Raman Analyzer for Illicit Drugs (RAID)

Group 2

Nicole Parker

Michael Soto

Asha Waters

Jean Georges

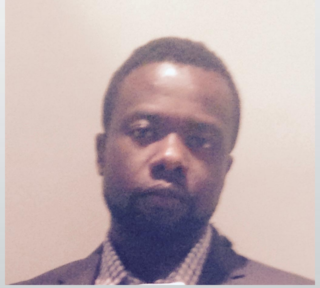
RAID

Team Composition:

Nicole Parker
Photonic Engineer

Michael Soto
Photonic Engineer

Asha Waters
Computer Engineer



Jean Georges
Computer Engineer

Sponsor

GOALS

- Develop a system capable of accurately determining the presence of GABA (in lieu of GHB) within liquid samples at and above a threshold defined experimentally.
- Enhance spectral resolution to enable finer analysis of molecular structures and compositions, aiming for a spectral resolution of approximately 1nm or better.
- Establish efficient data acquisition and processing methodologies to streamline analytical procedures. This includes:
  - Developing algorithms for efficient acquisition of Raman spectra.
  - Optimizing exposure times and signal-to-noise ratios.
- Create a user-friendly interface to ensure accessibility and ease of operation for researchers of varying expertise levels.
- Focus on cost optimization to deliver high performance at an affordable price point, thus maximizing the instrument's accessibility.

Incorporate a motorized rotation stage to enable precise measurements.

OBJECTIVES

- To determine the threshold at which our Raman spectrometer can detect the presence of GABA, the Raman spectrometer will be calibrated using known concentrations in an experimental set up. This will be compared to a baseline spectrum of pure GABA.
- To reach a spectral resolution of 1nm or better, different optical configurations will be tested, and narrow-band filters or advanced dispersive elements will be utilized.
- To develop algorithms for efficient acquisition of Raman spectra, software tools for real-time spectral processing, including background subtraction and baseline correction will be implemented. It will be validated by comparison with known reference spectra.
- A user-friendly interface will be developed by implementing an intuitive touchscreen interface for easy spectrometer control and data visualization. Selectable options for identifying the liquid in which the sample is immersed, and a real-time substance detection output will also be implemented.
- Cost-effective alternatives for optical parts will be evaluated for trade-offs between cost, performance, and reliability.
- To make the rotation stage effective, a code will be developed to move in discrete steps and to automatically home it after the spectrum has been measured.

SPECIFICATIONS AND REQUIREMENTS

Specifications	
Total bootup time	2 minutes
Spectral resolution	< 1nm
Total runtime	~20 secs
Spectral range	550nm – 790nm
Lowest concentration measured	750 mg
Motor accuracy	±0.01 mm to ±0.1 mm
Computer interface	Touch screen
Touchscreen responsivity	5 ms

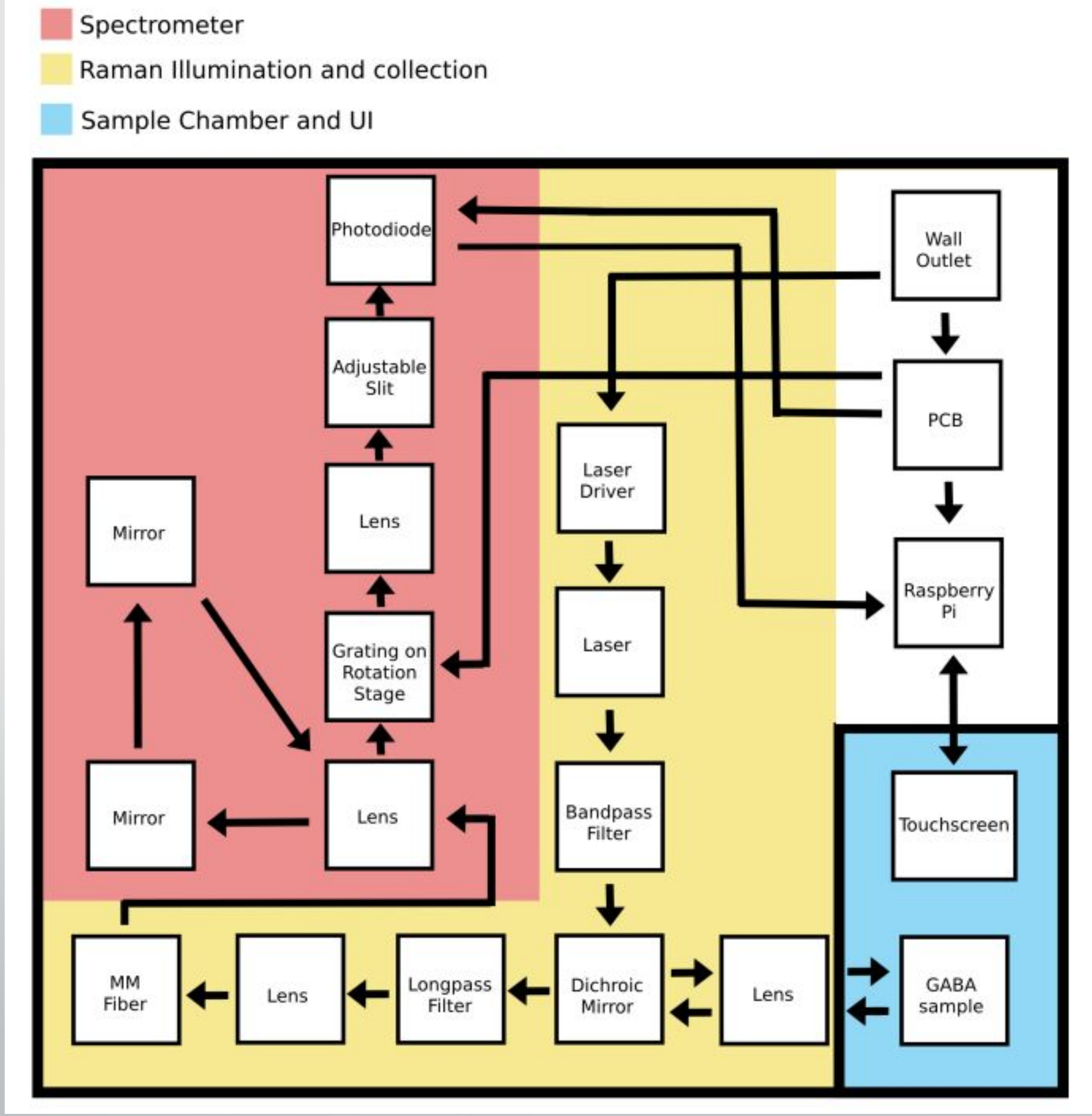
DESIGN APPROACH AND IMPLEMENTATION

This Raman Spectrometer is composed of two parts: (1) the excitation and collection stage and (2) the Czerny Turner spectrometer

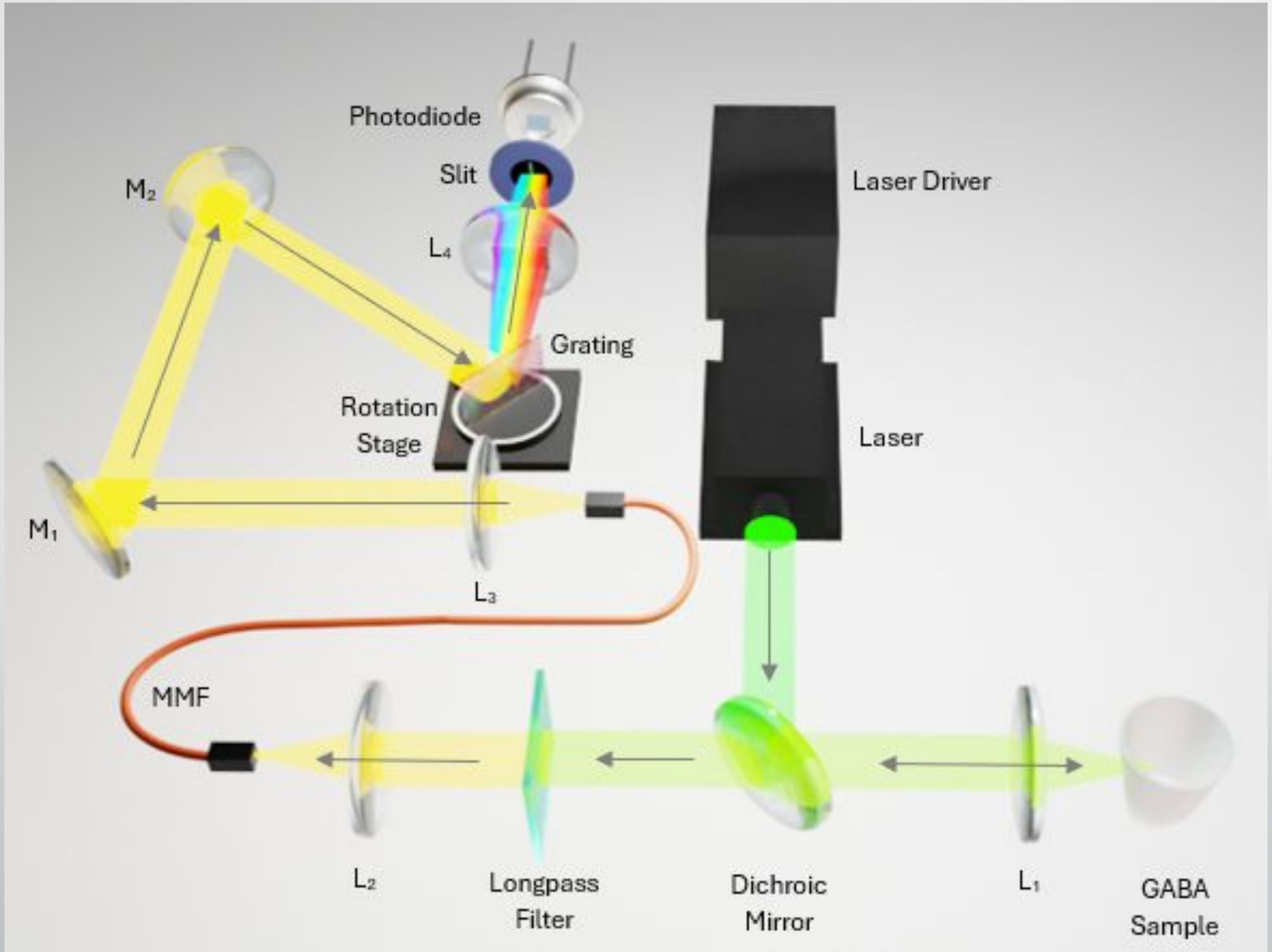
RAID was designed to be used in bars, clubs, and any other venue where roofies are of concern.

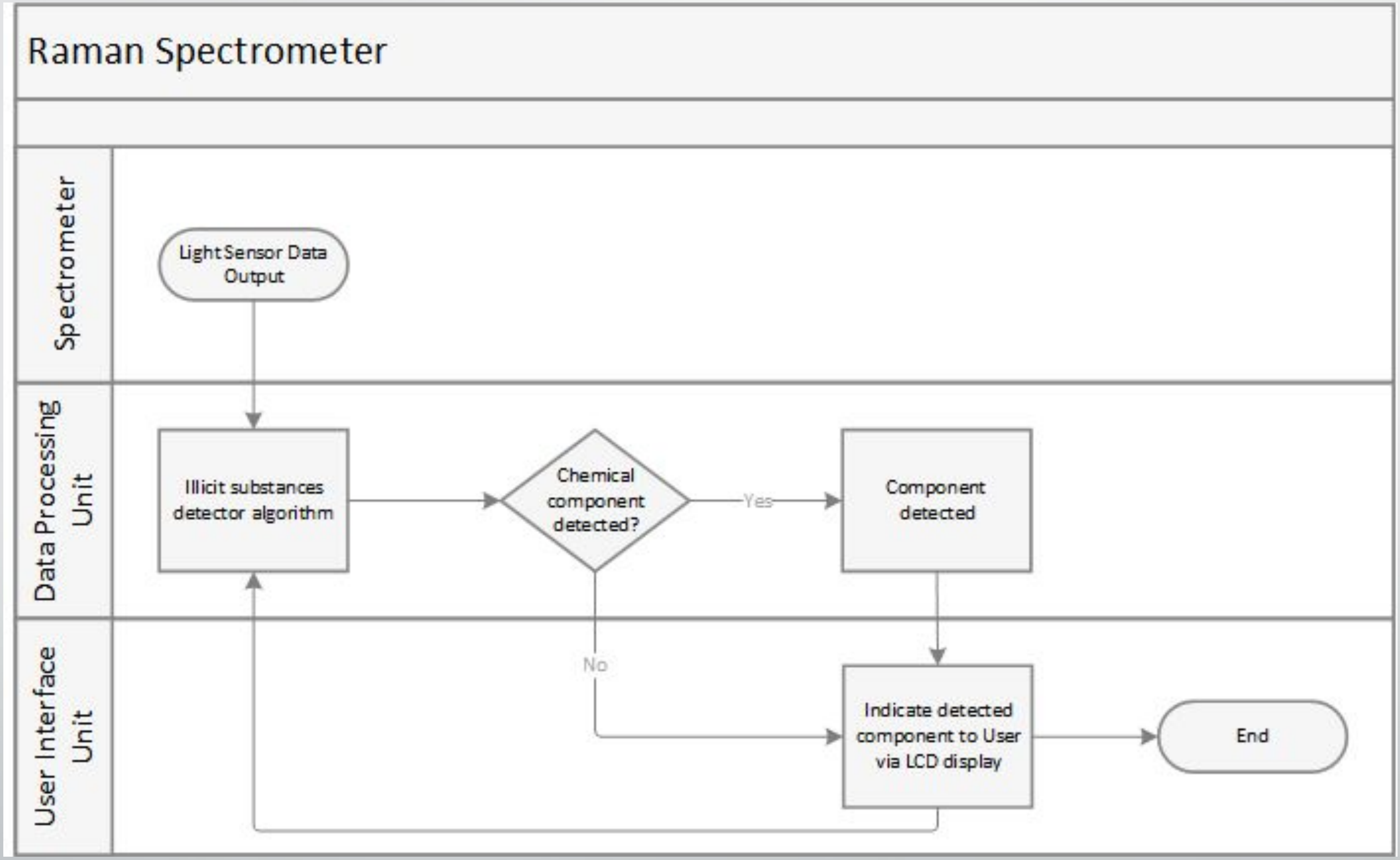
SYSTEM DESIGN

System Design

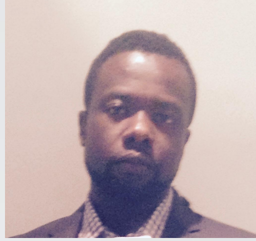


Optical Design



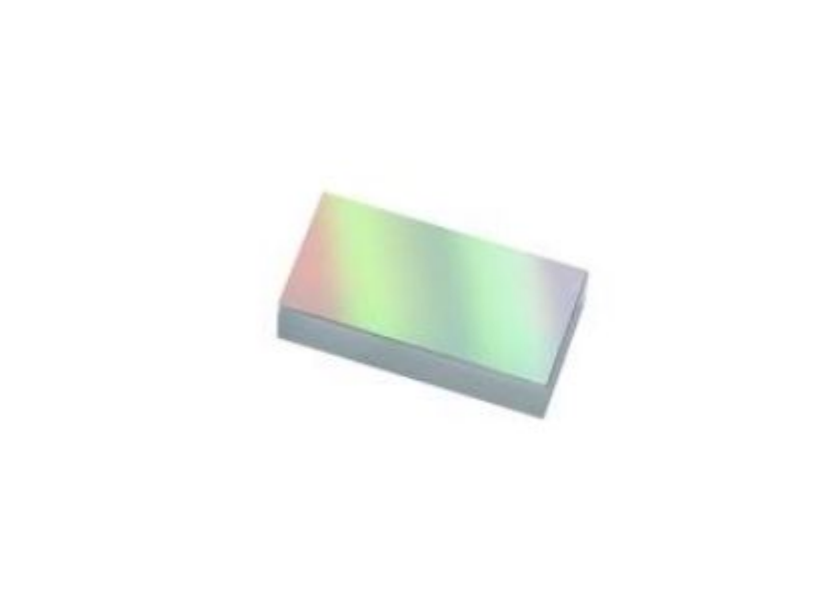


Raman Spectrometer
Spectrometer
Data Processing Unit
User Interface Unit
Light Sensor Data Output
Illicit substances detector algorithm
Chemical component detected?
Yes
No
Component detected
Indicate detected component to User via LCD display
End



HARDWARE COMPONENTS

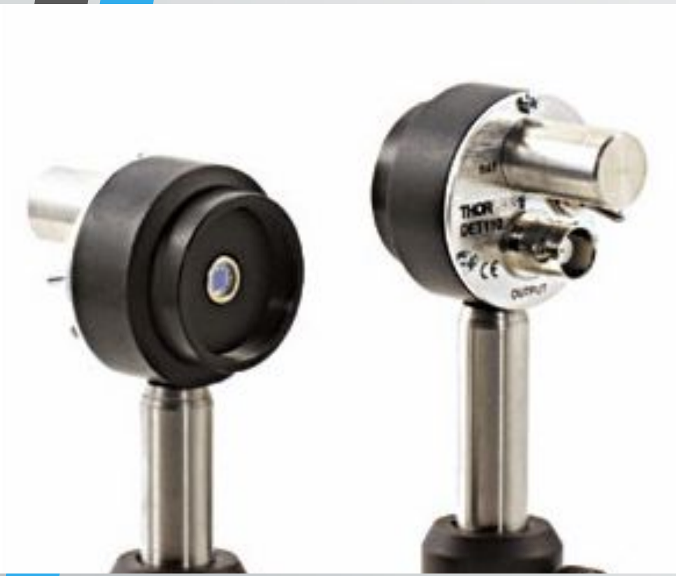
Grating Selection



Model #: 33066FL01-560R
Ruled Reflective Diffraction Grating

Transmissive Diffraction Gratings	Reflective Diffraction Gratings
Transmits most light. Absorption causes possible light loss; impacts signal strength.	Reflect all incident light; modulate undesired components. Excellent at maintaining polarization control.
Requires precise alignment in optical systems to ensure optimal performance and accuracy.	Effectively redirect incoming light in the direction of the detector to make the most of the available light and improve signal detection.
Typically, "in-line," requiring longer optical paths. Ideal for minimizing optical distortion and maximizing spectrum resolution in imaging systems, fluorescence spectroscopy, and some optical microscopy.	Common, flexible, compact, and effective optical setups. Used in Raman spectroscopy and some optical imaging systems for focusing dispersed light onto a detector or focal point.

Photodiode Selection



DET 210 – High Speed Si Photo Detector

	Specifications
Detector	Silicon PIN
Spectral Response	200 - 1100nm
Peak Wavelength	730nm+/-50nm
Rise/Fall Time	1 ns
NEP	5 E-14 W/sqrt(Hz)
Active Area	1mm
Output	BNC, DC Coupled biased with 12V battery
Cost	$181.68

Excitation Source

Common Raman Pump Wavelengths

Pump Wavelength (nm)	Laser Type	Application/Advantages	Disadvantages
532	Diode-Pumped Solid-State Laser (DPSS)	High sensitivity, good for visible range applications	Fluorescence interference can be significant
633	Helium-Neon (HeNe) Laser	Lower fluorescence interference compared to 532 nm	Lower Raman scattering efficiency compared to 532 nm
785	Diode Laser	Reduced fluorescence, good for biological samples	Lower spatial resolution, lower scattering efficiency
830	Diode Laser	Further reduced fluorescence, good for dark samples	Even lower scattering efficiency, more expensive
1064	Nd Laser	Minimal fluorescence, good for highly fluorescent samples	Significantly lower Raman scattering efficiency, expensive

Final Decision: 532 nm @ 500 mW

Longpass Filter Options

Feature	MKS Newport 20CGA-550	Thorlabs FELH0550	Edmund Optics #47-505
Size	50.8x50.8mm	25.0mm	25.0mm
Cut-on wavelength	550nm	550nm	532
Transmission Wavelength	>570nm	559-2150nm	538.9-1200nm
Thickness	1.1mm	3.5mm	3.5mm

MKS Newport 20CGA-500

Beam Splitting Mechanism

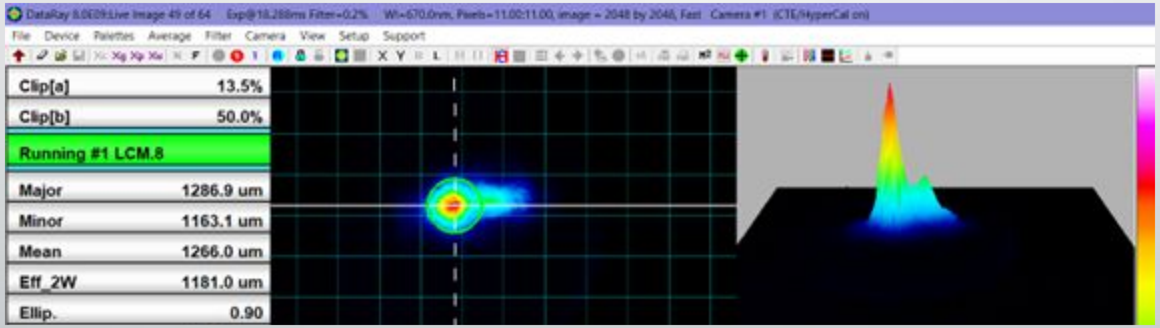
Feature	MKS Newport DCM13	Thorlabs DMLP550T	Edmund Optics #86-386
Diameter	25.0mm	0.5in	12.55mm
Cut-on wavelength	552nm	550nm	552nm
Transmittance Range	561.4-790.0nm	565-800nm	561.4-790
Reflectance Band	514.5-543.5nm	380-535nm	514.5-543.5
Angle of Incidence	45	45	45
Thickness	3.5mm	3.2mm	3.5mm
Clear Aperture	22.0mm	> ø11.43mm	8.8mm

MKS Newport
DCM13

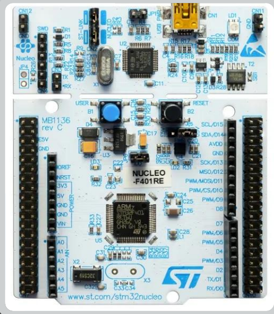
Lens Choices

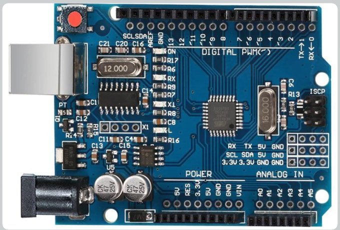
	Lens	Purpose
1	KPX046AR.14 EFL 38.1	Focus pump onto sample and collimate Raman signal
2	KPX043AR.14 EFL 25.4	Focus beam into fiber
3	KPX082AR.14 EFL 50.2	Collimate signal from fiber to spectrometer
4	EFL 50	Focus into photodiode

Beam measurement – 1.2mm



Features	STM32 Nucleo-F401RpyET6	Raspberry Pi 3 Model B+	Arduino Uno
Processor	32-bit ARM Cortex-M4 core, up to 84 MHz	1.4 GHz 64-bit quad core ARM Cortex-A53	16 MHz
RAM	512 KB	1 GB	2 KB SRAM
Drive Space	512 KB Flash	32 GB Flash, microSD card	32 KB Flash
Input Voltage	3.3 - 12 V	5.1 V DC	7 - 12 V
Dimensions	4” x 3” x 1”	3.7” x 2.8” x 1.14”	3.15” x 2.17” x 0.98”
Weight	3.2 oz	7.1 oz	1.6 oz
Other features	GPIO pins, USB, Arduino Uno Rev 3 connectivity	Extended 40-pin GPIO header, USB	14 DIO Pins, USB
Pricing	$13.83	$46	$24.99





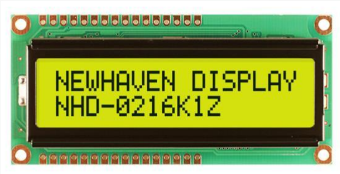
Microcontroller Options

Key Features of Our Selection:

- 1.4 GHz processor
- Larger computing power
- Increased memory & storage
- Community support available for troubleshooting

Display Options

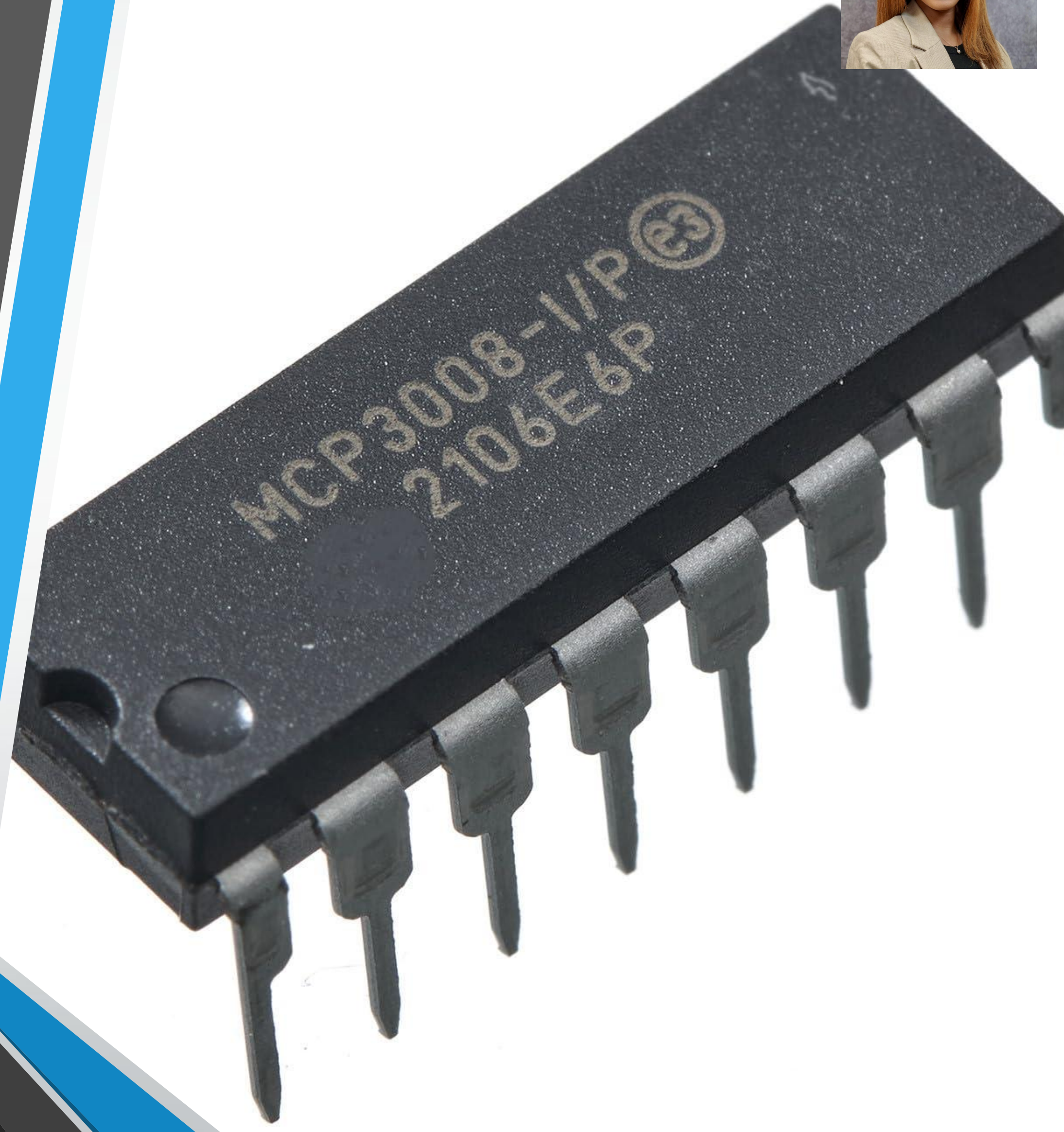
Features	NewHaven Display	Waveshare	HAMTYSAN
Screen size	2-line by 16 characters	2 inches	8 inches
Display resolution	2560 x 1600 pixels	240 x 320 pixels	1920 x 1080 pixels
Interface	Parallel	SPI	GPIO
Display type	OLED	LCD	TFT LCD
Touchscreen capability	No	No	Yes
Type of touchscreen	-	-	Capacitive touch
Dimensions	4.9” x 1.7” x 0.4”	2.28” x 1.37” x 0.19”	8.74” x 5.98” x 2.24”
Operating Voltage	5 V	3.3 - 5 V	5 V
Compatible with Raspberry Pi 3 Model B+	Yes	Yes	Yes
Pricing	$9.99	$14.65	$65.49



Key Features of Our Selection:
- Touchscreen capability
- Larger display size
- Quick responsiveness
- Multitouch functionality
- Compatible with Raspberry Pi 3 Model B+ microcontroller selection

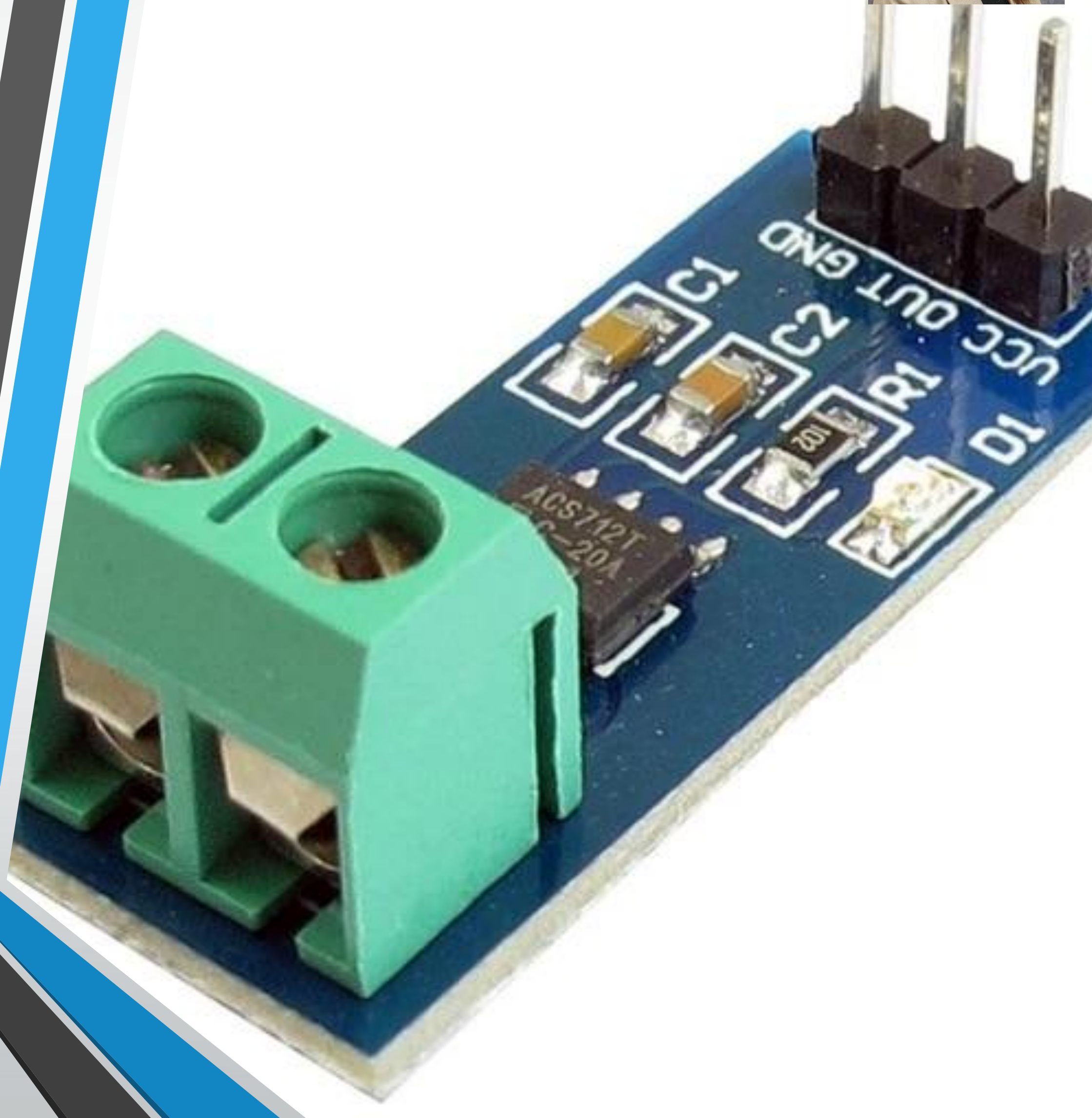
Bridgold MCP3008 ADC

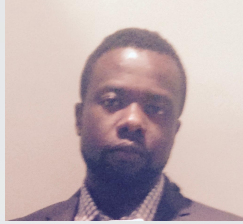
- Resolution: 10 bit
- Channels: 8 analog input channels
- SPI Interface
- Sampling Rate: maximum rate of 200 kilosamples per second (ksps) based on operating conditions
- Voltage Range: 2.7 V to 5.5 V
- Low power consumption



Allegro Microsystems ACS712 Current Sensor

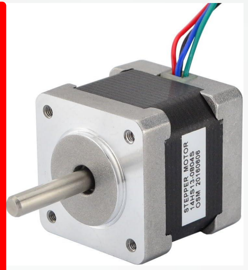
- Current Sensing Range: ±30 A
- Output Voltage Sensitivity: 66 to 185 mV/A
- Supply Voltage: 4.5V to 5.5V
- Operating Temperature Range: -40° C to 85° C
- Output Type: analog
- Bandwidth: close to 80 kHz





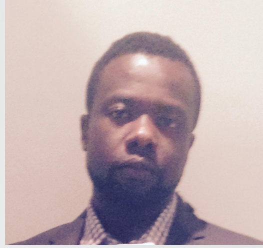
Motorized Stage

Feature	NEMA 17	NEMA 14
Mounting Size	1.7 x 1.7 inches (NEMA 17)	1.4 x 1.4 inches (NEMA 14)
Torque Output	Higher	Lower
Step Angle	1.8 degrees	1.8 degrees
Voltage Range	3V - 12V	3V - 12V
Price Range	$10 - $30 (approx.)	$5 - $20 (approx.)
Arduino Compatibility	Yes	Yes
MSP430FR6989 Compatibility	Yes	Yes



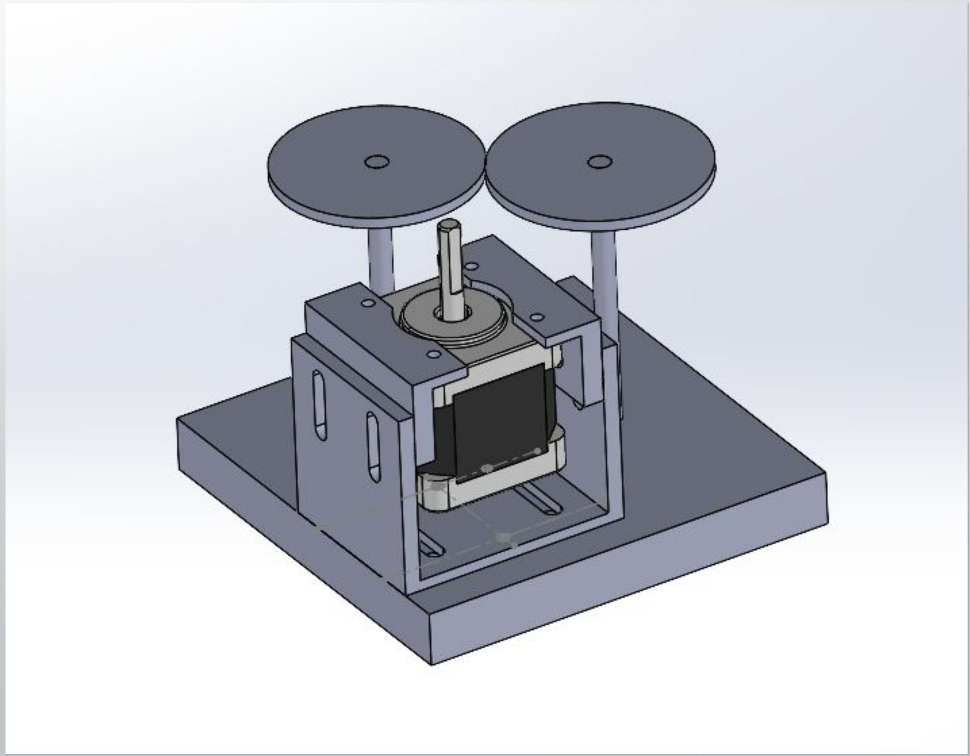
Feature	A4988	TMC2209	DRV8825
Manufacturer	Allegro MicroSystems	BigtreeTech	Texas Instruments
Max Current per Phase	2A	2.5A	2.5A
Operating Voltage	8V - 35V	8.2V - 45V	8.2V - 45V
Micro-stepping	Full, Half, 1/4, 1/8, 1/16 steps	Full, Half, 1/4, 1/8, 1/16, 1/32, 1/64, 1/256 steps	Full, Half, 1/4, 1/8, 1/16, 1/32 steps
Overcurrent Protection	Yes	Yes	Yes
Overtemperature Protection	Yes	Yes	Yes
Suitable Applications	General purpose projects	Projects requiring higher resolution and smoother motion	Projects requiring higher resolution and smoother motion
Compatible with Arduino	Yes	Yes	Yes
Compatible with Raspberry Pi	Yes	Yes	Yes

Motorized Stage

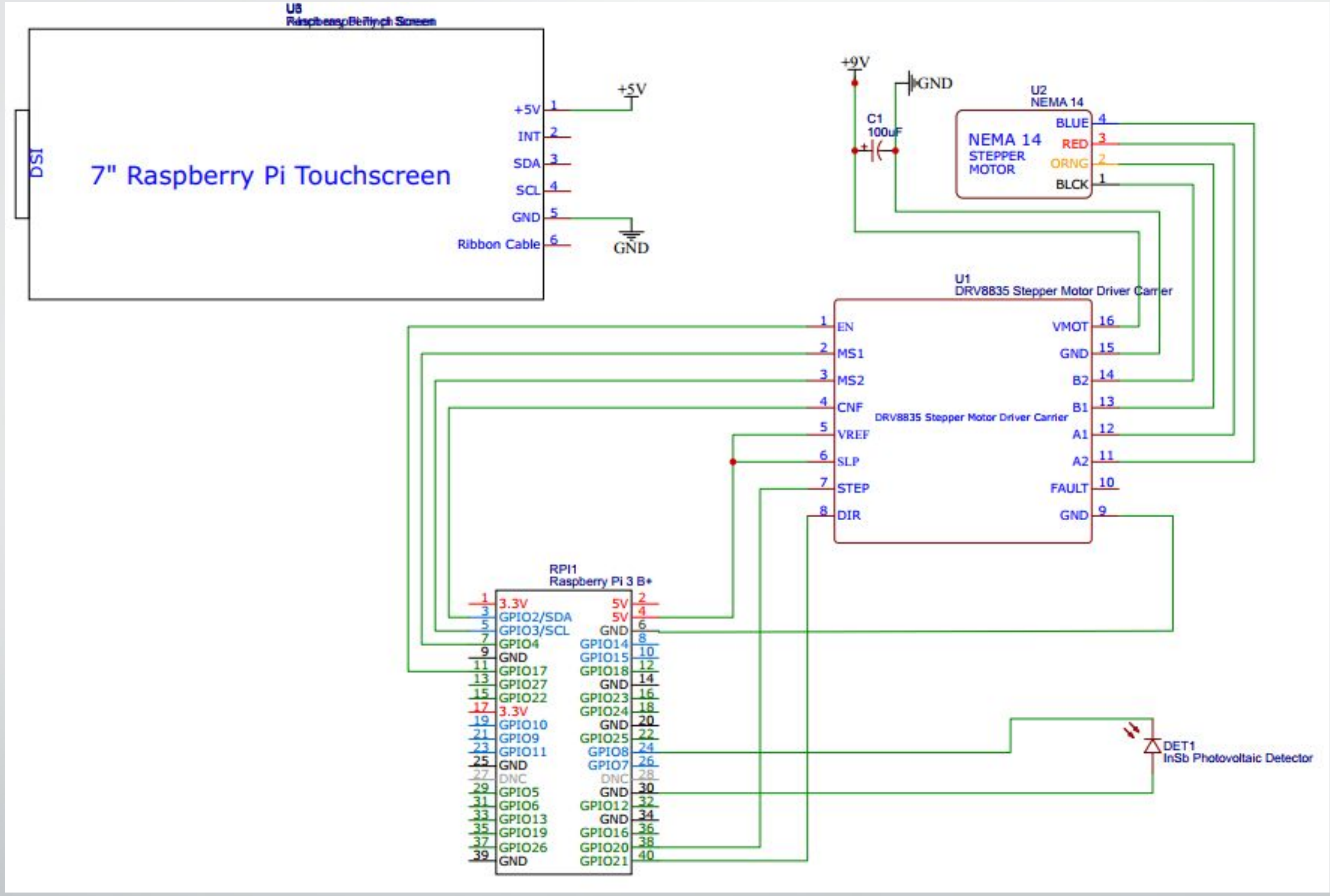


Desired step angle = 0.005°
Selected gears:
Pinion: 13T 48P
Driven gear: 90T 48P

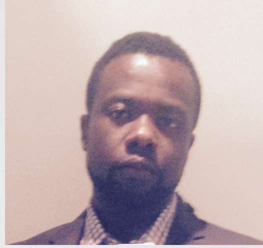
Overall Gear Ratio = 6.923
Effective step Angle = 1.8°
Effective step angle with 1/64 Microstepping = 1.8°/64 ≈0.028125°
Final step angle ≈ 0.00406°



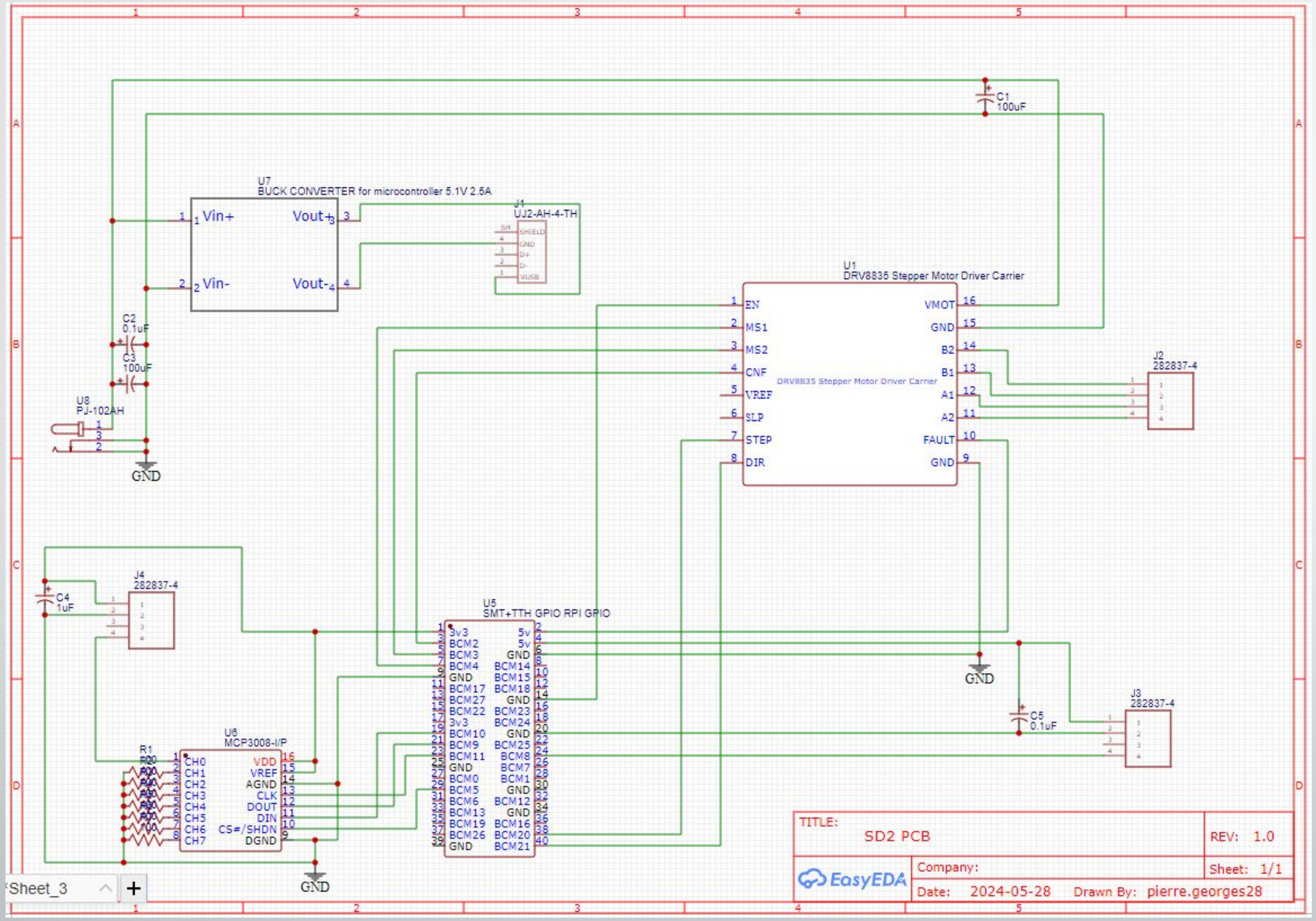
Schematics

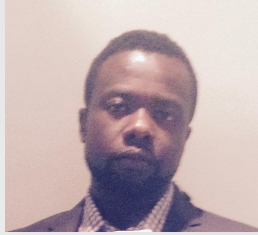


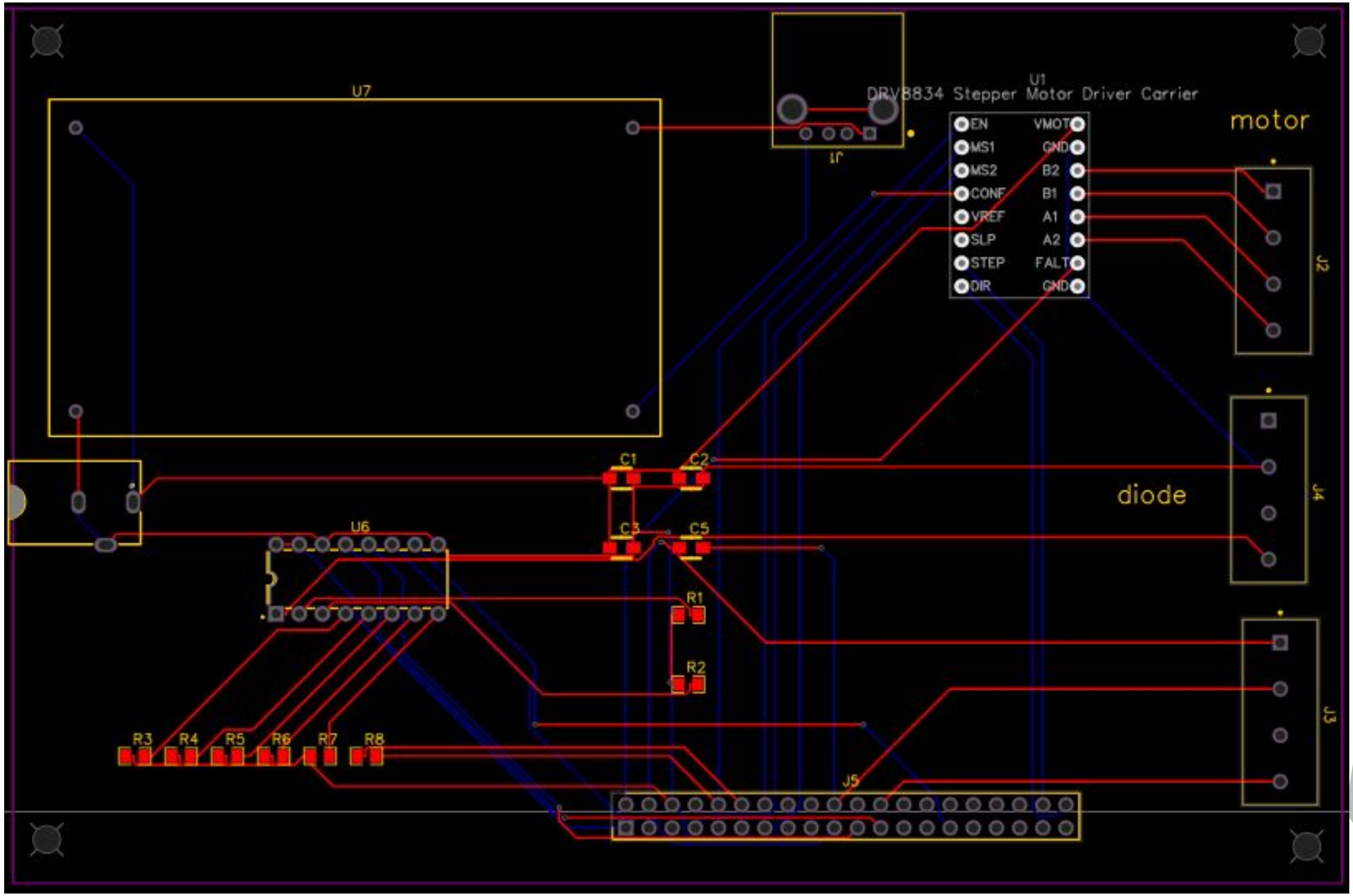
7" Raspberry Pi Touchscreen
DSI
+5V 1
INT 2
SDA 3
SCL 4
GND 5
Ribbon Cable 6
+5V
GND
+9V
GND
C1
100uF
U2
NEMA 14
NEMA 14
STEPPER
MOTOR
BLUE 4
RED 3
ORNG 2
BLCK 1
U1
DRV8835 Stepper Motor Driver Carrier
1 EN
2 MS1
3 MS2
4 CNF
5 VREF
6 SLP
7 STEP
8 DIR
DRV8835 Stepper Motor Driver Carrier
VMOT 16
GND 15
B2 14
B1 13
A1 12
A2 11
FAULT 10
GND 9
RPI1
Raspberry Pi 3 B+
1 3.3V
3 GPIO2/SDA
5 GPIO3/SCL
7 GPIO4
9 GND
11 GPIO17
13 GPIO27
15 GPIO22
17 3.3V
19 GPIO10
21 GPIO9
23 GPIO11
25 GND
27 DNC
29 GPIO5
31 GPIO6
33 GPIO13
35 GPIO19
37 GPIO26
39 GND
5V 2
5V 4
GND 6
GPIO14 8
GPIO15 10
GPIO18 12
GND 14
GPIO23 16
GPIO24 18
GND 20
GPIO25 22
GPIO8 24
GPIO7 26
DNC 28
GND 30
GPIO12 32
GND 34
GPIO16 36
GPIO20 38
GPIO21 40
DET1
InSb Photovoltaic Detector



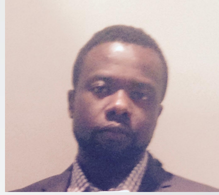
Schematics


U7
BUCK CONVERTER for microcontroller 5.1V 2.5A
Vin+
Vin-
Vout+
Vout-
J1
UJ2-AH-4-TH
U1
DRV8835 Stepper Motor Driver Carrier
EN
MS1
MS2
CNF
VREF
SLP
STEP
DIR
VMOT
GND
B2
B1
A1
A2
FAULT
DRV8835 Stepper Motor Driver Carrier
J2
282837-4
C1
100uF
C2
0.1uF
C3
100uF
U8
PJ-102AH
GND
J4
282837-4
C4
1uF
U5
SMT+TTH GPIO RPI GPIO
U6
MCP3008-I/P
CH0
CH1
CH2
CH3
CH4
CH5
CH6
CH7
VDD
VREF
AGND
CLK
DOUT
DIN
CS#/SHDN
DGND
R1
J3
282837-4
C5
0.1uF
TITLE:
SD2 PCB
REV: 1.0
Company:
Sheet: 1/1
EasyEDA
Date: 2024-05-28
Drawn By: pierre.georges28
Sheet_3




U7
U1
DRV8834 Stepper Motor Driver Carrier
EN
MS1
MS2
CONF
VREF
SLP
STEP
DIR
VMOT
GND
B2
B1
A1
A2
FALT
GND
motor
J1
J2
J4
diode
J3
C1
C2
C3
C5
U6
R1
R2
R3
R4
R5
R6
R7
R8
J5

PCB



Budget

Part	Unit	Unit Price	Total Amount
20CGA-550 Longpass Filter	1	$102.00	$0.00
33066FL01-280R Ruled Diffraction Grating	1	$176.00	$0.00
DCM13 Beam Combiner	1	$342.00	$0.00
DGF-12 Diffraction Grating Mount	1	$44.00	$0.00
KPX046AR.14 EFL 38.1 Lens	1	$42.00	$0.00
KPX043AR.14 EFL 25.4 Lens	1	$42.00	$0.00
KPX082AR.14 EFL 50.2 lens	1	$43.00	$0.00
EFL 50 Lens	1	-	$0.00
M1Q Mirror Mount	1	$46.00	$0.00
M-PPF50 Filter Mount	1	$112.00	$0.00
SV-0.5 Adjustable Slit	1	$347.00	$0.00
532nm 500mW Laser + Driver	1	-	$0.00
MMF NA 0.27 Optical Fiber	1	-	$0.00
Fiber Mount	2	-	$0.00
Lens Mount	2	-	$0.00
Mirrors	2	-	$0.00
Mirror Mount	3	-	$0.00
Rotation Stage	1	-	$0.00

Budget

Part	Unit	Unit Price	Total Amount
Post + Post Holder	10	-	$0.00
Optical Clamping Fork	8	-	$0.00
Screws	-	-	$0.00
Photodiode	1	$181.68	$0.00
Cuvette 4pc	1	$36.99	$36.99
Gamma Aminobutyric Acid Powder (GABA supplement)		$18.96	$18.96
Raspberry Pi Container	1	$5.99	$5.99
Raspberry Pi 3 Model B+ Board	2	$46.00	$92.00
HAMTYSAN 8 Inch Touch Screen	1	$65.49	$65.49
SanDisk MicroSD Card	1	$14.39	$14.39
MCP3008 ADC Converter	1	$6.99	$6.99
ACS712 Current Sensor Detector	1	$3.25	$3.25
NEMA14 Motor	1	$15.91	$15.91
Stepper Motor Driver	1	$11.88	$11.88
Gears	1	$13.95	$13.95
PCB Components	1	$30.97	$30.97
Power Supply Adapter	1	$11.99	$11.99

Budget

	Unit Price	Total Amount
Total Price	$1,760.44	**$328.76**

Thanks to MKS Newport for sponsoring the optical components!

SOFTWARE COMPONENTS

Software Overview

OBJECTIVE: Develop a graphical user interface to run an algorithm that process the data captured and determines the presence of GABA, notifying the user whether beverage is safe or spiked.

Operating System:	Raspberry Pi OS also known as Raspbian
Integrated Developed Environment (IDE):	Visual Studio Code
Programming Language:	Python

Raspberry Pi OS Key Features

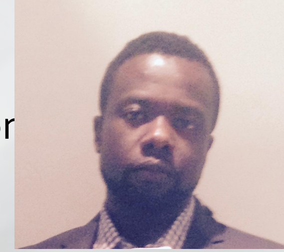
- **Optimized for Raspberry Pi Hardware**
    - Ensuring maximum compatibility and performance
- **Pre-installed software & development tools**
    - Including Python which saves time during initial setup
- **Extensive documentation**
    - Making it easier to develop & troubleshoot applications
- **Security updates**
    - OS has regular security updates ensuring the application environment is secure
- **Efficient**
    - Consumes minimal resources such as memory and processing power

RELATED STANDARDS

Standards

Standard	Reason
ISO 9001:2015 – Quality Management	It helps organizations of all sizes and sectors to improve their performance, meet customer expectations and demonstrate their commitment to quality.
IEC 60825-1:2014 – Safety of Laser Products	To introduce a system of classification of lasers and laser products emitting radiation in the wavelength range 180 nm to 1 mm according to their degree of optical radiation hazard in order to aid hazard evaluation and to aid the determination of user control measures

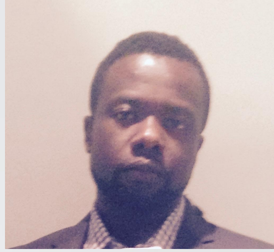
DESIGN CONSTRAINTS



- **Ethical Considerations:**
  - Ensuring accurate detection to avoid false positives/negatives which could have serious implicatio
- **Health and Safety:**
  - Due to its controlled substance nature, illicit drugs were not readily available for testing.
  - PPE is required when assembling or troubleshooting due to laser.
- **User Training:**
  - Providing comprehensive training for users to ensure safe and effective operation.
  - Clear instructions and user-friendly design to minimize user error.
- Energy Efficiency:
  - Due to time constraints and limited know how our prototype is not the most energy efficient.
  - More R&D would yield more efficient methods to accomplish said goal.
- **Manufacturability**:
  - Limited knowledge of mounting optics outside of the breadboard.
- **Economical and Time:**
  - Because these spectrometers are complex and precise, we are limited to what we can include in our design's

SUCCESSES AND DIFFICULTIES

Successes and Difficulties



- **PCB**
  - Success: Learning how to solder
  - Difficulty: Noise and electromagnetic interference
- **Motorized Stage**
  - Success: Integrating the NEMA14 with the stepper driver
  - Difficulty: Getting down to the 0.005° required to rotate the grating lens
- **Spectrometer**
  - Success: Aligning the optical components to the system
  - Difficulty: Integrating the stepper motor rotation stage into the system
- **GABA Analysis**
  - Success: Installing necessary software needed to run program via microcontroller
  - Difficulty: Converting analog signal from photodiode to digital signal for microcontroller

CHALLENGES FACED COMPLETING RAID PROJECT

Challenges Faced During Completion

- **The Creation of the Housing**
- Due to our lack of Mechanical Engineering experience with CAD, we struggled designing a housing.
- Given that we are building a spectrometer for Raman Spectroscopy, we need to be very precise when aligning our RAID systems. Aligning on our systems without the use of an optical breadboard (creating our own by hand) served as a MAJOR challenge. Given the time and cost constraints, we had to use wood rather than aluminum to recreate the optical breadboard.

- **Photodiode Calibration:**
- Struggled to determine the proper algorithm necessary to analyze the Raman signal we were receiving.

- **Rotation Stage Calibration:**
- Determining a way to calibrate the motor, grating, and wavelength was difficult to find a solution for. We ended up using a Helium and Neon lamp which has peaks that are between 500 – 600 nm which is close to where our GABA peaks lie (around 580 nm).
- Building a step motor with such a small resolution (0.005-degree steps)

If we had more time…

- **Find a lighter housing alternative to enable better portability.**
- **Calibrate the photodiode properly.**
- **Try testing with different substances.**

Questions?