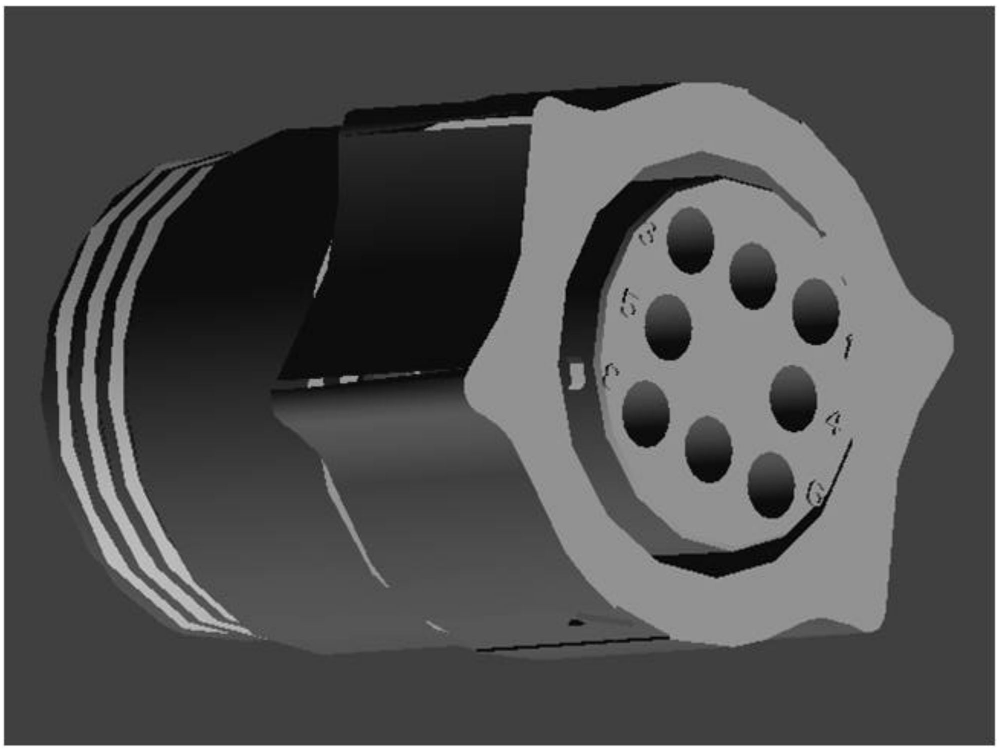
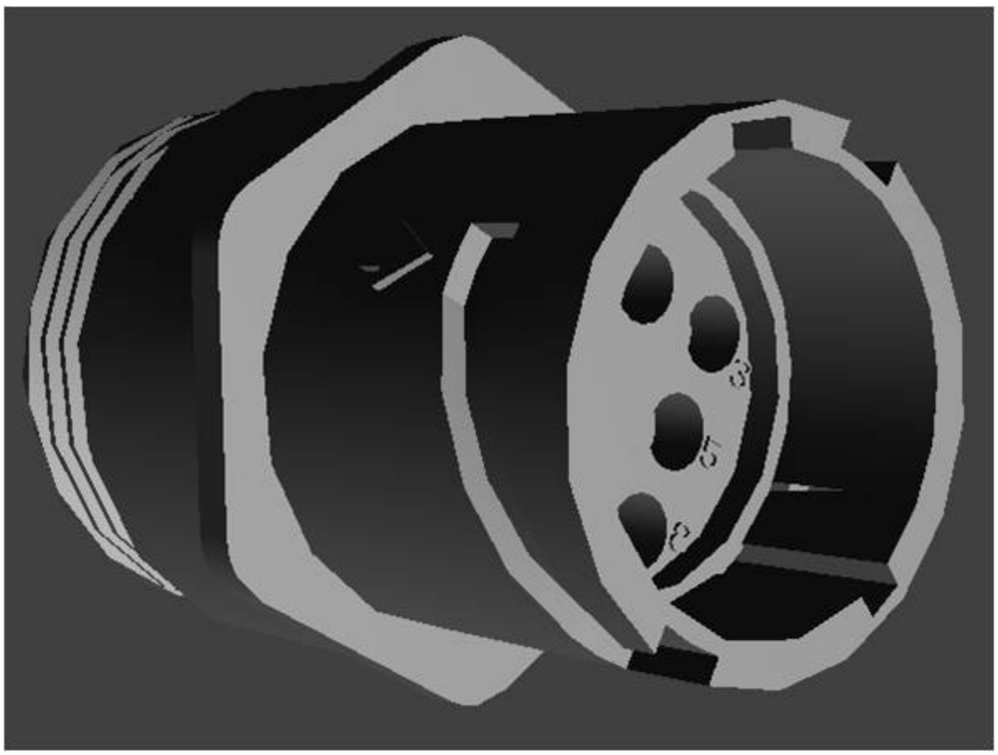
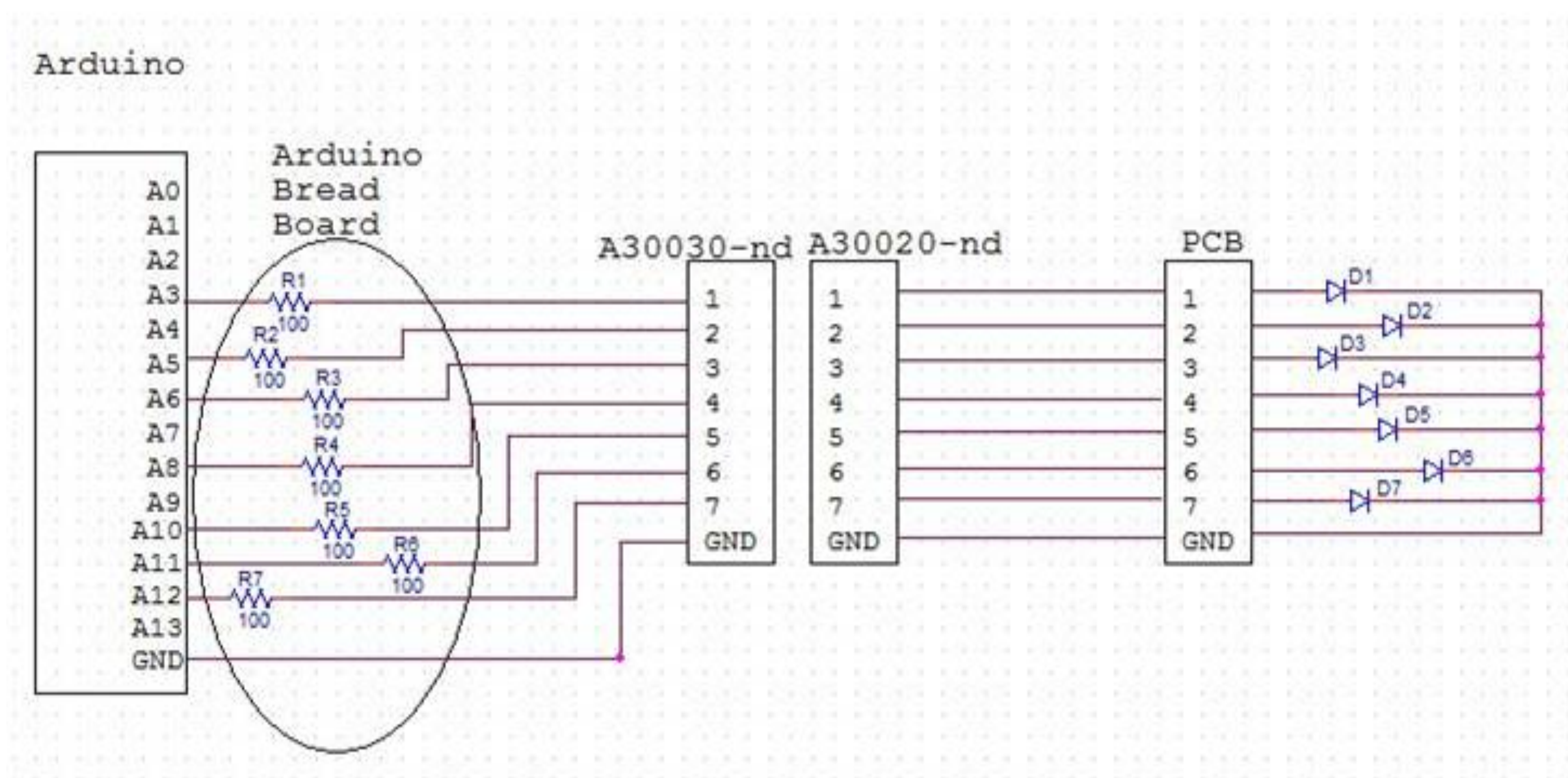
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	SJR	2/6/11	TITLE:	
	CHECKED			Cluster Housing	
INTERPRET GEOMETRIC TOLERANCING PER:	ENG APPR.				
MATERIAL Aluminum	MFG APPR.			SIZE A	DWG. NO. LED_Housing	REV 2
FINISH None	Q.A.				
DO NOT SCALE DRAWING	COMMENTS:			SCALE: 2:1	WEIGHT:	SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1







Arduino
A0
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
A13
GND
Arduino
Bread
Board
R1
100
R2
100
R3
100
R4
100
R5
100
R6
100
R7
100
A30030-nd
1
2
3
4
5
6
7
GND
A30020-nd
1
2
3
4
5
6
7
GND
PCB
1
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GND
D1
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D4
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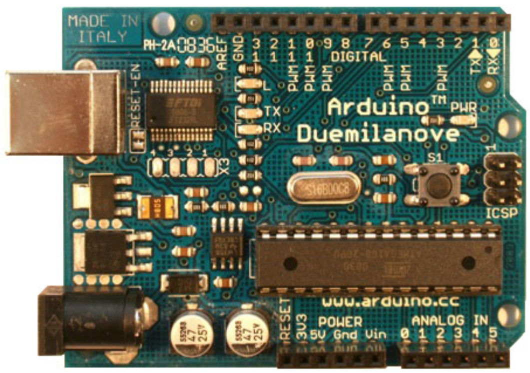
D6
D7

Arduino Duemilanove



Overview

The Arduino Duemilanove ("2009") is a microcontroller board based on the ATmega168 (datasheet) or ATmega328(datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

"Duemilanove" means 2009 in Italian and is named after the year of its release. The Duemilanove is the latest in a series of USB Arduino boards; for a comparison with previous versions, see the index of Arduino boards.

Summary

Microcontroller	ATmega168
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	16 KB (ATmega168) or 32 KB (ATmega328) of which 2 KB used by bootloader
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512 bytes (ATmega168) or 1 KB (ATmega328)
Clock Speed	16 MHz

Schematic & Reference Design

EAGLE files: arduino-duemilanove-reference-design.zip

Schematic: arduino-duemilanove-schematic.pdf

Power

The Arduino Duemilanove can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board FTDI chip. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega168 has 16 KB of flash memory for storing code (of which 2 KB is used for the bootloader); the ATmega328 has 32 KB, (also with 2 KB used for the bootloader). The ATmega168 has 1 KB of SRAM and 512 bytes of EEPROM (which can be read and written with the EEPROM library); the ATmega328 has 2 KB of SRAM and 1 KB of EEPROM.

Input and Output

Each of the 14 digital pins on the Duemilanove can be used as an input or output, using pinMode(), digitalWrite(), anddigitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

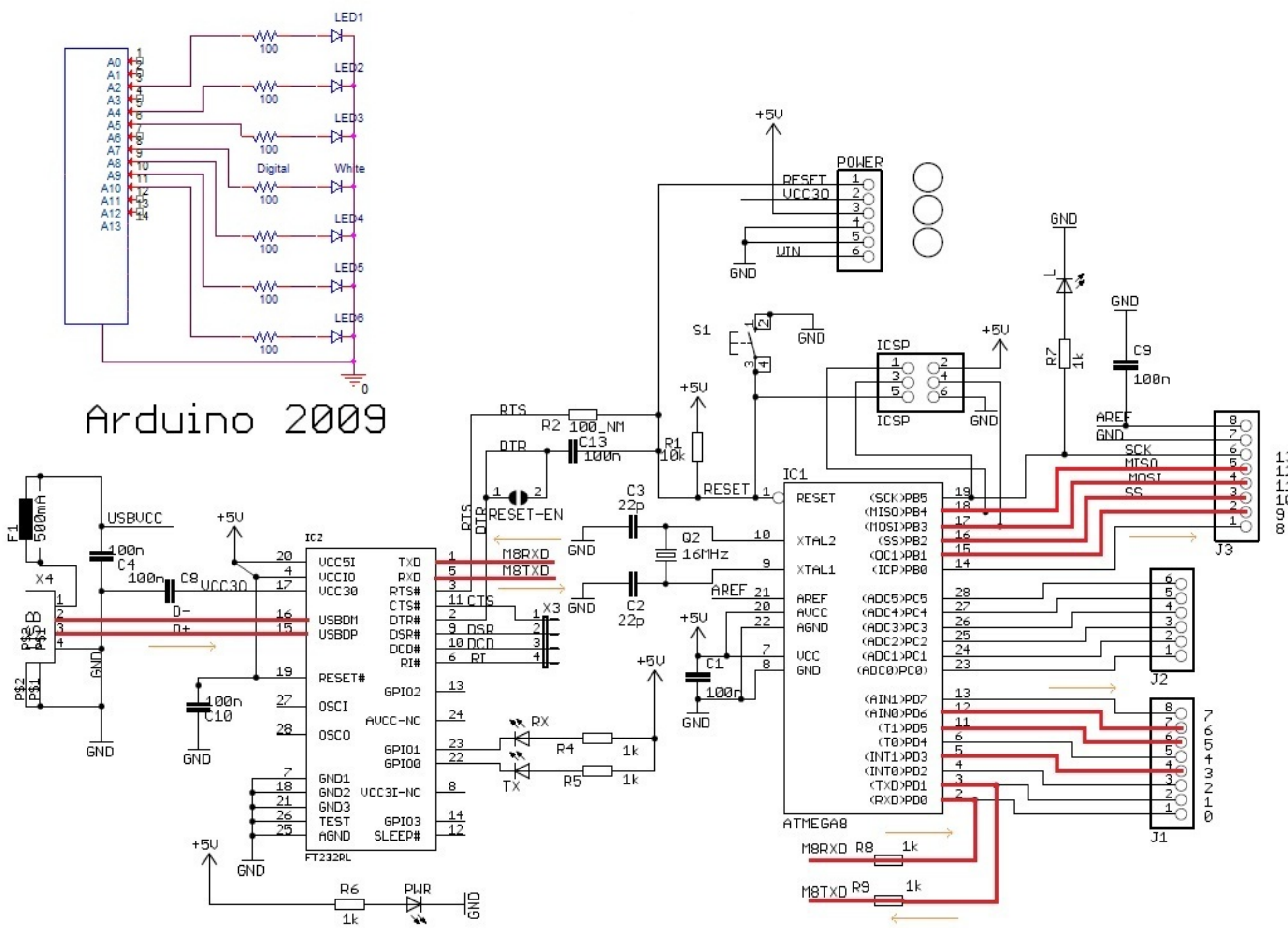
- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication using the SPI library.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Duemilanove has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- **I²C: 4 (SDA) and 5 (SCL).** Support I²C (TWI) communication using the Wire library.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().



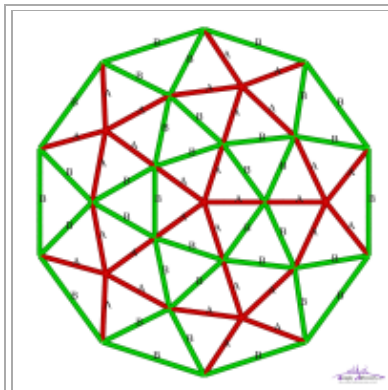
Arduino 2009

Geodesic Dome Concepts

Geodesic Dome Concepts

2V/L2 Icosahedral Dome Concept

The plans for this dome can be found here. The concept was built using toothpicks and a hot glue gun. The length of each strut was normalized to the length of one toothpick, meaning that the longest strut was a toothpick in length, the second longest was a certain percentage of that, et cetera.



2V/L2 Icosahedral Dome Construction Map

Dome Parameters

From the website mentioned above, the following parameters for the dome were found:

- Vertices/connections: 26
  - 10 x 4-way
  - 6 x 5-way
  - 10 x 6-way
- Edges/struts and bending angles
  - A x 30: 0.54653 (15.86°)
  - B x 35: 0.61803 (18.00°)
  - Total: 65 struts (2 different kinds)
  - Strut variance of 13.1%[1]
- Faces: 40 (3-sided)
  - A-A-A x 30 (55.57°, 55.57°, 68.86°)
  - B-B-B x 10 (60.00°, 60.00°, 60.00°)
  - 2 different kinds of faces
- Diameter: 2.000, radius: 1.000
- Height: 1.000 or 50.00% of diameter

[1] *The variance is the percent difference between the longest and shortest struts. The lower the value, the better.*

Dome Construction

Using the provided dome calculator at the website mentioned above, the following strut lengths were obtained. It should be noted that the strut lengths were normalized such that the longest strut is a toothpick in length.

- Strut A: 0.8843 (2-3/16 in.)
- Strut B : 1.0000 (2-9/16 in.)

2V/L2 Icosahedral Dome Completed Concept

Comments

Some things learned from building this dome concept:

- Has a very rigid structure.
- If expanded to full scale, the various strut orientations would allow for easy location of mounting points for the LED clusters.
- When compared to the 3V octahedral dome, this dome is larger in size while using only five more struts.

A rough estimate of manufacturing time to construct this dome concept would be between 80 and 105 minutes based on the estimates listed below.

- Time to prepare struts (counting, measuring, and cutting):
  - 20-30 minutes
- Time to assemble struts into dome:
  - 60-75 minutes

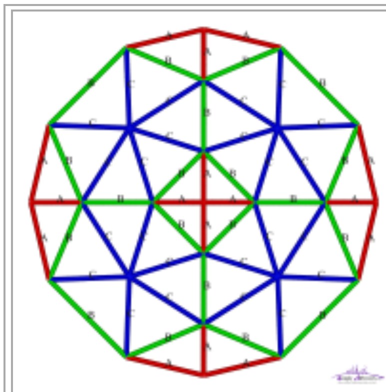
- Total time required:
    - 80-105 minutes

3V Octahedral Dome Concept

The plans for this dome can be found here. The concept was built using toothpicks and a hot glue gun. The length of each strut was normalized to the length of one toothpick, meaning that the longest strut was a toothpick in length, the second longest was a certain percentage of that, et cetera.

Dome Parameters

From the website mentioned above, the following parameters for the dome were found:



3V Octahedral Dome Construction Map

- Vertices/connections: 25
    - 4 x 3-way
    - 9 x 4-way
    - 12 x 6-way
- Edges/struts and bending angles
    - A x 16: 0.45951 (13.28°)
    - B x 20: 0.63246 (18.44°)
    - C x 24: 0.67142 (19.62°)
    - Total: 60 struts (3 different kinds)
    - Strut variance of 46.1%[1]
- Faces: 36 (3-sided)
    - A-A-B x 12 (46.51°, 46.51°, 89.98°)
    - B-C-C x 24 (56.20°, 61.90°, 61.90°)
    - 2 different kinds of faces
- Diameter: 2.000, radius: 1.000
- Height: 1.000 or 50.00% of diameter

[1] *The variance is the percent difference between the longest and shortest struts. The lower the value, the better.*

Dome Construction

Using the provided dome calculator at the website mentioned above, the following strut lengths were obtained. It should be noted that the strut lengths were normalized such that the longest strut is a toothpick in length.

3V Octahedral Dome Completed Concept

- Strut A: 0.6844 (1-12/16 in.)
- Strut B : 0.9420 (2-7/16 in.)
- Strut C: 1.0000 (2-9/16 in.)

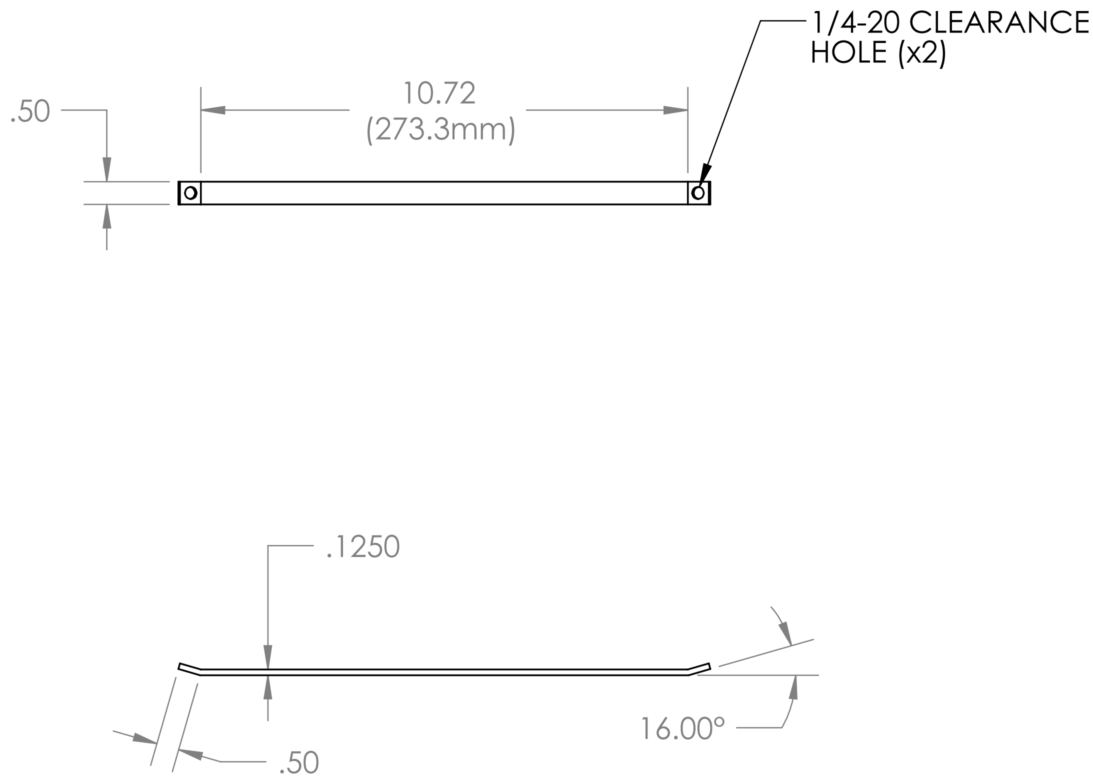
Comments

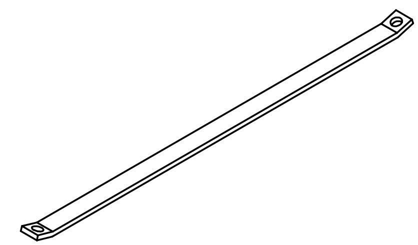
Some things learned from building this dome concept:

- Has a less rigid structure when compare to the 2V/L2 icosahedral dome.
- If expanded to full scale, the various strut orientations would allow for somewhat difficult location of mounting points for the LED clusters.
- When compared to the 3V octahedral dome, this dome appears to be far less "elegant".

A rough estimate of manufacturing time to construct this dome concept would be between 100 and 120 minutes based on the estimates listed below.

- Time to prepare struts (counting, measuring, and cutting):
    - 30-40 minutes
- Time to assemble struts into dome:
    - 70-80 minutes
- Total time required:
    - 100-120 minutes





UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	SJR	2/1/11
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL Steel	COMMENTS:		
FINISH None			
DO NOT SCALE DRAWING			

NEXT ASSY	USED ON
APPLICATION	

PROPRIETARY AND CONFIDENTIAL

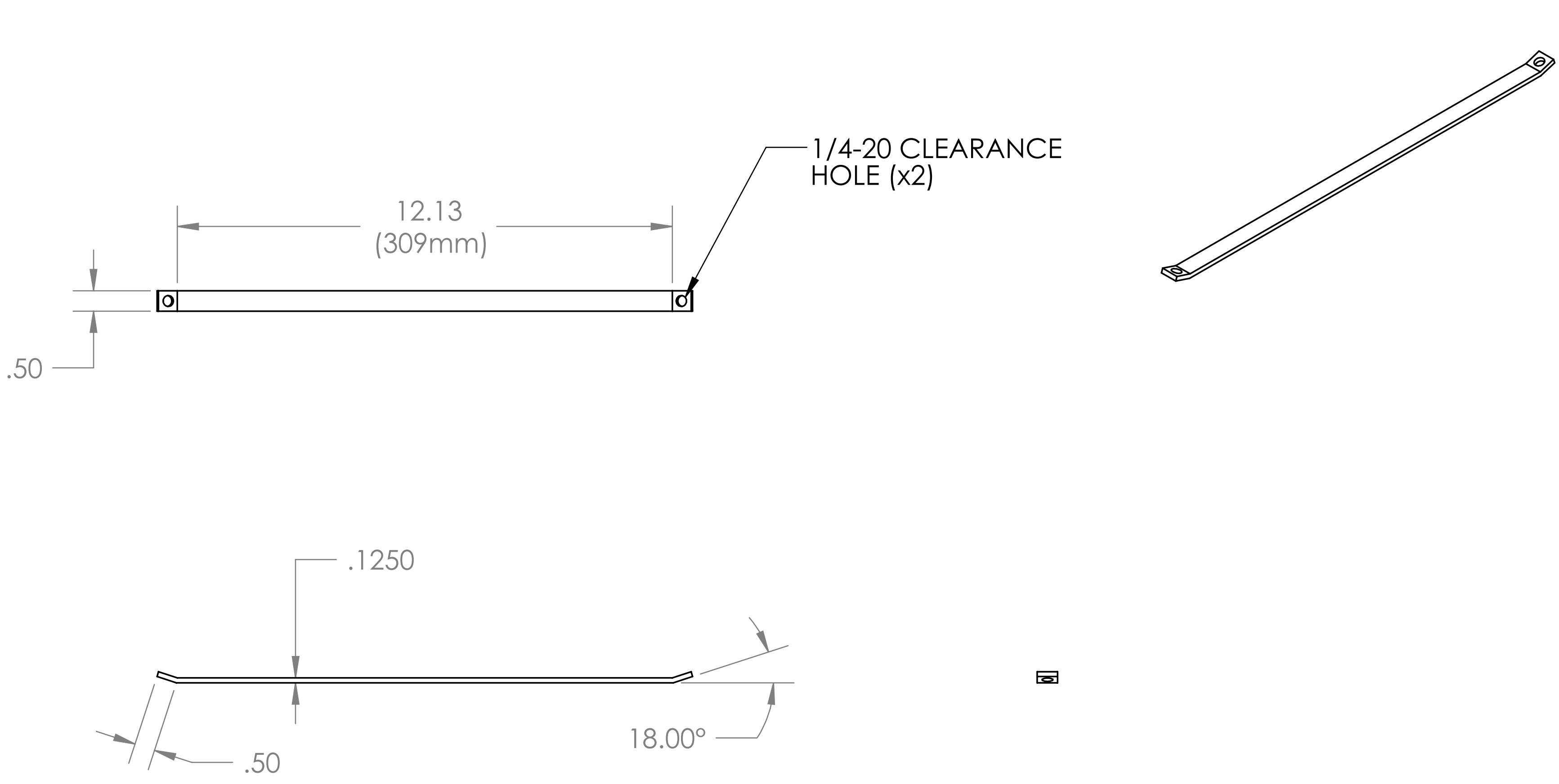
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

TITLE:

Strut Type "A"

SIZE	DWG. NO.	REV
A	A_Strut	1
SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL Steel

FINISH None

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	SJR	2/1/11
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

Strut Type "B"

SIZE	DWG. NO.	REV
A	B_Strut	1
SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

Gantt Chart


01 – 11
February 2011
March 2011
30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Work on detailed design
Detailed level design review
Finalize detailed design
Prepare for project management review
Project management review
Move onto MSD II
LED MATLAB Control Design
Microcontroller selection
Microcontroller programming research
Output stage design
PC software interface design
Finalize design choices
LED Cluster Design
LED subsystem
Spec and source parts
Test and evaluate LEDs
Characterize chosen LEDs
Design LED cluster board
Housing subsystem
Design generation
Finalize design choices
Hemisphere Design
Research design options
Research material options
Generate concept mockups
Design cluster mounting points
Design vertex connectors
Finalize design choices

Revision #	2							
ID	**Risk Item**	**Effect**	**Cause**	**Likelihood**	**Severity**	**Importance**	**Action to Minimize Risk**	**Owner**
1	Possibility of sphere	Need to make two hemispheres that are easily connected together	Customer changes need (should know by 12/17)	3	3	9	Talk with customer and decide on action as soon as possible	ALL
2	More than 2 clusters	Need larger microcontroller, more LEDs, more housings, et cetera	Additional requirements from the customer	2	3	6	Be able to build more clusters and use a larger microcontroller than needed	Usachev
3	>75 mA LEDs	Budget	Need to cover required spectrum	3	1	3	Understand what spectrum range can be covered. Request larger budget	Miranda
4	Nodes not being accurate	Cluster location unknown to computer software	Poor manufacturing	2	9	18	Jig hemisphere accurately	Rimkus, Boranbayev
5	Not having enough PWM outputs	Need multiple microcontrollers	More than two clusters required by customer	2	3	6	Find a device with enough PWM outputs.	Usachev
6	Need more components to interface cluster with microcontroller	Redesign control circuit or black box	Poor engineering	1	1	1	Build a good prototype	Liotta
7	MATLAB functionality	Cannot control PWM	Bugs in code	2	9	18	Simulate with prototype	Usachev
8	Testing equipment availability	Unable to characterize LEDs and spectrum covered	Unavailability of needed testing equipment	1	9	9	Confirm equipment availability with customer	Miranda

Likelihood: Scale of 1-3 (1 = unlikely, 3 = very likely)
Severity: Scale of 1,3,9 (1 = not severe, 3 = somewhat severe, 9 = critically severe)

Engineering Spec #	Specification (description)	Unit of Measure	Marginal Value	Ideal Value	Test Plan/How Engineering Specs will be Accomplised
	LED				
1	Individual addressability	Binary	Yes	Yes	Test with Prototype of Arduino Hooked up to LED's
2	Individual intensity control	bit	8	8	Done with Arduino-ALL PWM outputs are 8 bit
3	Amount per cluster	#	7	7	If using UV or IR cluster, 6 can be used since 7th output will be digital
4	Individual disconnect time	sec	10	S	Disconnect
5	Individual replaceability	Binary	Yes	Yes	Need to Test when the PCB boards are populated by Changing different LED's
6	Cone angle	deg	15-20	<18	Bought all LED's within Marginal Value
7	Casing	mm		5	Bought Correct LED'S
8	Individual drive current	mA	15-25	20	Accomplished with Arduino Tested with Amp Meter
	LED Cluster				
9	Spectral range covered	nm	415-690	400-650	Measure Individual intenisities of each LED with SpectraScan 655
10	Illumination of sample area	Binary		Yes	Visually and Measure with tools Dr. Wyble and Jinwei have (Need more details)
11	Casing	Binary		Yes	
12	Casing diameter	cm		<5.1	Measure With Calipers
13	Amount	#	2	>2	Count
14	Disconnect time	sec		<30	With Stop Watch
	Microprocessor				
15	Separate PWM output for each LED	Binary	Yes	Yes	Center LED will be digital, most likely to be white
16	Input voltage	V	6 - 20	7 - 12	Test With Volt Meter
17	USB connection	Binary	Yes	Yes	Arduino microprocessor comes with USB port
18	MATLAB compatibility	Binary	Yes	Yes	Arduino is MATLAB compatible
19	Power constraints	Binary		No	
	Hemisphere				
20	Diameter	m		1	Measure
21	Measurable location of each node	Binary		Yes	Take a picture of sample area (Jinwei will help with this)
22	Number of cluster mounting locations	#		324	~10 degree separation of nodes for longitude and latitude
23	Weight	kg		<14	Weigh

Description	Qty	Unit Cost	Item Total	Ordered Vendor	PN	Notes		Lead Tme	
Hemisphere									
Struts	14	$6.38	$89.32	McMastercarr	8910K113	.125"x.5"x6' Steel		None	
1/4-20 Bolts	100	$0.06	$6.28	McMastercarr	92865A540			None	
1/4-20 Nuts	100	$0.06	$6.11	McMastercarr	93827A211			None	
Attachment	24	$1.73	$41.52	McMastercarr	5902K48	Neodymium-iron-boron			
Magnets									
LED Cluster									
White LED	20	$0.71	$14.20	superbrightleds.com	RL5-W10015			Arrived	
Blue LED	20	$0.59	$11.80	superbrightleds.com	RL5-B5515			Arrived	
Green LED	20	$0.49	$9.80	superbrightleds.com	RL5-G8020			Arrived	
Aqua LED	20	$0.49	$9.80	superbrightleds.com	RL5-A9018			Arrived	
Red LED	20	$0.22	$4.40	superbrightleds.com	RL5-R5015			Arrived	
Yellow LED	20	$0.22	$4.40	superbrightleds.com	RL5-Y5615			Arrived	
Orange LED	20	$0.22	$4.40	superbrightleds.com	RL5-O5015			Arrived	
Violet LED	20	$1.25	$25.00	superbrightleds.com	RL5-V1015				
UV LED	20	$0.60	$12.00	superbrightleds.com	RL5-UV0315-380				
Housing	1	$14.67	$14.67	McMastercarr	8974K681	1.75"x12" round stock Al			
PCB Board-with Removable LED's	6	$24.17	$145.02	PCB Express		Need to Find Out Lead Time			
Plug Housing Connector	16	$4.26	$68.16	Digikey	A30020-nd	CONN Recept 11-8POS Free-Hanging, Tyco			
Socket Connector	16	$3.94	$63.04	Digikey	A30030-nd	CONN Plug Housing 11-8POS CPC, Tyco			
22-26AWG Tin Crimp	150	$0.09	$13.26	Digikey	A25675-nd	CONN Pin 22-26 AWG Tin Crimp, Tyco			
Socket 22-26 AWG Ting Crimp	150	$0.09	$13.26	Digikey	A25676-nd	CONN Socket 22-26 AWG Tin Crimp, Tyco			
Socket PCB	150	$0.32	$47.25	Digikey	952-1463-nd	CONN Socket PCB for 0.8mm Pin, Harwin			
Focusing Lens LED's			$0.00			TBD			
Wire			$0.00			From Ken Snyder			
Resistors			$0.00			From Ken Snyder			
Microcontroller									
Arduino Deumilanove	8	$24.00	$192.00	Bizoner.com		Need 4 More		Arrived	
Power Cord	8	$9.00	$72.00	Bizoner.com		AC/DC adapter			
USB Hub	1	$29.99	$29.99	newegg.com					
Bread Boards	8	$4.00	$32.00	adafruit.com					
Total			$929.68						

(purple)	Ordered/Already HAve
(green)	Ok to Order
(yellow)	Waiting for Final Design to Order
(red)	Need More Information to Order