Solar Vector Simulator (SVS)

SVS Design Requirements

Requirement ID	Requirement	Compliance
SVS_001	A Solar Simulator Panel shall be **capable of illuminating an area of 211 cm^2**	Compliant
SVS_002	Irradiance Uniformity shall be **more than 20% in ASTM standards**	Compliant
SVS_003	Solar Simulator shall **emit a spectral match less than 30% in ASTM standard**	Compliant
SVS_004	Solar Vector Simulator shall **change intensity simulating the change in distance from sun**	Compliant
SVS_005	Solar Simulator shall **emit a spectral range between 400-1100 nm**	Compliant
SVS_006	Solar Simulator shall **illuminate cubesat with incident rays less than 20 degrees**	Not Compliant
SVS_007	Solar Vector Simulator shall **interface with user to control solar environment**	Compliant

Table 5: SVS Performance Requirements Rev 2.0 - 5/12/2020

Solar Simulator Panel Layout Reference

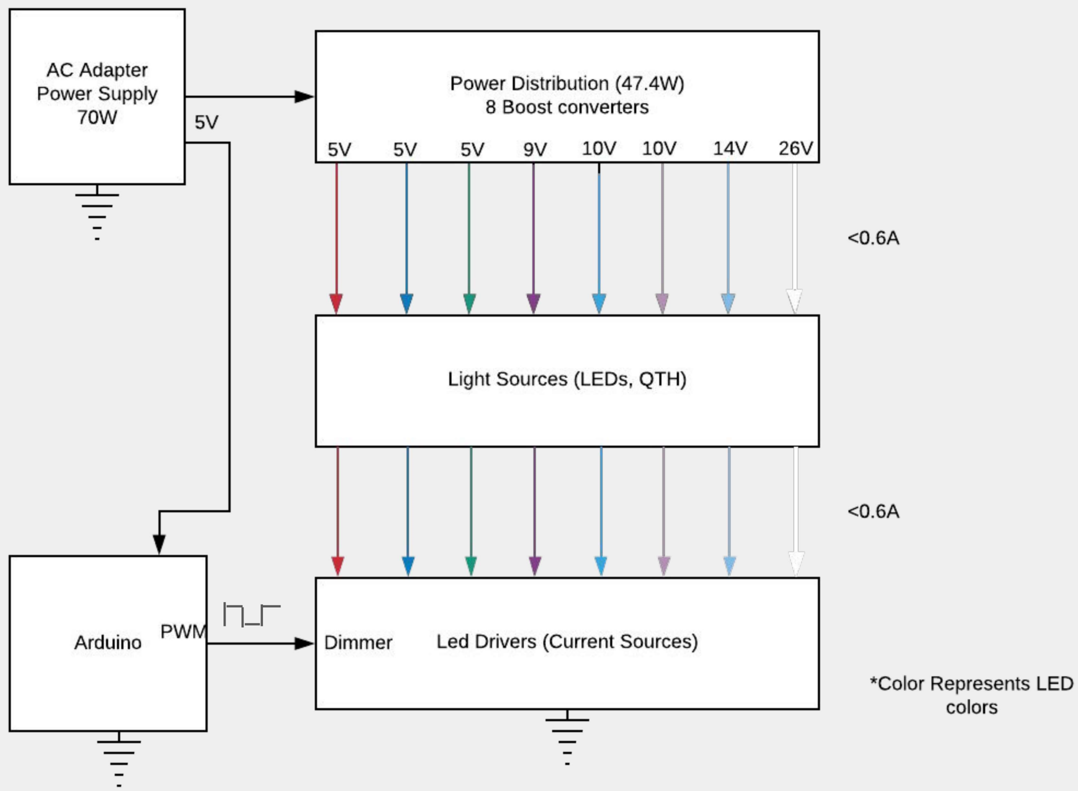


Figure 13: Power and LED Driver for Solar Simulator Unit Diagram
Rev. 2 (6/1/20)

Solar Simulator Panel Circuit Schematic

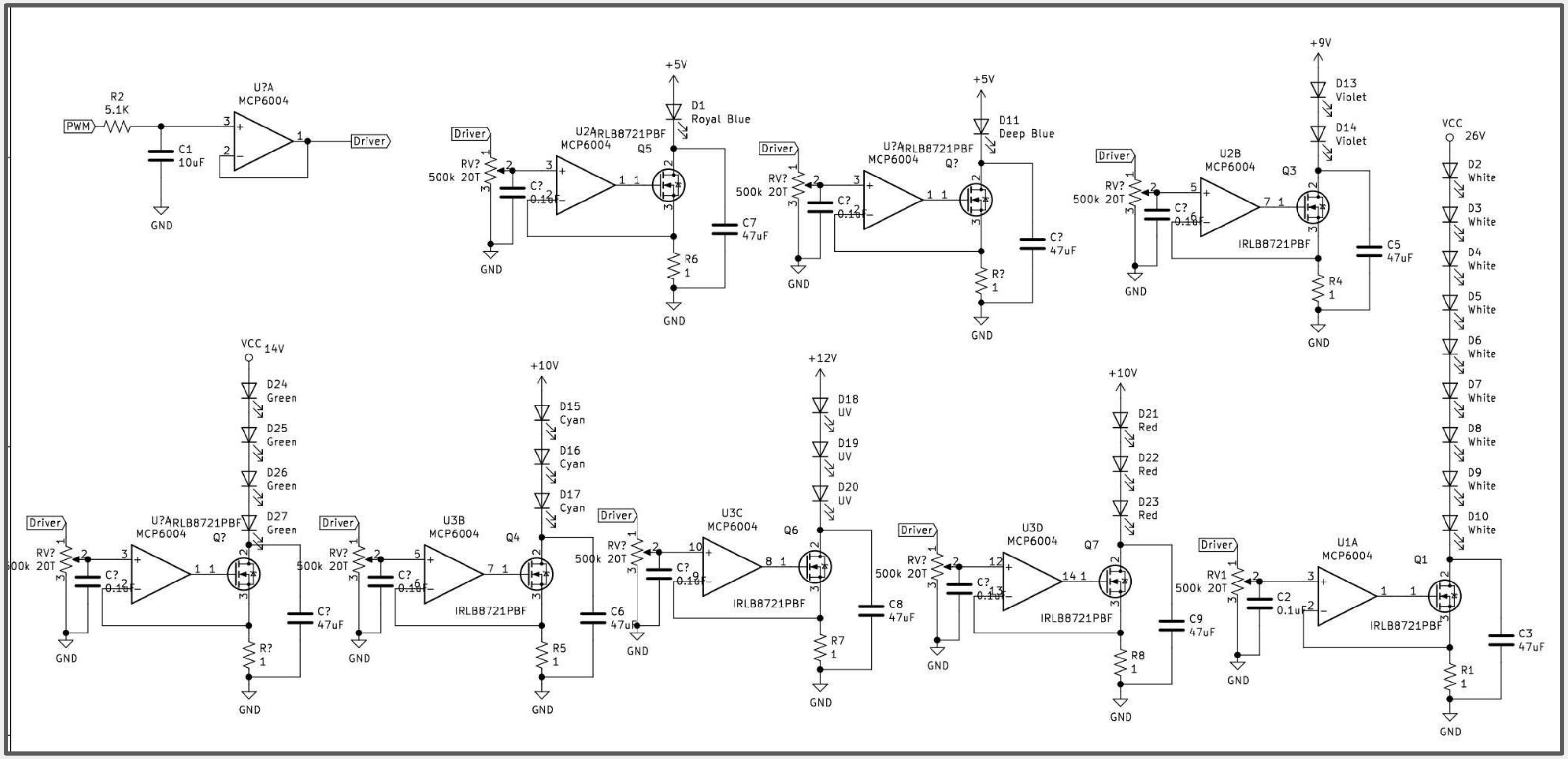


Figure 14: Power and LED Driver for Solar Simulator Unit Diagram
Rev. 2 (6/1/20)

LED Placement Change Due to Component Resizing

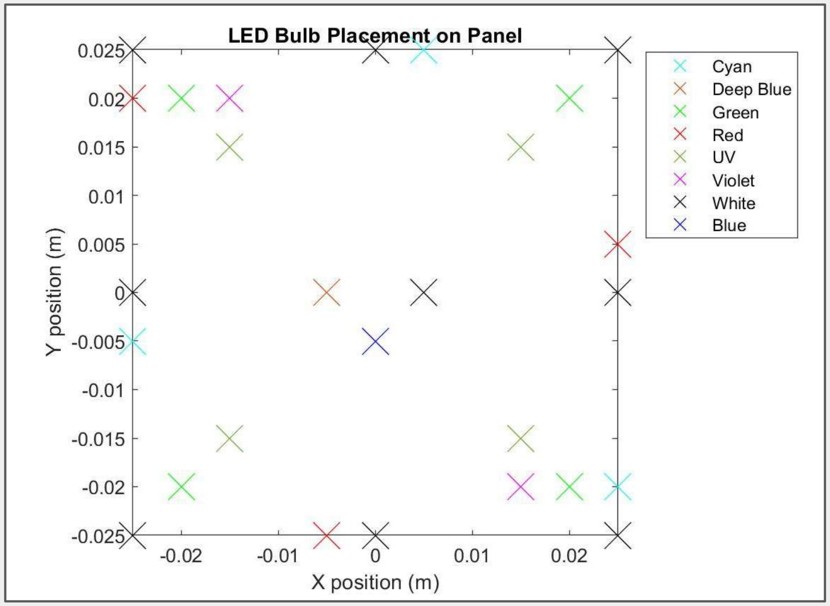


Figure 14: LED Position on Panel Plane
Rev 1.0 - 5/10/2020

X 1.4

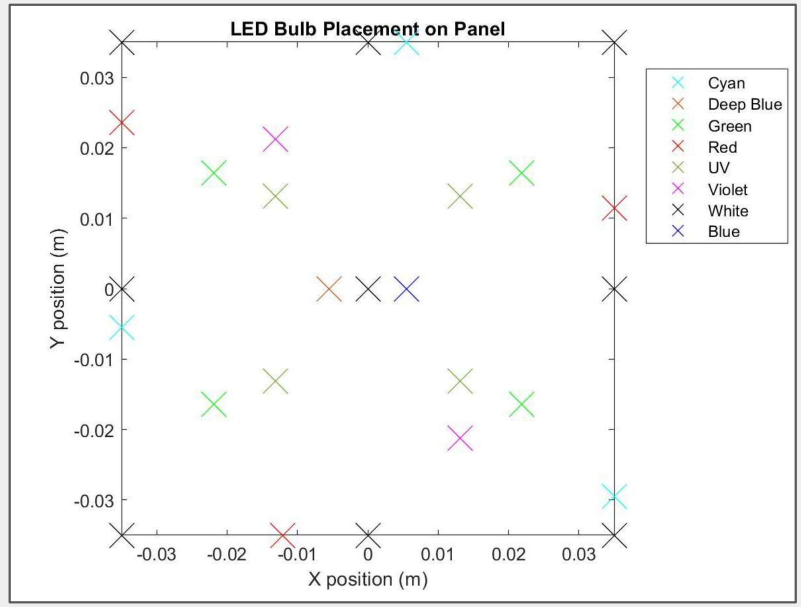
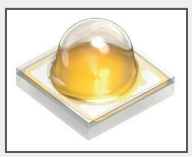
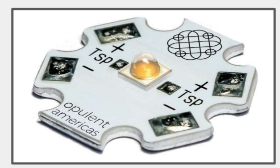


Figure 15: LED Position on Panel Plane
Rev 2.0 - 6/3/2020

Surface Mount
(Too small to solder)





Same LED
Mounted to
Heatsink Carrier

Developing Light Source Housing Model from LED Simulation Results

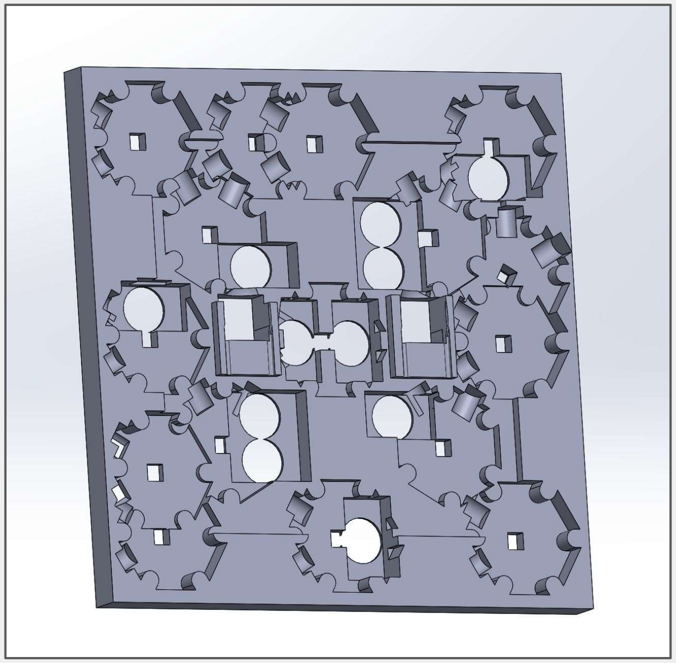


Figure 16: Back Side of Housing
Rev 4.0 - 6/3/2020

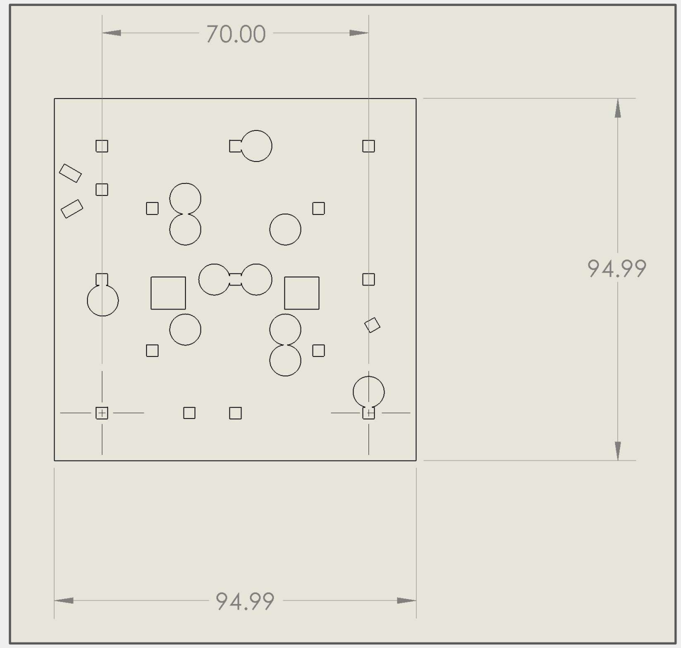


Figure 17: Front Side of Housing (units are in mm)
Rev 4.0 - 6/3/2020

ASTM Standard Review: Spectral Match is the Same

Wavelengths (nm)	Grade
400-500	A
500-600	A
600-700	A
700-800	A
800-900	A
900-1100	B

Table 6 Spectral Match Grade
Rev 3.0 - 6/3/2020

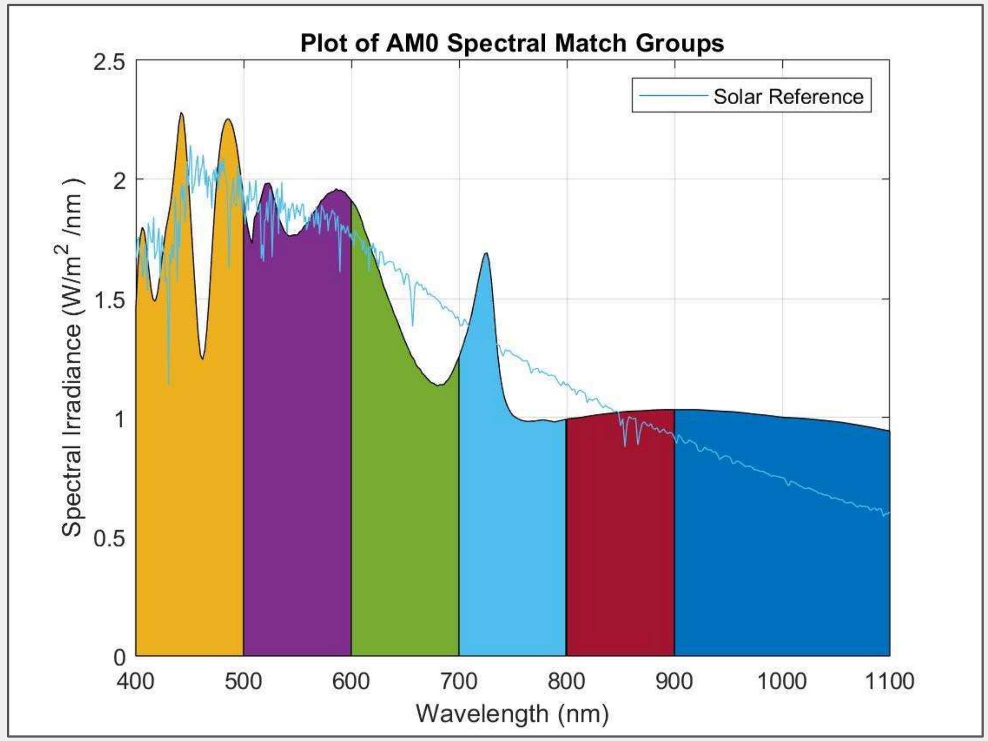


Figure 18: Plot of spectral match groups at each wavelength based on 70mm panel
Rev. 2 - 6/3/20

Recap of ASTM Uniformity and LED panel Scalability

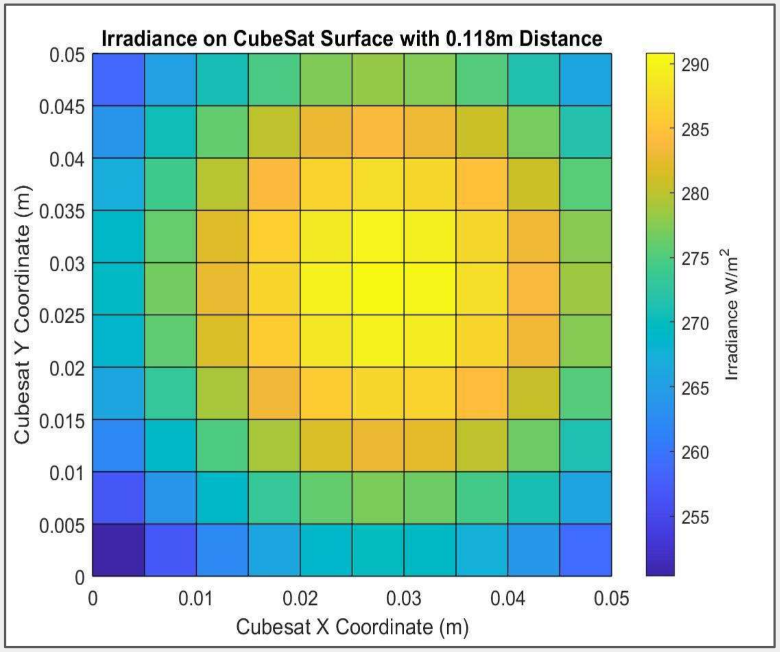


Figure 19: Irradiance on 2.5mm^2 surface of 10 by 10 Grid
Rev 1.0 - 5/10/2020

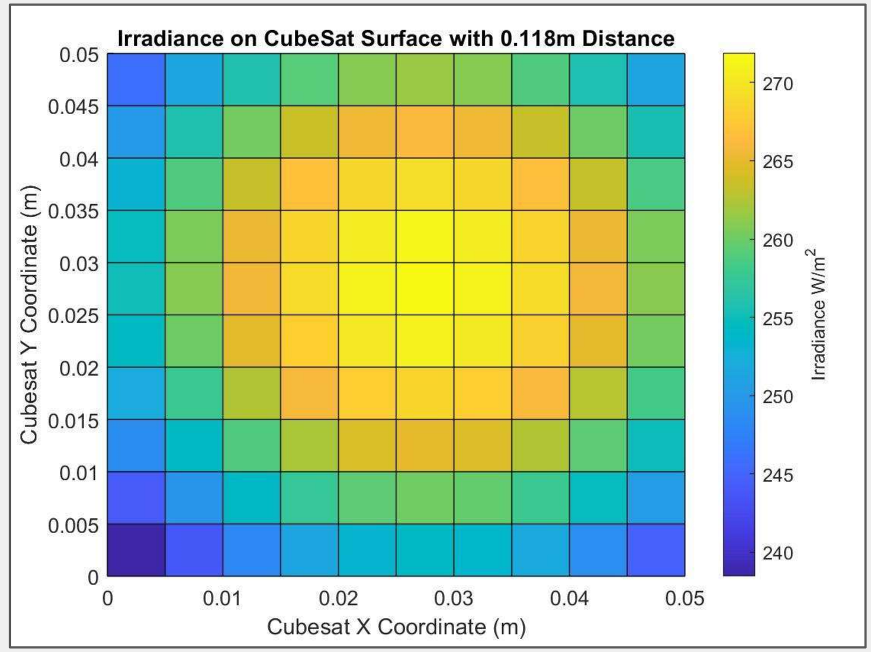


Figure 20: Scaled Irradiance on 2.5mm^2 surface of 10 by 10 Grid
Rev 1.0 - 6/3/2020

- Non-Uniformity 7.5%
- Class C

Near same Non-Uniformity
w/ larger panel

- Non-Uniformity 6.5%
- Class C

ASTM Standard: Temporal Instability

- This grade determines how long the simulator irradiance can be sampled
  - Finds the maximum and minimum irradiance within 2 seconds of steady state
- There are two large causes for a high Temporal instability
  - Voltage ripples in driver/power supply
  - Dimming Features
- The radiant flux of the light nearly changes linearly with current but exponentially with voltage
- Dimming circuits turn the light sources on and off to *appear* less bright
  - This does not provide a constant light source

$$\text{Temporal instability } (\%) = \left[\frac{\text{max irradiance - min irradiance}}{\text{max irradiance } + \text{ min irradiance}}\right] \times 100\%$$

Maximum Voltage Ripple for ASTM Temporal Instability Grade

- The radiant flux for the simulated spectral match and irradiance uniformity had a set voltage and current
- To achieve an ASTM grade, the radiant flux cannot change by more than ±10%
- To find the minimum Voltage Ripple:

1. Determine max radiant flux change
   a. In our case < 10%
2. Determine the maximum LED current peak to peak variation
   a. Use Luminous Flux vs Forward Current curve
3. Determine dynamic resistance
   a. Use current vs voltage curve
4. Calculate Max voltage ripple
   a. $V_{pp} = I_{pp} R_{\text{Dynamic}}$
5. Determine required output capacitor
   a. $C_{out} = \frac{I_{pp}}{2\pi f V_{pp}} R_{Dynamic}$
   b. Useful for LED Driver

Temporal Stability	
	ASTM
A	2%
B	5%
C	10%

Table 7: ASTM Temporal Stability Grades
Rev. 2 (6/1/20)

Maximum Voltage Ripple Calculation Results

Color	# in Series	Voltage Source (V)	Max Voltage Ripple (mV)
White	9	26	200
Royal Blue	1	5	180
Deep Blue	1	5	180
Green	4	14	165
Red	3	10	213
UV	3	12	170
Violet	2	9	170
Cyan	3	10	180

Table 8: Voltage Ripple Calculation Results
Rev. 2 (6/1/20)

Power Distribution Based on Minimum Voltage Ripple

- The power supply is an AC adapter that provides 75 W
  - 5V 14A
  - Chosen as it was already on hand and met desired specifications
- Due to the low voltage, boost converters are needed for the large strings
- Boost converter for design is the DC-DC XL6009 Step Up module
  - Input Voltage: 3V-32V
  - Output Voltage: 5V-35V
  - Max input current: 4A
  - Switching Frequency: 400KHz
  - Max output ripple: 50mV

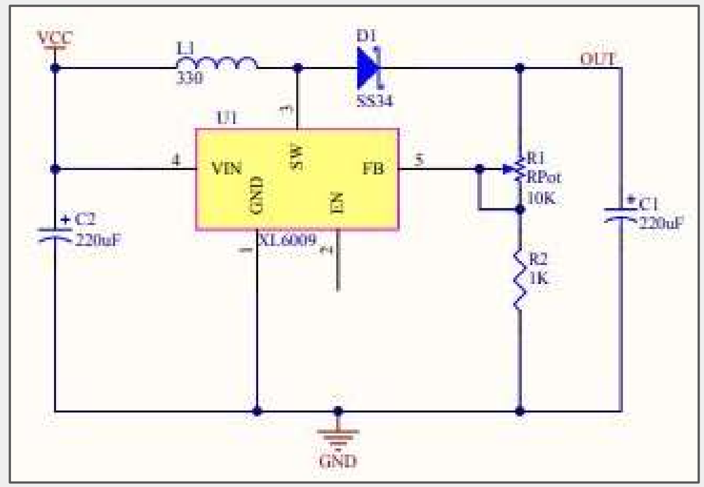


Figure 20:Boost Converter Circuit

Rev 1.0 - 5/10/2020

Driver Based on Minimum Voltage Ripple

- To control the brightness, the light sources need to be current controlled
- Each light string is controlled with a current source using an opamp and a sense resistor
  - The feedback from the resistor allows the current to be calculated as: $I_D = \frac{Va}{R_1}$
- Potentiometer controls each string uniquely to adjust for change in Irradiance Spectrum
- RC filter and buffer convert PWM (dimming) signal to DC equivalent voltage with 50mV ripple

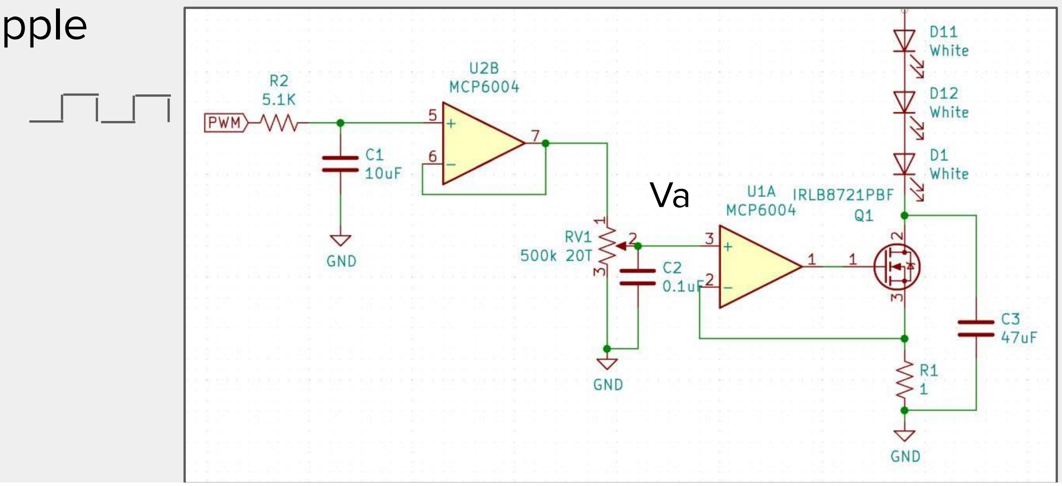


Figure 21: Simplified Current Source
Rev 1.0 - 5/10/2020

Solar Simulator Prototype

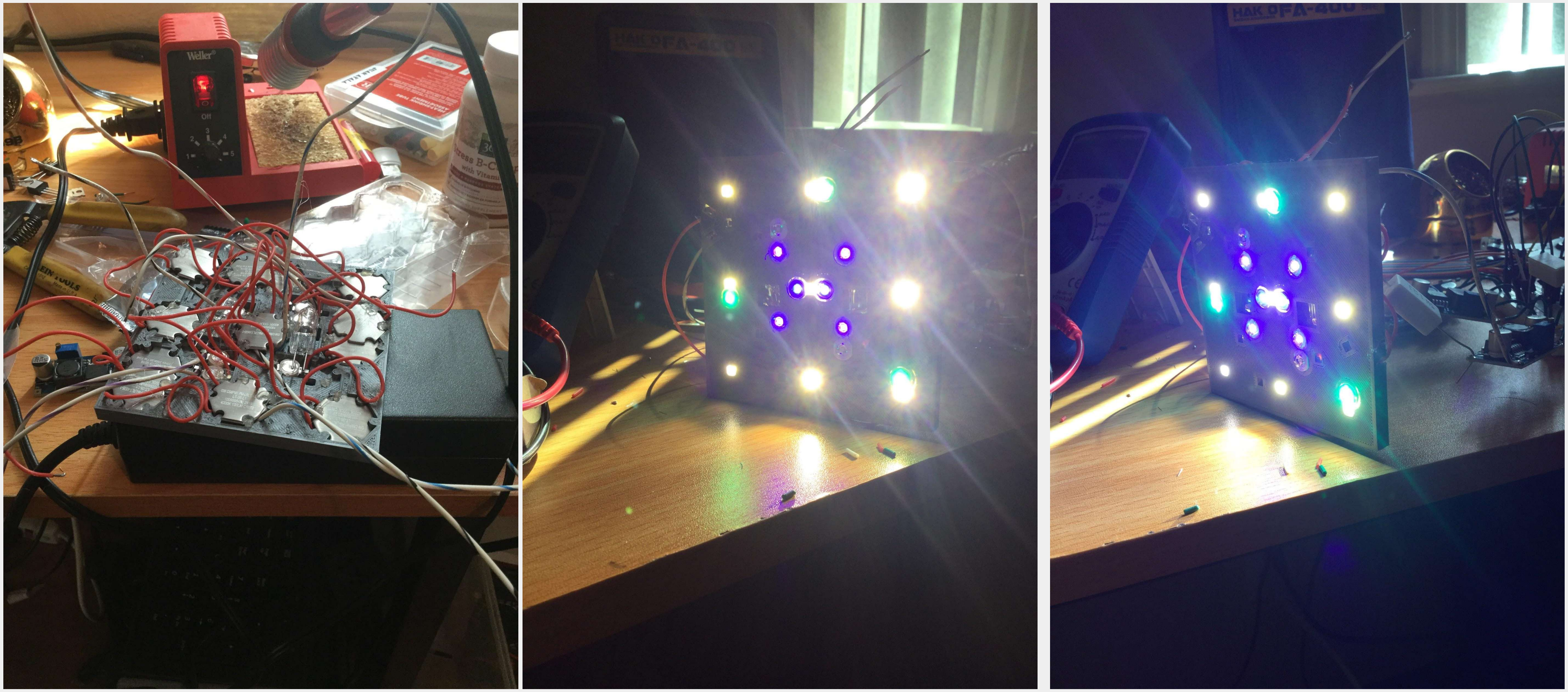


Figure 22: Solar Simulator Prototype
Rev 1.0 - 5/10/2020

Recommended Future Work & Additions for SVS

- Electrical
  - Design PCB panel to decrease size of board
  - Include more efficient LED drivers
  - Design photodiode array sensor for calibration
- Optical
  - Determine concentrator or lens to collimate rays
- Mechanical
  - Design housing for LEDs that allows individual LEDs to be changes
  - Design attachment mechanism to CubeSat prototype

Deliverables Checklist for SVS

Deliverable	Status
Simulated Spectral Match ASTM Standard	Completed
Simulated Non-Uniformity in ASTM Standard	Completed
Design Light Source Driver Circuits	Completed
Assemble Solar Simulator Unit Panel	Completed
Feedback Sensor for Simulator Adjustment	Not Completed
Collimated Rays (<20 degrees incident)	In progress

Figure 23: SVS Deliverables Status Rev. 1 6/3/2020