Ruby Analysis via Spectroscopy Systems

Group 7

Design Goal

To develop a system that performs more than one spectroscopy test to determine corundum vs imitations. In using quantitative tests vs qualitative ones, we can have more reliable results.

Our Team

Atman Atman

Electrical Engineer

Brandon Lopez

Computer Engineer

Brianna Hurrell

Photonic Engineer

Isabelle Lebron

Photonic Engineer

Project Features

Visible wavelengths

Low power

Data storage

Two Tests

Isabelle Lebron -
Photonic Engineer

Project Motivation

- Developing a single device that can accurately tell if a gemstone, like a ruby, is genuine or not, cutting down on the need for years of experience to do so.
- This device would help prevent people from being tricked into buying fake rubies online by confirming their authenticity.
- It would be useful for gem enthusiasts and businesses, offering a cheaper and easier way to check gemstones before making a purchase.

Brianna Hurrell -
Photonic Engineer

Goals

Goals

- Build a spectrometer that tests for the correct ruby fluorescence wavelength.
- Implement a dichroscope into the system to ensure proper pleochroism properties.

Stretch Goals

- Include a magnification system with a camera to image the impurities and detect them in software to enable distinctions between real and synthetic rubies.

Advanced Goals

- Implement other common gemology tests into the system such as a refractive index meter.
- Study other gem properties and implement tests for them into the system to enable multiple gem distinction.

Brianna Hurrell - Photonic Engineer

Objectives

Objectives

- Build a spectrometer that operates within the visible range.
    - Will read fluorescence and impurity spectra.
- Develop a dichroscope that will measure the crystalline properties of the ruby and implement the results into the spectrometer.
- Design a system that will orient the ruby in three different directions while illuminating the sample with an LED.
- Develop software that will analyze the data provided by the above tests and display the results to the user.

Brianna Hurrell -
Photonic Engineer

Engineering Specifications

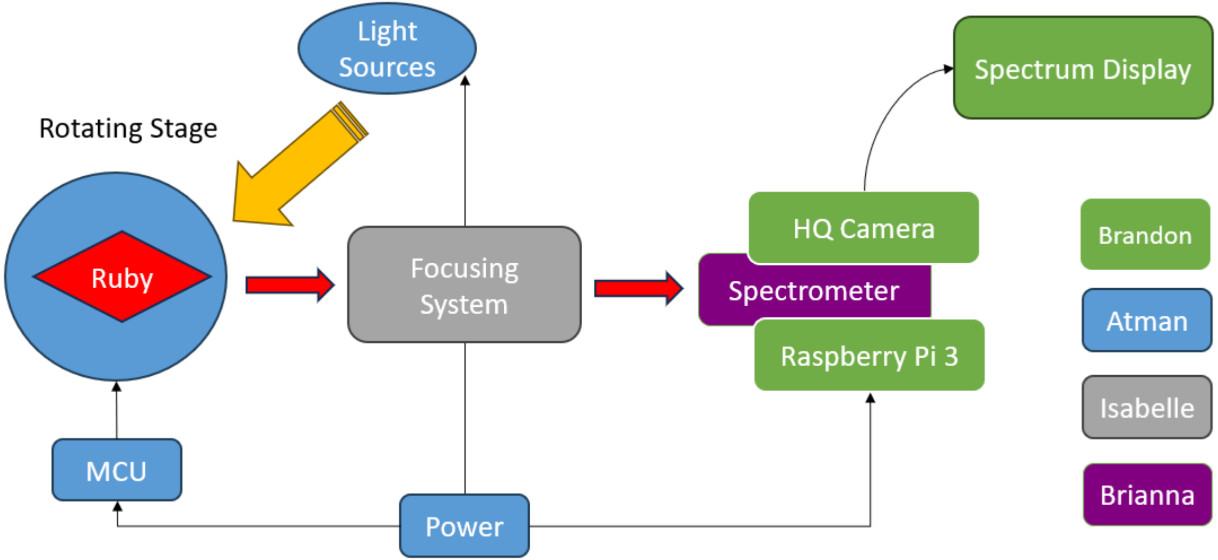
Table 1: RASS Specifications List

Component	Parameter	Specification
Ruby	Test Subject	Synthetic
Fiber	Light Propagation	MMF
Diffraction Grating	Wavelength Dispersion	300 groove/mm Plane ruled reflective
Calcite	Pleochroism	Optical Grade (High clarity)
Pi Camera	Runtime	~7 sec*
Pi Camera	Accuracy	90%
Mirrors	Reflection	$R_{avg} \geq 95\%$

*Tested with high power system

Brandon Lopez -
Computer Engineer

Hardware Block Diagram



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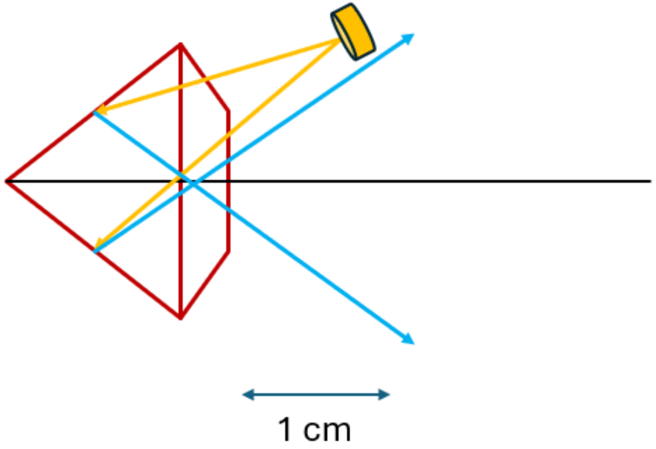
Ruby Restrictions

- Back facets can range anywhere from 30-65 degrees depending on type of cut
- Viewing angle of LED is 12 degrees
- Incoming LED light is put at an angle so reflected light diverges greatly



Ruby (red) and back facet interaction with LED light (yellow) producing blue output light. An image arrow is give on both sides to indicate the skew. Image is based off observations in testing.

Isabelle Lebron - Photonic Engineer

Lens Comparison

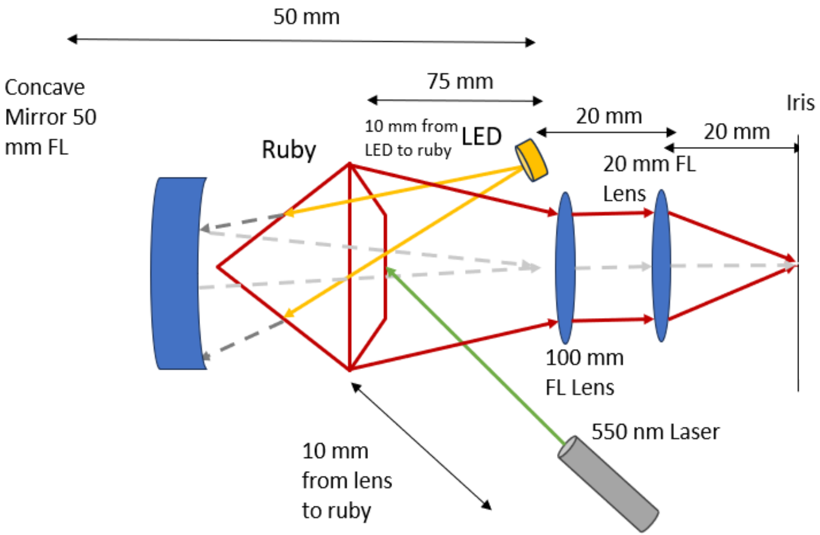
Light from the ruby diverges very quickly, so a large initial lens with a shorter focal length is needed. We chose one of the largest sizes of lenses available, with a 75 mm diameter.

Manufacturer	ThorLabs	Edmund Optics	Newport
Part ID	LA1238	#45-369	KPX223
Radius of Curvature	51.5 mm	77.52 mm	51.680 mm
Focal Length	100 mm	150 mm	100 mm
Price	$100.97	$75.00	$137.00

Isabelle Lebron - Photonic Engineer

Concave Mirror Explanation and Implementation

- A lot of light is lost due to transmission through the ruby, so to have as much light as possible we implement a concave mirror behind the ruby.



Concave Mirror Comparison

- For this mirror we chose an overall size of 50 mm to cover the back of the ruby mount and a 50 mm focal length, as it was the shortest available.
- All choices are Aluminum coated.

Manufacturer	Thorlabs	Edmund Optics	Newport
Part Number	CM508-050-G01	#43-470	20DC100ER.1
Wavelength Range	450 nm - 20 µm	400 - 2000nm	450-700 nm
Price	$128.52	$55.00	$227

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Diffraction Grating Comparison

Diffraction Grating			
	MKS Newport	Thorlabs	Thorlabs
Type	Ruled	Ruled	Transmission
Size (mm)	12.5 x 12.5	12.7 x12.7 x 6	12.7 x 12.7
Groove Density (grooves/mm)	300	300	600
Blaze Angle	4.3°	4.18°	28.7°

Brianna Hurrell -
Photonic Engineer

Sensor Comparison

	Camera Module v1	Camera Module 3	HQ Camera	GS Camera
Image sensor	OmniVision OV5647	Sony IMX219	Sony IMX477	Sony IMX477
Resolution	5 Megapixels	8 Megapixels	12.3 Megapixels	12.3 Megapixels
Pixel Size	1.4 µm	1.12 µm	1.55 µm	1.55 µm
Aperture	f/2.9	f/2.0	Adjustable	Adjustable
Field of View	54 x 41 Degrees	62.2 x 48.8 Degrees	Depends on lens	Depends on lens
Focus Type	Fixed	Fixed or Manual	Manual	Fixed or Manual

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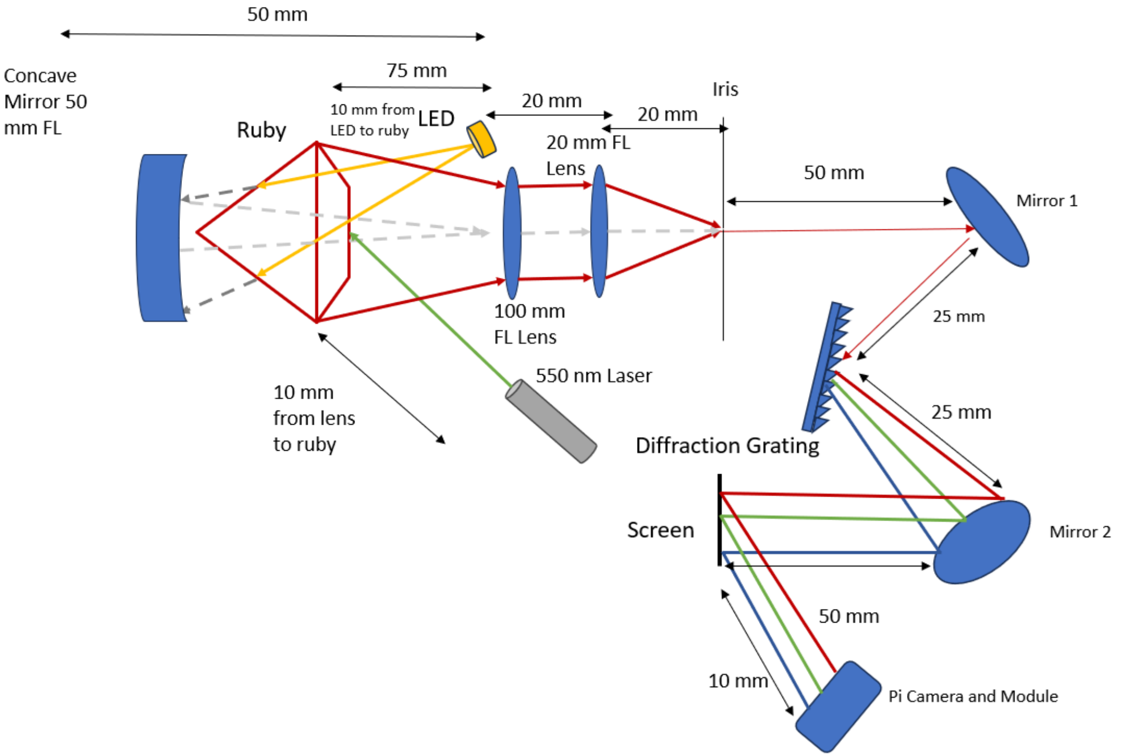
Optical Design



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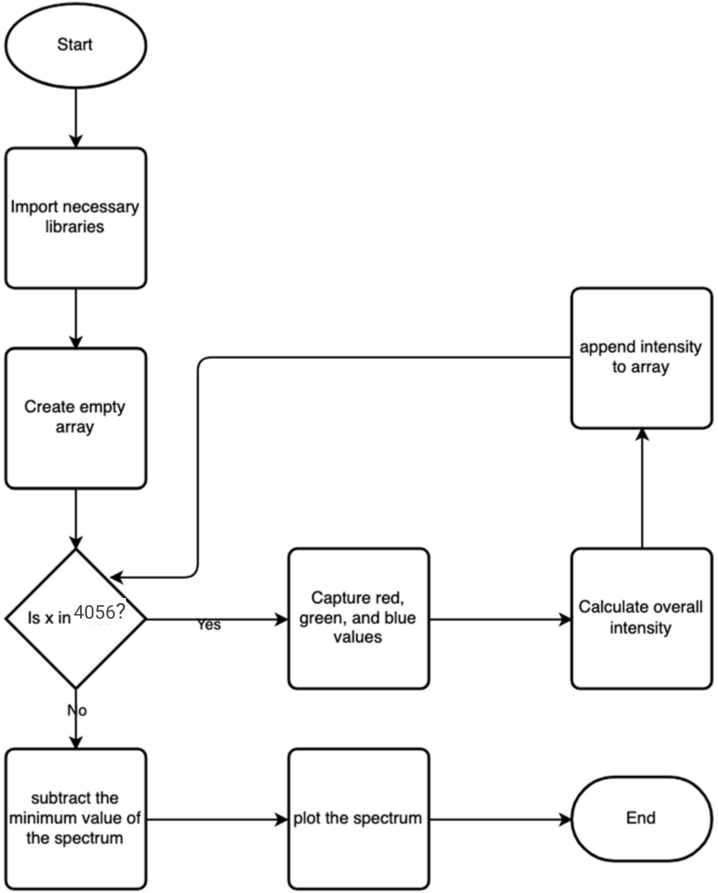
Photonic Engineer

Software Block Diagram



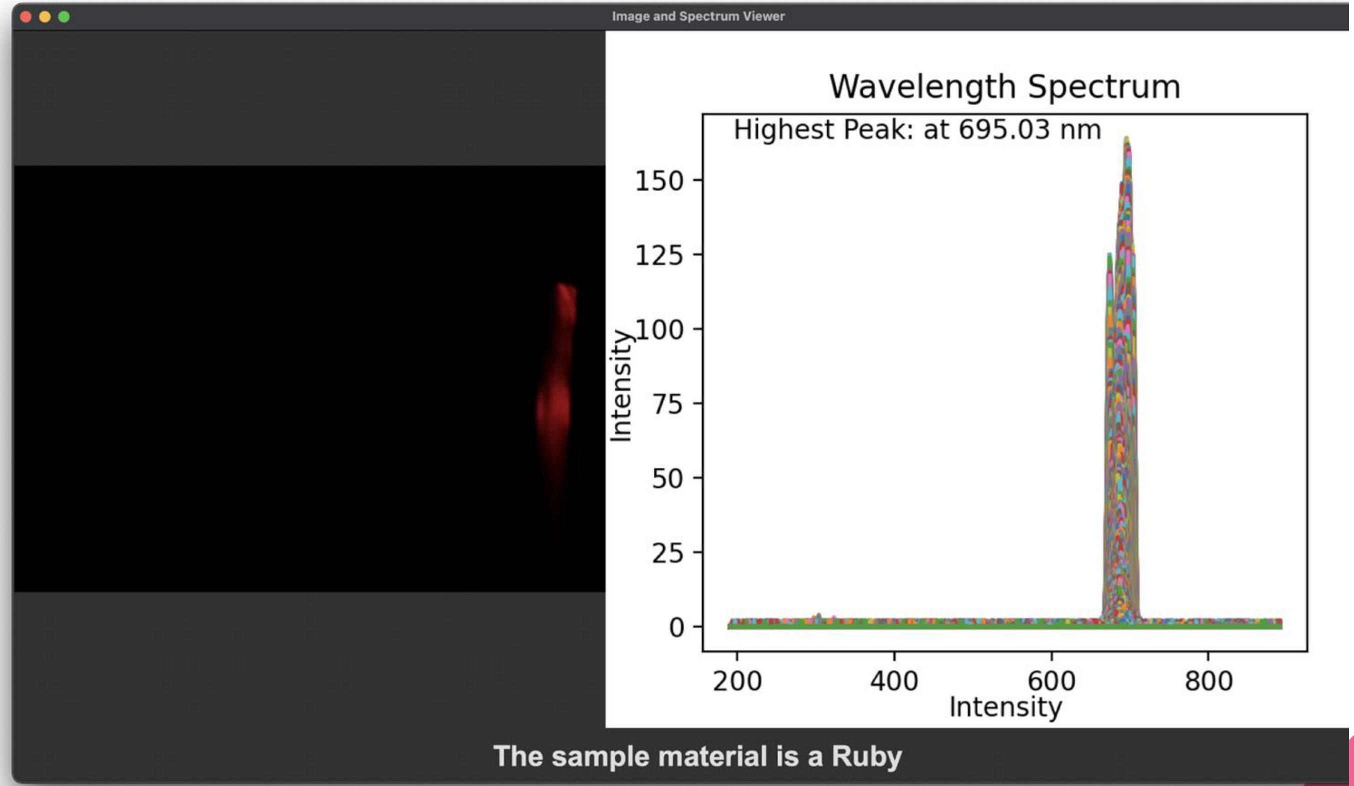
Brandon Lopez - Computer Engineer

Software Design

Image Analysis	Plotting	Data Handling/Analyzing
OpenCV: ● Comprehensive functionality ● High performance	Matplotlib.pyplot: ● Versatility and flexibility ● Integration with other libraries	Numpy: ● Efficiency ● Integration with other libraries
Pillow (PIL): ● Simple and intuitive ● Widely compatible	Seaborn: ● High-level interface ● Statistical plotting	Scipy: ● Comprehensive functionality ● Integration with other libraries
scikit-image: ● Focused on scientific computing ● Extensible and modular	Plotly: ● Interactive visualizations ● Modern design	Statsmodels: ● Statistical modeling

Brandon Lopez -
Computer Engineer

Program Output



Brandon Lopez -
Computer Engineer

Design Constraints

- Economic
  - College student budget
- Environmental
  - Consumer awareness
- Ethical
  - No infringement on patents
- Health and Safety
  - Operating within safe wavelengths within an enclosed system
- Manufacturability
  - Part availability
- Equipment
  - Tolerances and software
- Time
  - Designed and built over two college semesters

Isabelle Lebron - Photonic Engineer

Standards

- GIA
- ASME Y14
- ANSI/ESD S20.20
- ANSI Z535
- IEC 60130-10
- ISO 9001

Atman Atman - Electrical Engineer

Bill of Materials

Table 16: Overall Budget	
Component	Price
Spectrometer	
Multi-mode Fiber	$9.00
Mirror (2x)	$130.00
Grating	$77.00
Pi Camera	$50.00
Raspberry Pi Module	$20.00
Dichroscope	
Beamsplitter	$46.00
Calcite Rhombus	$38.00
Glass Prisms	$57.00

Electrical Components	Unit Price
Printed Circuit Board	$12.00
Transformer	$18.00
Bridge Rectifier	$1.00
Linear Voltage Regulator	$66.00
Fixed Terminal Block	$1.00
USB 2.0 Type A Connector	$1.00
LEDs	$3.00
LDO Voltage Regulator	$1.00
Miscellaneous	
Ruby 1	$17.00
Total	$547.00

Brianna Hurrell -
Photonic Engineer

Project Management Tools

Brandon Lopez -
Computer Engineer

Work Distribution

	Primary	Secondary
Spectrometer	Brianna	Isabelle
Lens System	Isabelle	Brianna
PCB Design	Atman	Brandon
MCU	Atman	Brandon
Spectral Graph	Brandon	Brianna/Isabelle

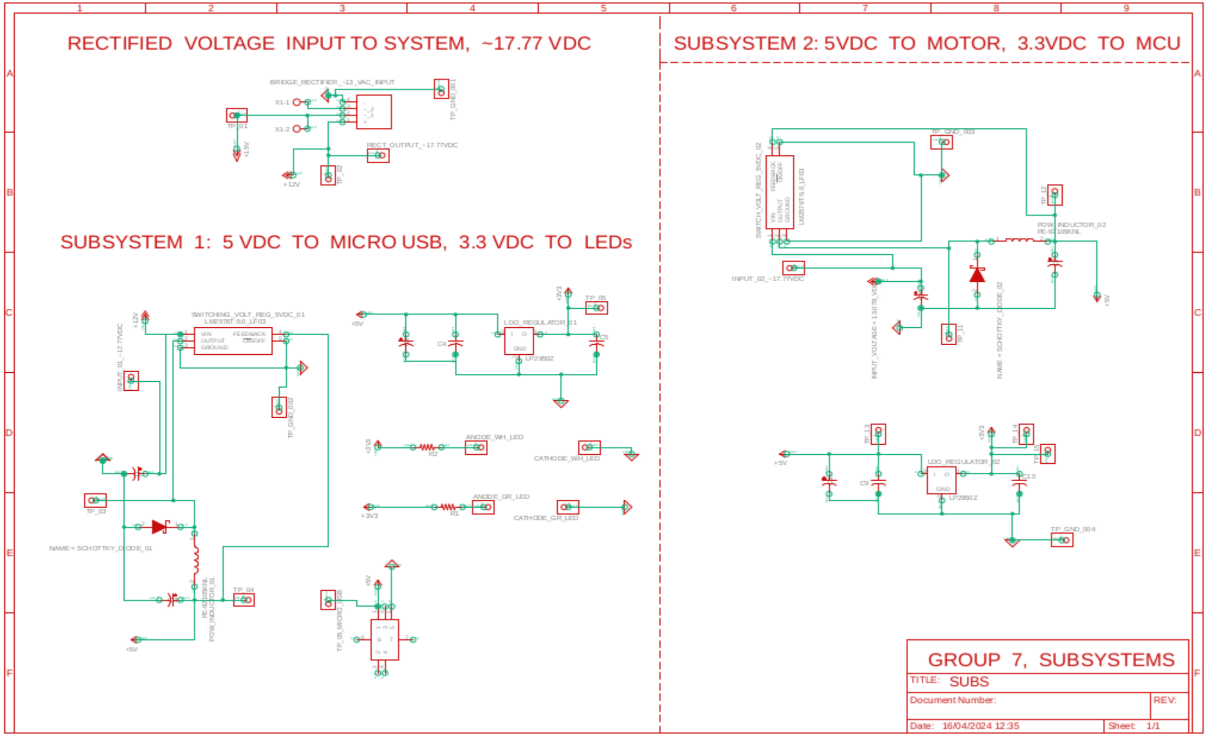
Brianna Hurrell - Photonic Engineer

Power Distribution

	COMPONENT	VOLTAGE	CURRENT
1	LINEAR VOLTAGE REGULATOR	5 V	3 A
2	LOW DROPOUT REGULATOR	3.3 V	100 mA
3	SPECTROMETER	~5 V	~200 mA
4	HQ CAMERA	~5 V	~200 mA
5	TRANSFORMER (FROM SECONDARY)	12 V	4.17 A
6	SWITCHING VOLTAGE REGULATOR	5 V	3 A
7	GREEN LED	~3 V	20 mA
8	WHITE LED	~3 V	20 mA
9	MOTOR	5 V	1.69 A
10	CAPACITOR	16 V to 25 V	~2.62 A (ripple)
11	INDUCTOR	n/a	3 A
12	BRIDGE RECTIFIER	1000 V	4 A
13	USB CONNECTOR	5 V	1.8 A

Atman Atman - Electrical Engineer

PSU Schematic



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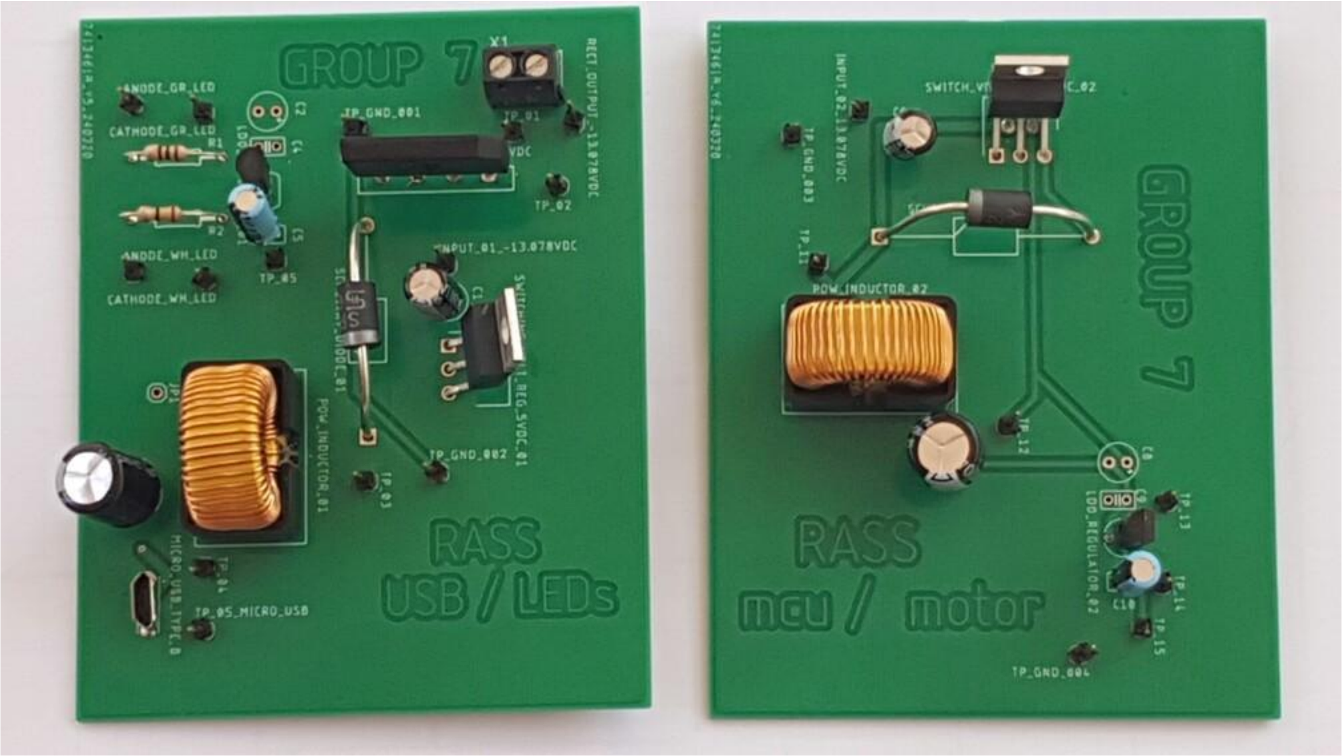
Atman Atman -
Electrical Engineer

PSU Board Layout



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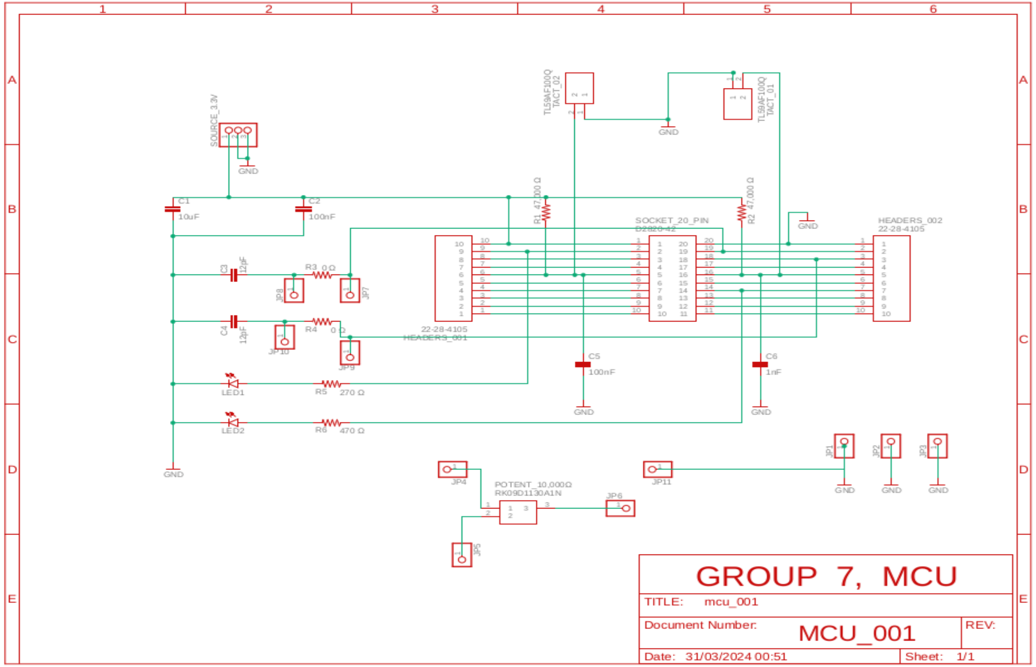
Electrical Engineer

MCU Schematic



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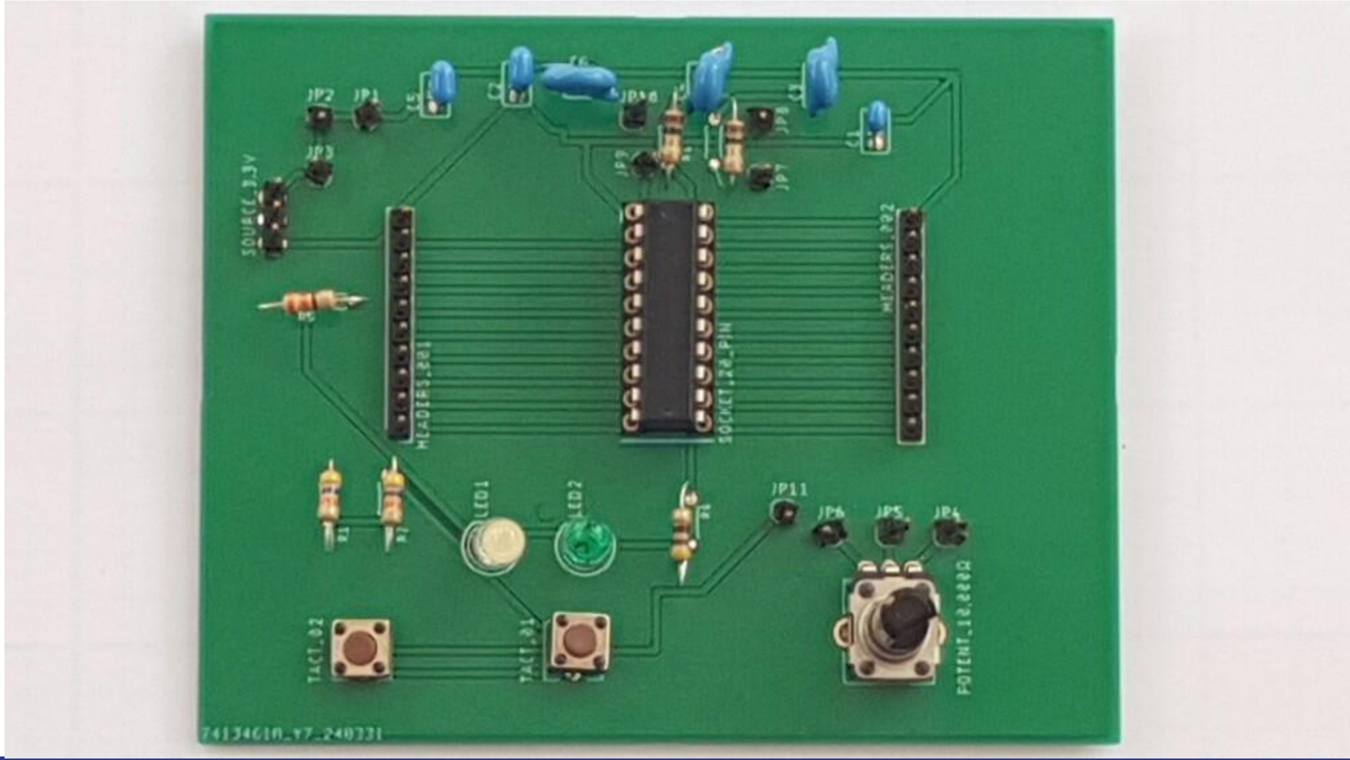
MCU Board Layout



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Electrical Engineer

ELECTRONIC PART / TECH COMPARISON (1 of 3)

LIGHT EMITTING DIODE						
		LUMEX	LUMEX	Dialight	Wurth	EAO
1	FORWARD CURRENT	20 mA	20 mA	10 mA	20 mA	20 mA
2	FORWARD VOLTAGE	3.6 V	2.2 V	3 V	2 V, 3.3 V	3 V
3	POWER	120 mW	105 mW	135 mW	48 mW, 78 mW, 78 mW	± (50 mW to 135 mW)
4	COLOR	WHITE	GREEN	GREEN	RGB	WHITE
5	TEMPERATURE	-30 C to 80 C	-40 C to 85 C	-20 C to 100 C	-40 C to 85 C	± (-20 C to 100 C)
6	VIEWING ANGLE	15 deg	60 deg	24 deg	120 deg	± (15 deg to 120 deg)
7	TYPICAL λ	550 nm	555 nm	565 nm	550 nm	x = 0.3 nm / y = 0.3 nm
8	UNIT PRICE ($)	1.77	0.32	1.06	1.25	2.66

Atman Atman - Electrical Engineer

ELECTRONIC PART / TECH COMPARISON (2 of 3)

LOW DROPOUT VOLTAGE REGULATOR						
		Texas Instr	**Texas Instr**	**Richtek**	**ANALOG DEV**	**ONSEMI**
1	CURRENT OUTPUT	150 mA	500 mA	20 mA	20 mA	100 mA
2	VOLTAGE OUTPUT	1.2 V	3.6 V	5 V	5 V	3.3 V
3	MOUNT STYLE	SMD/SMT	SMD/SMT	SMD/SMT	SMD/SMT	TH
4	DROPOUT VOLTAGE	225 mV	50 mV	60 mV	300 mV	30 mV
5	UNIT PRICE ($)	1.73	1.03	0.64	4.58	0.92

Atman Atman -
Electrical Engineer

ELECTRONIC PART / TECH COMPARISON (3 of 3)

SWITCHING VOLTAGE REGULATOR						
		Texas Inst	Texas Inst	Texas Inst	Texas Inst	Texas Inst
1	CURRENT OUTPUT	3 A	3 A	4 A	4 A	4 A
2	VOLTAGE OUTPUT	5 V	5 V	5 V	5 V	5 V
3	MOUNT STYLE	TH	TH	SMD/SMT	TH	TH
4	POWER DISSIPATION	BUCK	BUCK	Flyback	Flyback	Flyback
5	UNIT PRICE ($)	3.58	3.66	8.25	8.25	7.93

Atman Atman -
Electrical Engineer