Portable 3D Scanner Feasibility Study

Group 17:

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Project Discussion

- Discuss the overall project block diagram, system design diagram
- Discuss the project design approach and proposed implementation
- Discuss and support significant design decisions and significant component decisions
- Discuss the feasibility possible of the project and not feasibility
- Identification and review of related standard of the project
- Discuss the project budget

Motivation

- To give us the opportunity to work in a group, delve into complex applications that will serve us for our careers and future.
- To spark passion and creativity in our respective fields to make us better engineers.
- Using ultrasonic sensors to build 3D scanner
- to find a way to build a reliable and efficient scanner that can also model 3D, but with a way lower cost.

Goals And Objectives

- ❖Have a camera that can 3d scan an object using ultrasonic sensors for depth.
- ❖Upload images to a website/interface.
- ❖Have an interface that a user can save and edit images, along with exporting them.
- ❖To be able to study the viability of a 3D scanner that is affordable relative to what already exists on the market but is up-to par in performance and reliability.

Our Stretch Goal

- ❖The main goal of our project is to discover whether or not it is possible to scan an object with an ultrasonic sensor to create a 3D image
- ❖If we are able to make our goal (as in successfully scan a 3D object), we will add a camera to the scanner, for the purpose of adding color to the image.
- ❖Because this would make the overall project more difficult, we have decided it would be best to focus on the 3D model first.

Specifications and Requirements

- The device should operate as a portable, but not handheld, device and transmit data wirelessly to a PC over Wi-Fi 802.11ac/n.
- The device should be no longer than 10 inches in length.
- The device should not weigh more than 5 pounds.
- The device should not cost more than $300.
- The device must have an interactive button to capture images within 30 seconds to 1 minute as well as an I/O switch for power.
- The device power will be powered via USB 2.0/USB 3.1.

Specifications and Requirements

- The power supply must last for a minimum of 2 hours before recharging.
- The device should be powered by a NiMH 7.2V battery.
- A buck converter is needed to step-down 5V to 3.3V for the microcontroller.
- At max 3 ultrasonic sensors must be utilized for triangulation and depth sensing.
- Ultrasonic sensors should operate within 1 to 3 meters.

Significant Component Decisions

- ❖The development board needs to be powerful enough to process the image capture to the sensor data and operate multiple accessories such as MIPI CSI-2.
- ❖FPGA is the ideal solution; however, the high cost and high development time goes against the goals of this project.
- ❖The camera must capture in high resolution with a narrow field of view to capture details.

3 Ultrasonic Sensors vs 1 Ultrasonic Sensors

- The image file created will be a list of facades (triangles) which can be processed by any 3D image viewing software.
- With 3 Ultrasonic Sensors, we could record one facade at a time. But with one Ultrasonic sensor we would have an easier time recording multiple points, then creating each facade afterwards.

Ultrasonic Sensor Advantages and Disadvantages

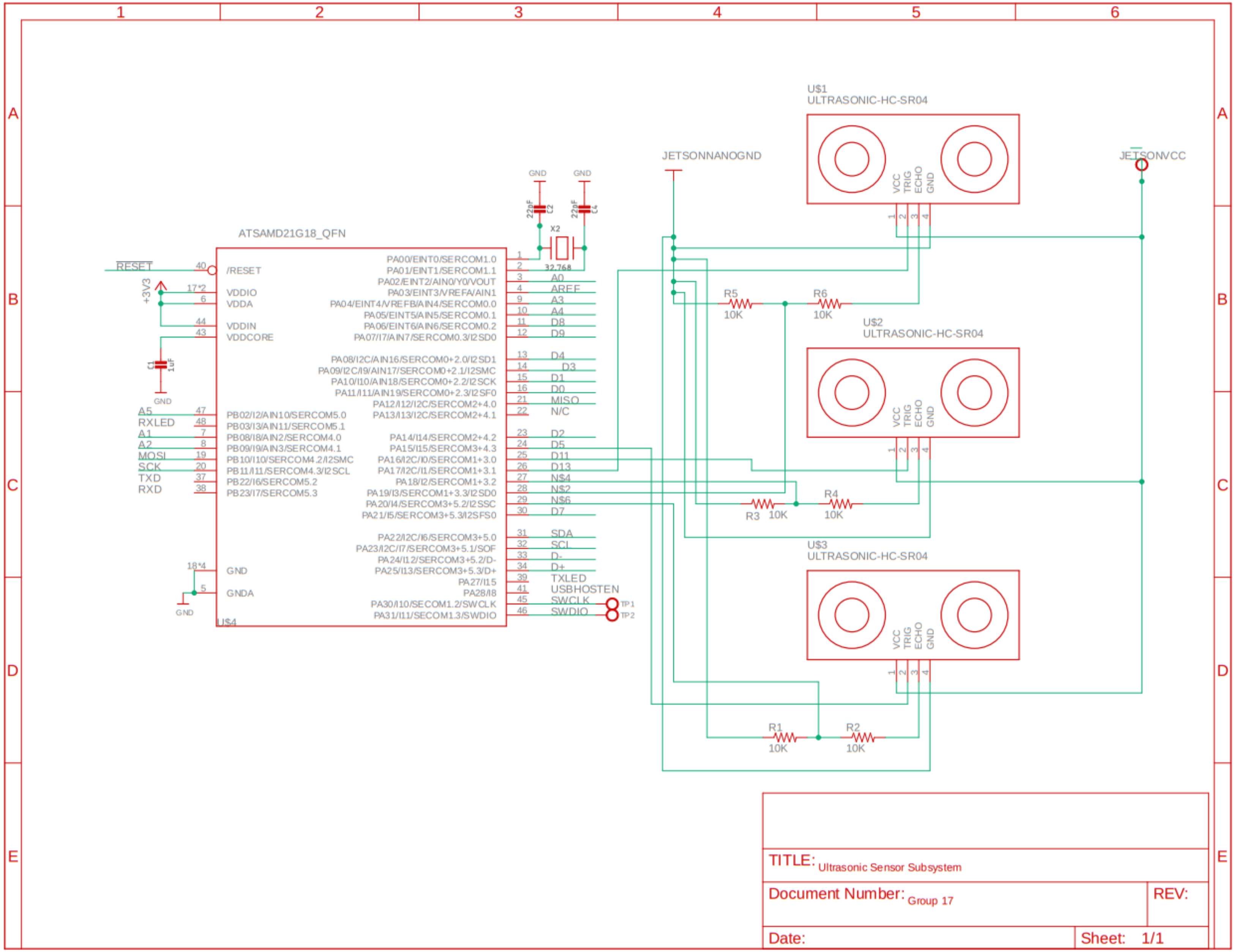
- ❖Reliable as it is insensitive to environmental influences such as dust, light, smoke, and can detect transparent objects.
- ❖Unreliable in fluctuating environments that alter the medium.
- ❖Sound absorbing materials will be impossible to scan.

Ultrasonic Subsystem

- ❖Consists of the 3 Ultrasonic sensors and a microcontroller.
- ❖The HC-SR04 sensors run on 5V logic while the Adafruit Feather M0 microcontroller runs on 3.3V.
- ❖Each ultrasonic sensor will operate sequentially to prevent crosstalk.
- ❖The sensors will not be mounted on the PCB.

Feature	HY-SRF05	HC-SR04	URM37 V5.0
Operating Voltage	4.5V ~ 5.5V	5V	3.3V ~ 5.5V
Resolution	0.3cm	0.3cm	1cm
Shape	Sqaure	Rectangle	
Current Draw	10 to 40mA	15mA	20mA
Pins	5	4	9
Operational Range	2cm - 450cm	2cm - 400cm	2cm - 800cm
Precision	~ 3mm	~ 2mm	
Dimensions	45 x 15 x 27 mm	45 x 20 x 15 mm	51 x 22 x 13 mm
Price	$2.49	$3.95	$13.90

Schematic of Ultrasonic Subsystem

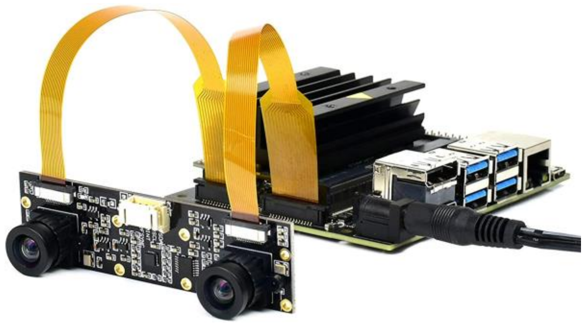


Development Board (NVIDIA Jetson Nano)

- ❖2-lane CSI interface for dedicated camera sensors.
- ❖40-pin expansion header for multiple ultrasonic sensors.
- ❖Built in 802.11ac wireless adapter for uploading image captures.
- ❖MicroSD card port for local file storage.
- ❖Dedicated GPU for image processing.

Feature	NVIDIA Jetson Nano Developer Kit 2GB	NVIDIA Jetson Nano Developer Kit B01	MaaXBoard Mini	NanoPi M4V2
Operating Voltage	≥4.75V	≥4.75V	5V	5V
Operating Temperature	-25°C – 80°C	-25°C – 80°C	0 - 70°C	-25°C – 70°C
Max Clock Frequency	1.43GHz	1.43GHz	1.8GHz	2.0GHz
GPU	Nvidia Maxwell	Nvidia Maxwell	GC NanoUltra	Mali-T864
CPU	Arm Cortex-A57	Arm Cortex-A57	Arm Cortex-A53	2x Arm Cortex-A72
Memory	2GB LPDDR4	4GB LPDDR4	2GB DDR4 SDRAM	4GB LPDDR4
Power Consumption	5W-10W	5W-10W	5W	10W
Price	$59.00	$99.00	$73.00	$70.00

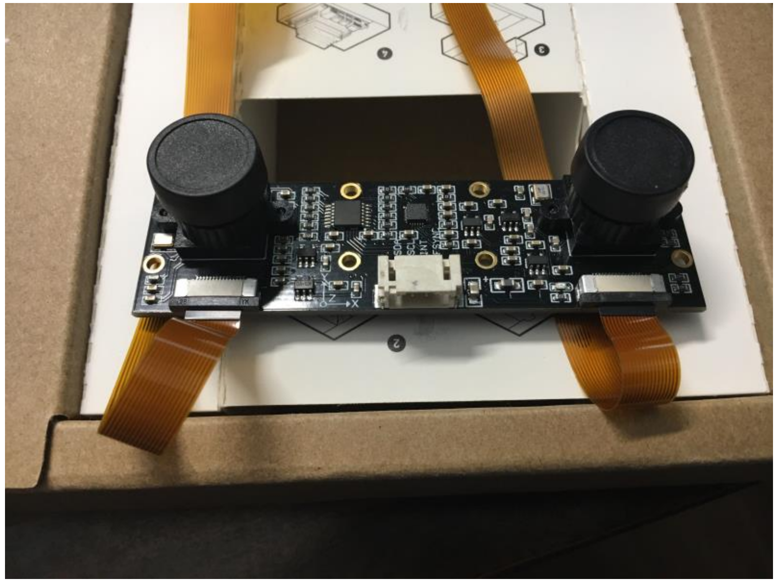
Camera (IMX219-83 Stereo)



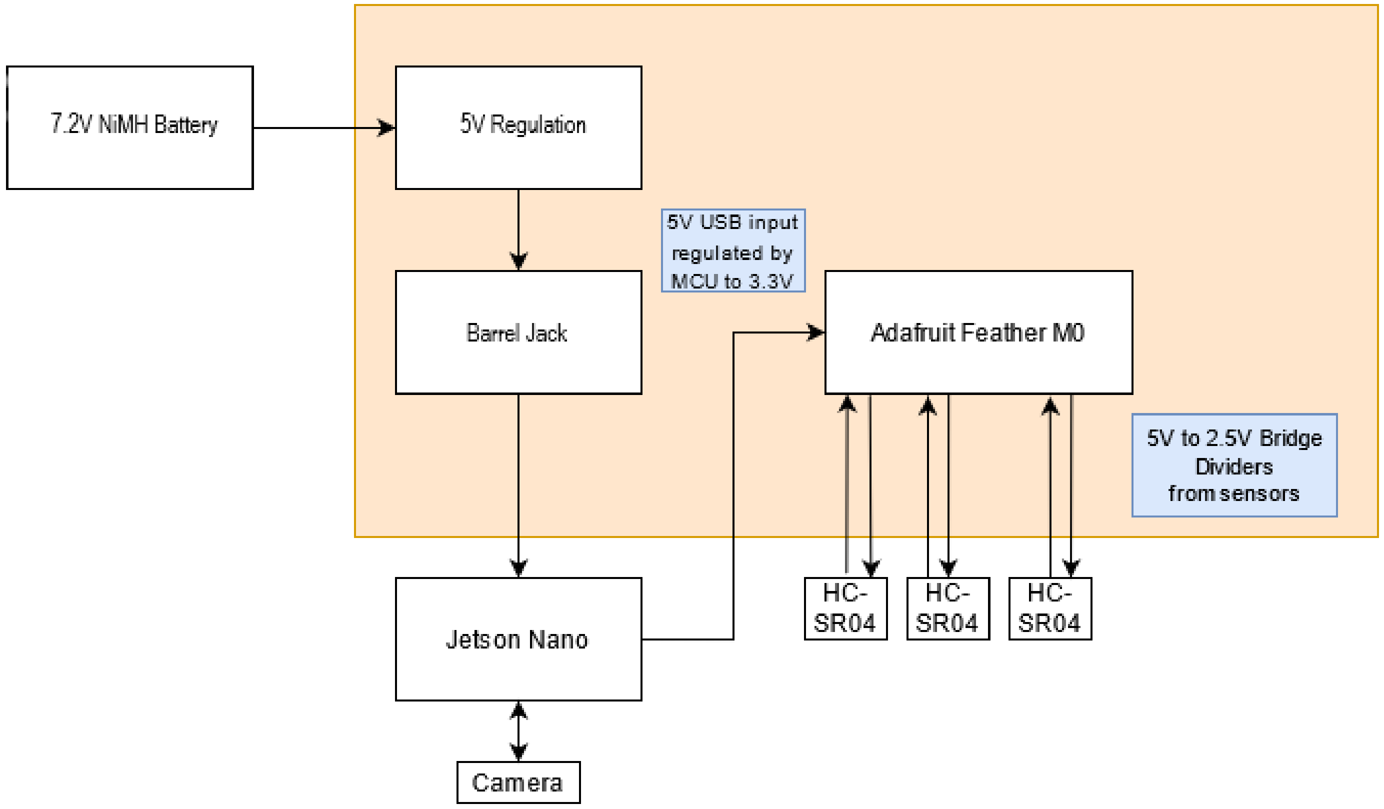
- ❖Two Sony IMX219 sensors capable of 3280x2464 resolution images.
- ❖4 times the pixel count of 1080p images.
- ❖2 camera ribbon cables limit the project to one camera.
- ❖83-degree field-of-view allows for more detailed images.

Feature	SVPRO-1MP2CAM001	Dual OV9281	IMX219-83 Stereo	IMX219-77
Active Array Size	1280 x 720	1280 x 800	3280 x 2464	3280 x 2464
Output Interface	USB 2.0	MIPI CSI-2	2x MIPI CSI-2	MIPI CSI-2
Field-of-View	90°	120°	83°	77°
Transfer Rate	30fps@1280x720	60fps@1280x800	30fps@1920x1080	30fps@1920x1080
Board Size	80 x 16.5mm	105 x 24 x 22.5mm	85 x 24mm	25 x 24mm
Price	$71.99	$99.99	$48.95	$18.90

Components Collected



Power management system on PCB

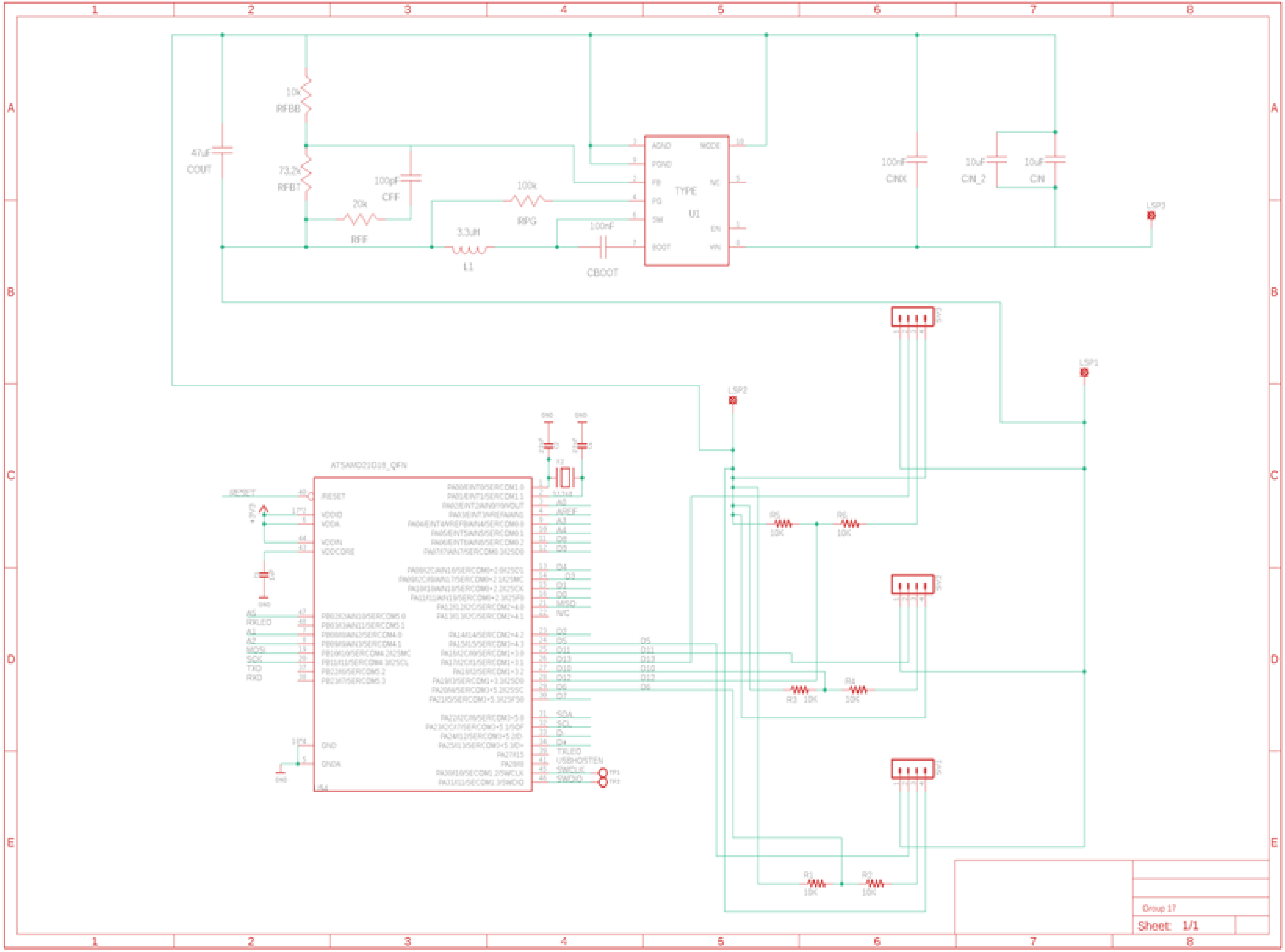


PCB Schematic Design

- Texas Instruments TPS56637 Buck convertor will regulate the 7.2V NiMH Battery to 5V logic and feed into the Jetson Nano female barrel jack port.
- The Adafruit Feather M0 will then be powered via USB 3.0 from the Jetson Nano as the Feather M0 can regulate USB 3.0 to 3.3V.
- Due to USB 3.0 having a limit of 0.9A, we must power the HC-SR04 ultrasonic sensors from the power distribution circuit directly.
- Since the echo signal of the sensors will be 5V, the voltage must be regulated once again via bridge dividers, so that the microprocessor does not burn out due to the higher voltage.
- Three separate 4 pin headers on the PCB will allow us to connect the sensors without limiting the range of motion.

Component	Operating Voltage	Operating Current	Total Power
NVIDIA Jetson Nano	5V	2.5A	12.5W
IMX219-83 Stereo	1.8V	1.23mA	0.0022W
STM32F103C8T6	3.3V	1.4uA	0.00000462W
HC-SR04	5V	15mA	0.0075W
		Total:	12.50970462W

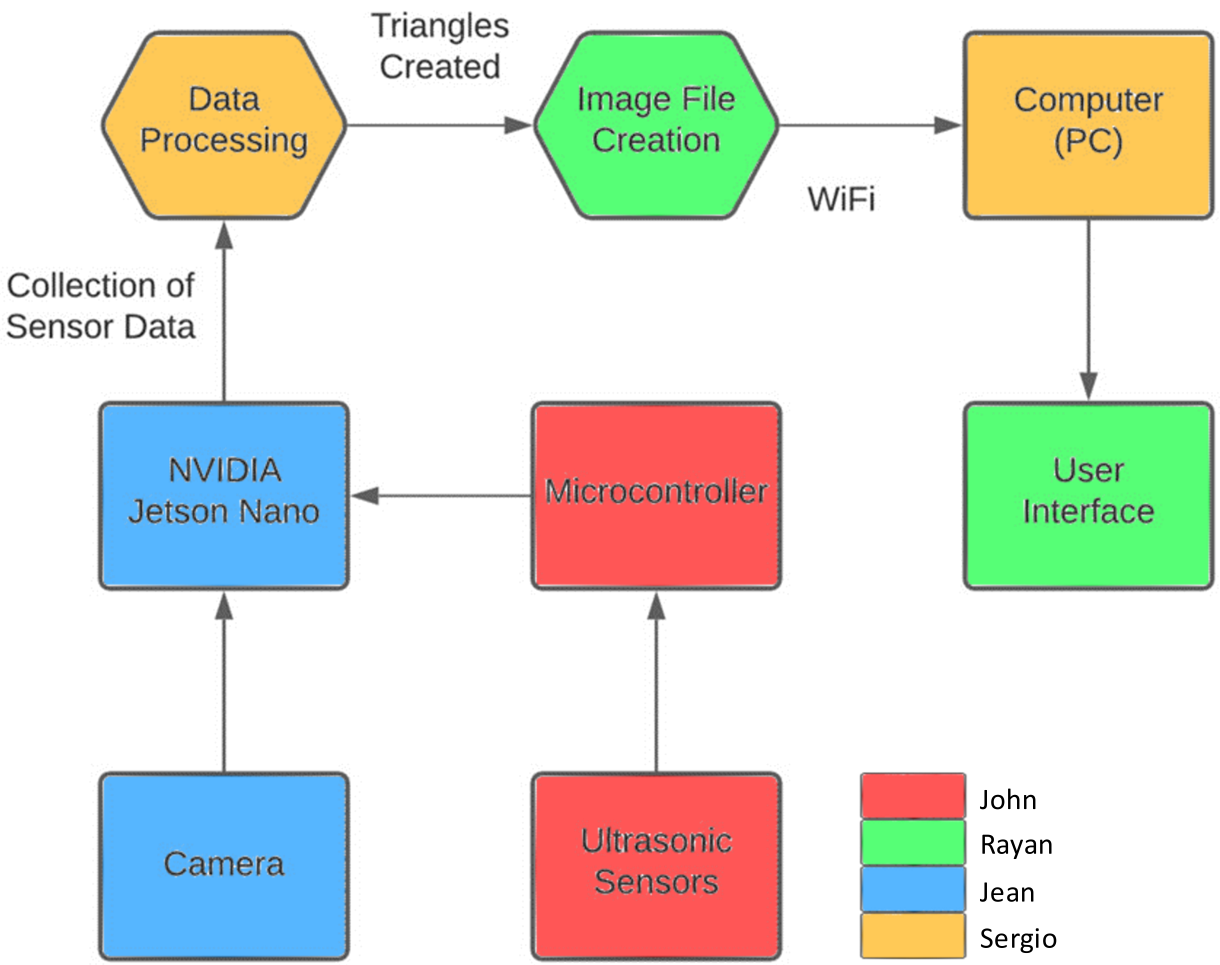
PCB Schematic



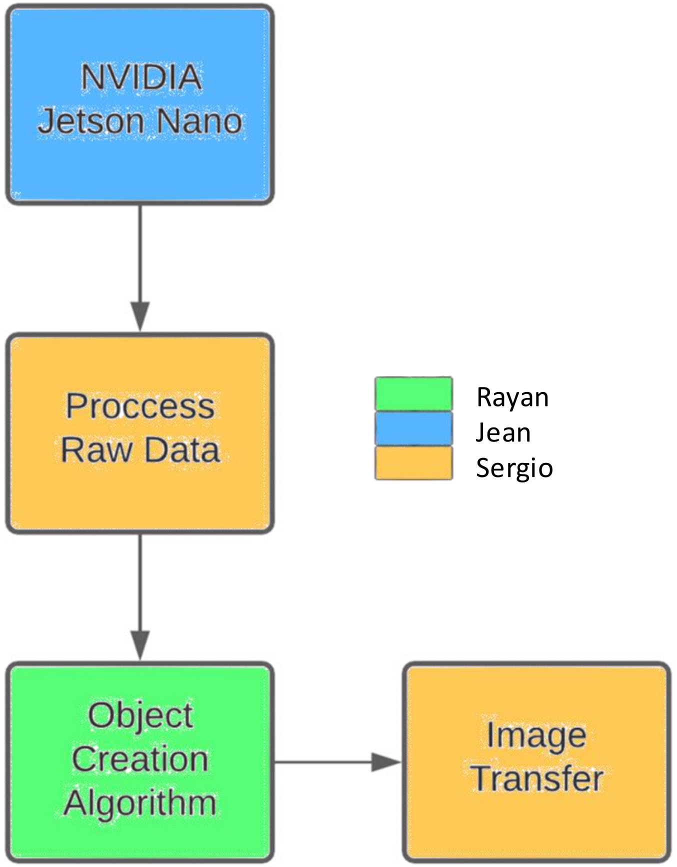
Testing

- ❖Portable scanner will have a blinking light when applied power.
- ❖Components will communicate with MCU.
- ❖Measure the voltage of the battery by adding 100K resistor bridge divider to the JST port that lets us measure the active current via pin D9.

Block Diagram For 3D Scanning Device



Software Block Diagram for 3D scanning Device



Data Processing

- Once the data from the Ultrasonic sensors is collected (an array of triangles or points), we can then begin to process the data collected.
- When the servo used to move the sensor tilts or pans, it makes the data collected inaccurate. This is because the distance is recorded at an angle.
- Using trigonometry, we can use the angle in which the data was collected, and the data itself to create an accurate measurement.
- If this wasn't done, a flat surface may seem curved when the data is written to the image file.

Image creation

- ❖A .stl file is a file type for 3D images.
- ❖If we want to create an image accurately, we need to add one triangle at a time.
- ❖Each triangle has 3 points on the xyz plane. The x and y of each point will be predetermined, the data collected from the Ultrasonic sensors will determine the z of each point (the depth).

Development Environments

- ❖Language: Python, C, C++
- ❖Schematics: Autodesk EAGLE 9.6.2
- ❖Implementation: Arduino IDE, JupyterLab

Constraints

- One Major constraint is the major difference between the 3D scanner we are creating, and 3D scanners sold already.
- 3D scanners on the market use grids of blue lasers to scan millions of points per second.
- Our Ultrasonic sensor(s) can scan 1 to 3 points per second.
- The more points we scan, the more accurate our image is, but it takes longer to scan.

Constraints

- ❖ Maximum budget of $200.
- ❖ The duration of the capture must be balanced with image fidelity and optimized to meet the requirement specifications.
- ❖ Input voltages must be accurately matched to avoid components imposing safety risks.
- ❖ Common environmental ultrasonic sensor obstructions such as dirt and condensation from high moisture environments such as Central Florida will not limit the functionality of the device.
- ❖ The program that runs with the scanner will not use any outside network as to limit the concern of information being stored externally.
- ❖ Part flexibility is greater as this is not a final product designed for consumer use.

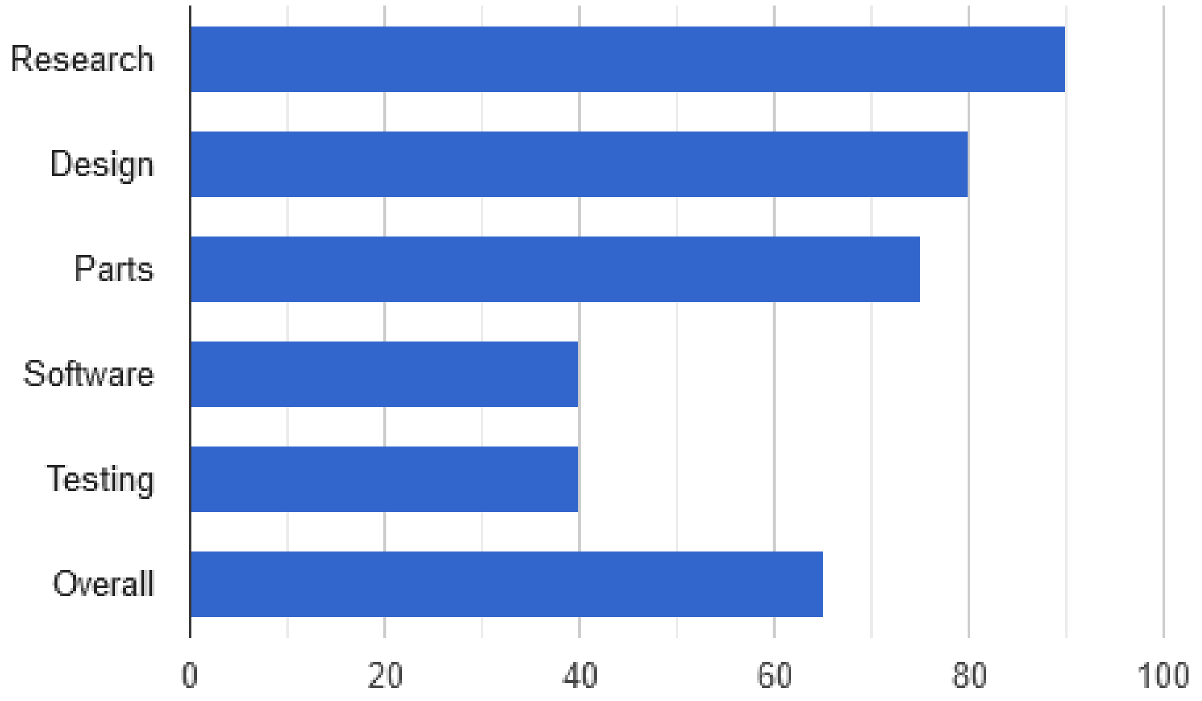
Related Standards

- **Battery Standard Testing and Certification IEC 60086**
- **ISO/IEC 9899:2018 Programming languages – C**
- **ISO/IEC/IEEE 29119-2 Test Processes**
- **IPC-2221A – Generic Standard on Printed Board Design**
- **ISO 5577:2017 – Non-destructive testing – Ultrasonic testing**
- **Quality management Standards**
  - ISO 9000:2015 Quality management systems

Project Budget to Date

Item	Price
Adafruit Feather M0	$23.35
3pcs Ultrasonic Sensors	$9.99
7.2V NiMH Battery	$19.95
Stereo Binocular Camera	$48.95
Jetson Nano 4GB	$99.99
Pan/Tilt Servo kit	$9.99
Total --	$212.22

Progress



Research
Design
Parts
Software
Testing
Overall
0
20
40
60
80
100

Immediate Plans for the Future

- ❖Finish and order PCB design
- ❖Continued development of the image processing algorithm
- ❖Develop microcontroller/development board interface
- ❖Image/scan capture testing