

# **PocketScope**

**ECE 445 FINAL REPORT SPRING 2026**

**Project # 14**

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# Abstract

This report examines the design and testing of the handheld oscilloscope PocketScope, a project developed with the guidance of Professor Craig Schultz and Teaching Assistant Lukas Dumasius. The device detects voltage waveforms and displays them on the screen in real-time, in addition to computing the FFT and classifying the waveform type. It is also portable with replaceable batteries and is small enough to fit into large pockets. The final result leaves room for improvement in the form of build quality, signal generation features, and voltage range- but the project shows how useful such a device could be for electrical enthusiasts.

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# 1. Introduction

## 1.1 Problem

Currently there is no cheap and extremely portable oscilloscope that serves the needs of hobbyists and technicians. Oscilloscope functionality and signal generation is typically confined to laboratory instruments, which are prohibitively expensive to the average consumer since they are intended for university and commercial labs [1]. The prices for lower-end oscilloscopes are in the \$300-\$700 range for standing oscilloscopes. For portable oscilloscopes, they range from \$100 to \$400 dollars, but the lower-end models leave much to be desired in build quality [2]. Furthermore, the portable options are not sufficiently small to be stored comfortably in a pants or jacket pocket and spending \$200 on an oscilloscope may be too expensive for most hobbyists, leaving many to settle for the much less expensive multimeter for their voltage measuring needs[3].

## 1.2 Solution

Our solution is a pocket-sized oscilloscope designed to give hobbyists, technicians, and students a powerful diagnostic tool in a portable form factor. The device enables high-resolution voltage-versus-time measurements, real-time FFT analysis, and waveform classification.

The system is battery-powered and built around an STM32G4 microcontroller, enabling real-time data acquisition and onboard digital signal processing without requiring a laptop. The analog front-end is designed to support high-precision measurements in the [0,20] V range. By integrating protection, scalable input conditioning, ADC sampling, and embedded DSP into a compact enclosure, the device provides lab-grade functionality in a portable, self-contained platform.

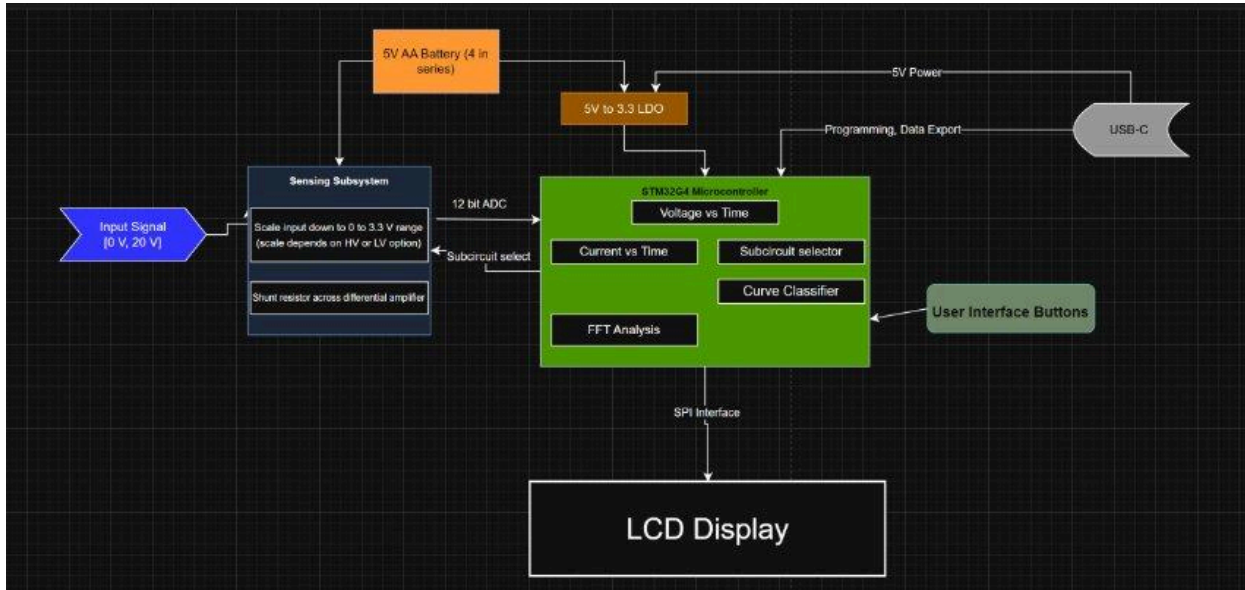


Figure 1. Current Block Diagram

Figure 1 shows an overview of the main subsystems in the final PocketScope iteration. There are five main subsystems:

1. **Sensing**- Takes voltage inputs from the wires and sends the scaled signal to the microcontroller.
2. **User Interface**- Displays code from the microcontroller on the LCD display as well as uses the physical buttons to interact with the display.
3. **Signal Generation**- Obsolete subsystem that was intended to output small-voltage waveforms from the wires..
4. **Compute**- Handles interactions between the subsystems as well as running the software, computing the FFT, and sending ADC inputs to the display.
5. **Battery**- Routes power from the battery pack to the PCB

### 1.3 High-Level Requirements

For our project to be successful we outlined these four criteria:

1. Fit inside of an average jeans pocket: Stay under 150x175x50 mm.
2. Read voltages in the [0,20] volt range and the [-170,170] volt range, being able to swap between the two modes.
3. Generate sine, sawtooth, and square waveforms in the [0,5] volt range.
4. Compute real-time FFT analysis and support basic curve-detection.

## 1.4 Block Level Changes

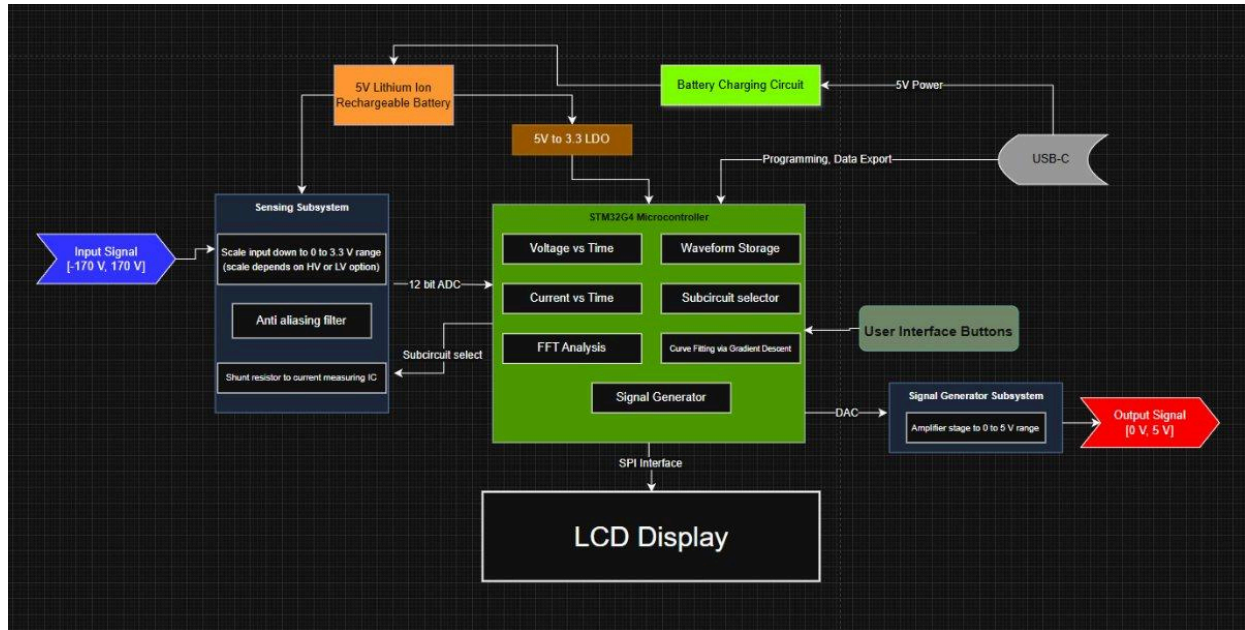


Figure 2. Original Block Diagram

As seen by comparing Figure 1 and Figure 2, the block diagram was simplified over the semester to account for setbacks and deadlines. Notable omissions include the battery charging circuit, signal generation, and current sensing. The first testable PCB was not fully assembled until after the final PCB order, meaning that when assembly errors caused board damage, there was no replacement available for the final demo. If the board could be reprinted there would be functionality for current sensing and signal generation.

## 2. Design and Verification

### 2.1 Sensing Subsystem

#### 2.1.1 Procedure

The primary objective of the sensing subsystem was to attenuate high-voltage input signals into a range safe for the microcontroller's analog-to-digital converters (ADCs). Initially, we prioritized safety through an isolation strategy between the microcontroller's ground and the input circuitry ground. However, we eventually chose to combine these grounds with a jumper wire after discovering that the isolated ground caused the attenuator circuit to malfunction. While this removed the ability to safely sense high or negative voltages, it was a necessary trade-off to ensure a functional product capable of 0 to 20 V waveform capture and FFT analysis for the final demonstration. Our design utilizes a voltage divider for signal scaling and an operational amplifier adder to provide a DC offset. The core transformation is governed by the mapping equation  $g(t) = \frac{V}{2A}f(t) + \frac{V}{2}$ , where  $f(t)$  is the input signal in the range  $[-A, A]$  and  $g(t)$  is the attenuated signal mapped to  $[0, V]$ . In our case,  $A$  is 20 and  $V$  is set to 3.1.

#### 2.1.2 Details

Our detailed design implements the attenuation mapping using the AD8606ARZ operational amplifier. To apply the design equations, we configured the circuit to scale input signals (initially calculated for ranges as wide as -170 to 170 V) down to the 0 to 3.3 V range required by the STM32G473CET6 microcontroller. Specifically, the voltage divider provides the  $\frac{V}{2A}$  scaling, while the op-amp adder supplies the  $\frac{V}{2}$  offset. In the final hardware revision, we designed separate paths for high-voltage (HV\_SENSE) and low-voltage (LV\_SENSE) sensing. However, due to the ground plane integration and the removal of the battery boost converter, the final implemented version supported a 0 to 20 V input range and one attenuator circuit (LV\_SENSE), which we successfully verified using our new SPI display.

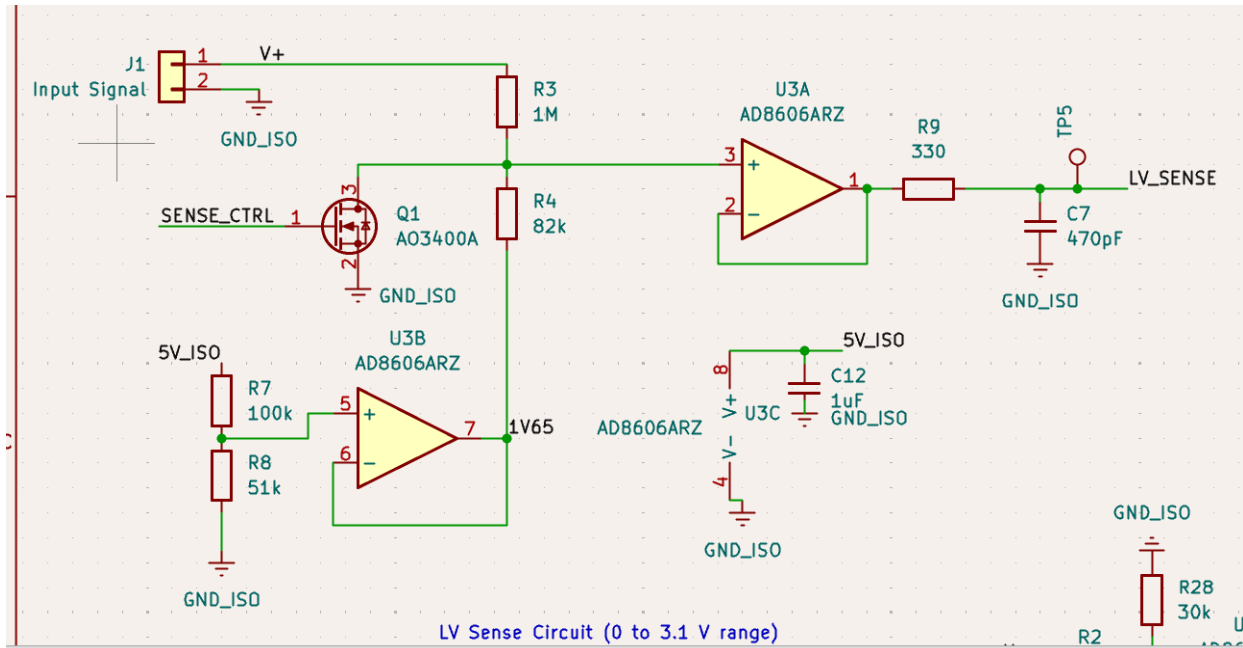


Figure 3. LV Sense circuit schematic

### 2.1.3 Verification

#### Voltage Measurement Tolerance

To verify our voltage measurement accuracy, we used a waveform generator to apply several DC offsets and sine waves to the input terminals. We then inspected the digitized readings through our serial terminal sent from the MCU to compare the sensed values against the source. For the 1 V, 5 V, and 20 V test points, we achieved a measurement tolerance of approximately 0.85%, which successfully met our goal of staying below 1%. For instance, at a 20 V input, the PocketScope consistently reported a value of 19.83 V, which represents a 0.85% difference.

#### 170V Capability and Current Sensing

Our prototype was unable to support 170 V and current sensing capabilities due to the lack of an isolated ground plane and damaged current sense during assembly.

#### Successfully be able to sample a 25 kHz signal

We verified the sampling subsystem by inputting a 25 kHz sine wave from a generator while the device was in voltage sensing mode. Our goal was to confirm that the internal FFT could correctly identify the frequency and that the waveform display remained clear. During the progress demo and final demonstration, we showcased that the FFT correctly identified the peak at 24 kHz with minimal noise interference, confirming our ADC's sampling rate and the efficiency of our DSP threads.

## 2.2 User Interface Subsystem

### 2.2.1 Procedure

Cost considerations served as the primary driver for the display selection. Although OLED modules offered superior contrast, those within the necessary physical dimensions were either monochrome or prohibitively expensive for the project's budget. A 2.4-inch TFT LCD with an ILI9341 controller was selected instead, providing 320×240 resolution and 16-bit color at a compatible unit cost. To minimize hardware complexity, discrete tactile switches were chosen over a touchscreen; a touchscreen would have necessitated an additional dedicated SPI line and increased firmware overhead for gesture recognition. The communication interface utilizes SPI2 in single-line mode on the STM32G4. Because the 8 MHz SPI bit rate cannot sustain full-frame 30 Hz refreshes, the firmware uses DMA-based block transfers and a "dirty-rectangle" redraw strategy to maintain a flicker-free refresh rate for the active waveform region

$$f_{pix} = W * H * f_{refresh} * 16 \text{ bits/pixel}$$

### 2.2.2 Details

This subsystem integrates the ILI9341 display, ten momentary switches, and the STM32G473 firmware. The display is mapped to SPI2, while the button matrix uses ten GPIO pins pulled to ground for clean logic-high transitions. Upon startup, the driver executes an initialization sequence to set landscape orientation and 16-bit RGB565 format via MADCTL and COLMOD registers. The driver manages rendering through windowed writes and selects DMA paths for rectangular fills based on geometry; this non-blocking pattern allows the CPU to process FFT and curve-fitting tasks concurrently. Line drawing is optimized using integer-based Bresenham's algorithm. Since a full-screen fill requires approximately  $f_{fill} = \frac{320*240*16}{8*10^6} = 153.6$  ms the firmware prioritizes updates to the trace and status regions. Input is managed by a Button Input Task that polls at 100 Hz, utilizing a two-sample software debouncer to ensure stability.

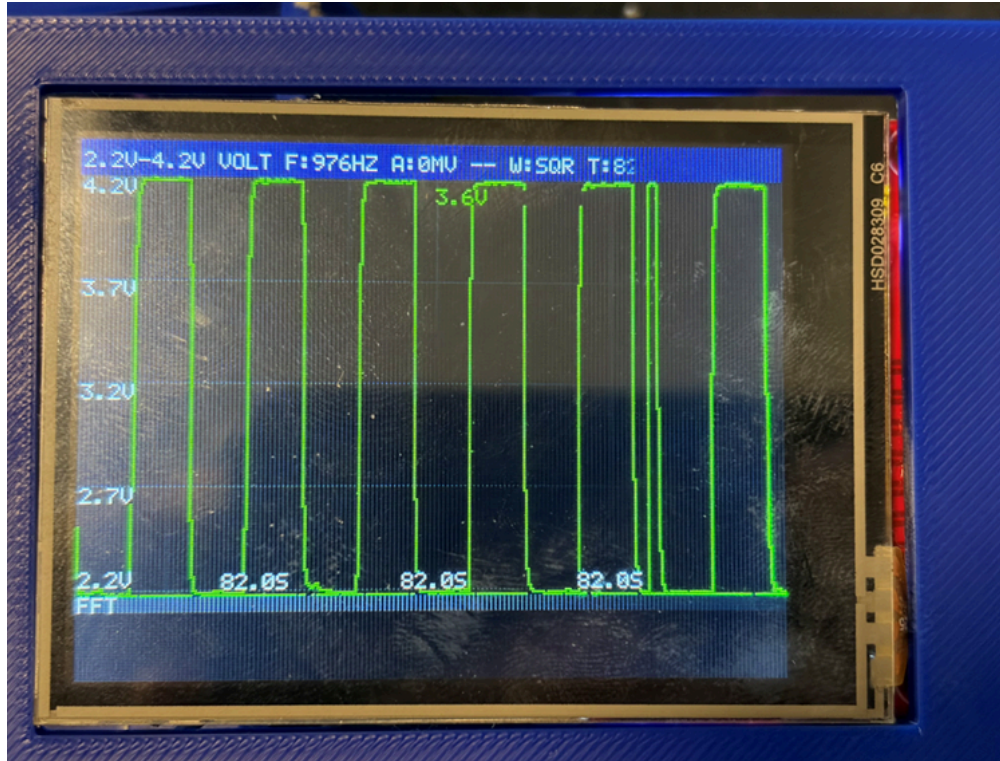


Figure 4. Voltage Menu Display

### 2.2.3 Verification

Verification confirmed that the subsystem meets all power, responsiveness, and fidelity specifications. Under worst-case conditions involving maximum backlight intensity and continuous waveform rendering, the total power draw remained within the established 1.5 W budget. Visual fidelity was validated by injecting a 1 kHz square wave; the rendered duty cycle and frequency readouts precisely matched bench equipment and debug console outputs.

## 2.3 Compute Subsystem

### 2.3.1 Procedure

The Compute Subsystem coordinates ADC sampling, signal processing, and display management using a preemptive FreeRTOS kernel. This RTOS approach was favored over a bare-metal superloop to manage real-time task priorities and synchronization through CMSIS-RTOS v2 while remaining within the STM32G473's memory constraints. For spectral analysis, an iterative Cooley-Tukey FFT with  $N=512$  was implemented to minimize function-call

overhead and enable in-place operation on the Cortex-M4. This configuration yields a 97.7 Hz bin width at a 50 kHz sample rate, satisfying the design's frequency resolution requirements. Waveform classification utilizes frequency-domain analysis of the FFT output, distinguishing signals through Total Harmonic Distortion (THD) and even-harmonic ratios. This method provides more robust identification of sine, square, and sawtooth waves than time-domain alternatives by examining mathematically distinct harmonic signatures.

### 2.3.2 Details

The software architecture comprises nine tasks across three priority tiers, utilizing queues, mutexes, and thread flags for synchronized data transfer. The FFT task implements the iterative Cooley-Tukey algorithm, optimizing the transform by updating twiddle factors multiplicatively across nine stages. It leverages the Cortex-M4F floating-point unit to accelerate butterfly computations within a static 4 kB SRAM workspace. Before the transform, the task copies samples from the voltage buffer, removes the DC offset by subtracting the mean, and normalizes the data. The classifier identifies waveforms by analyzing peak magnitudes and their harmonics, applying thresholds (THD\_SINE\_THRESH and EVEN\_SQR\_THRESH) to the FFT data. A signal is designated as unknown if the peak magnitude falls below the minimum detection floor. Debugging is facilitated by a GPIO-based timing toggle on PB3, allowing for external verification of computation cycles via oscilloscope.

### 2.3.3 Verification

Verification confirmed that the subsystem meets latency, frequency accuracy, and classification requirements. FFT execution time remained well under the 100 ms limit without requiring specialized DSP libraries. Frequency sweeps validated a 95% to 100% bin-level accuracy across the input range, with errors confined to single-bin offsets consistent with the inherent  $\Delta f$  resolution. While classification accuracy remained high at low frequencies, it decreased at higher fundamentals as harmonics moved above the Nyquist limit. This behavior resulted in a graceful degradation where the system reported an unknown state rather than an incorrect waveform type. All top-level functional requirements, including the 10% line-matching error limit, were satisfied within the operational bandwidth.

## 2.4 Battery Subsystem

### 2.4.1 Procedure

The primary objective of the battery subsystem was to provide regulated power to the device to ensure portability for students and hobbyists. Initially, we planned to use a 3 V lithium ion battery paired with a boost converter to reach the necessary 5 V and 3.3 V rails. However, we found that our boost converter layout was non-functional. As a desirable alternative to maintain

mobility, we chose to bypass the internal boost circuitry and utilize an external AA battery pack. This approach was selected because it allowed us to maintain the portability requirement despite the hardware failure on the PCB. The battery pack outputs around 6 V which can be used by the op-amps in the sensing subsystem and can still be converted to 3.3 V using the LDO for the microcontroller to use.

### 2.4.2 Details

Our detailed design originally integrated a battery port and a boost converter into the third PCB revision. In the final implementation, we modified the circuit by desoldering the failed battery boost converter section. We then added support for a 4-cell AA battery pack, which typically provides a nominal 6 V that is subsequently regulated down to the system's operating voltages. While the initial design intended for a more compact internal battery, the move to an external pack ensured the system remained mobile for use in the field. The final assembly included a 3D-printed enclosure designed to house both the main PCB and the battery pack.

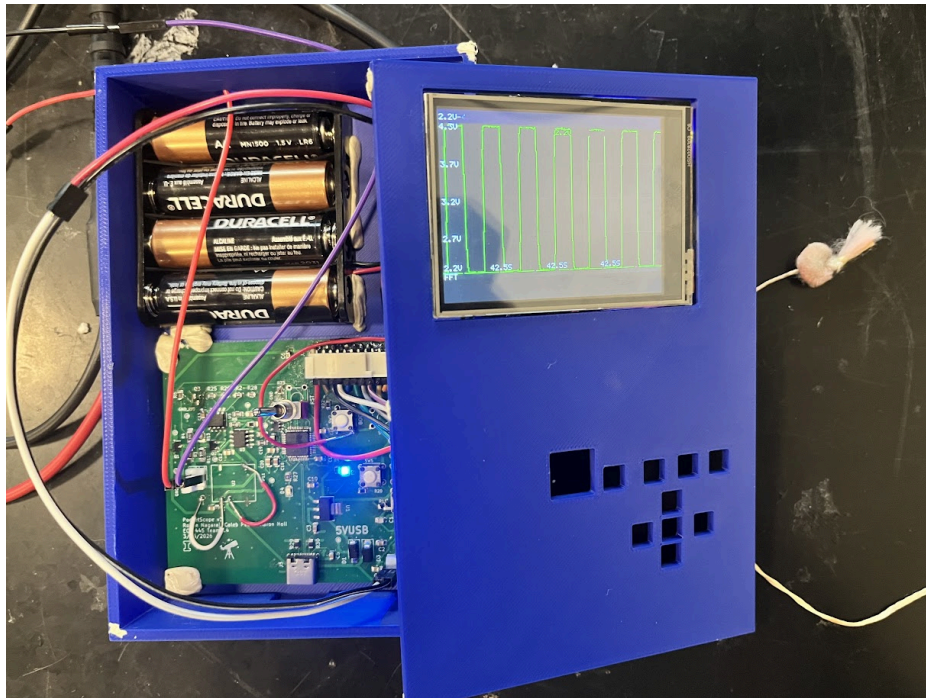


Figure 5. Battery Pack in enclosure

### 2.4.3 Verification

Verification of the battery subsystem focused on ensuring the device could operate reliably as a portable unit and maintaining a stable power supply over an extended duration. We successfully verified the core portability requirement during our final demonstration by powering the entire PocketScope solely via the external 4-cell AA battery pack, as we had previously desoldered the non-functional boost converter. To validate our power source, we used a digital multimeter to measure the battery pack directly, which yielded a reading of 5.5 V. We further assessed the subsystem's reliability by using a lab oscilloscope to monitor the battery voltage drift over time

while it was under the load of the PocketScope. The resulting graph shows the discharge curve over a 30 minute period, demonstrating that the voltage remained sufficiently high to power the system's regulators for a short amount of continued use. These tests confirmed that despite the failure of the integrated boost converter, our alternative battery solution met the necessary requirements for handheld operation.

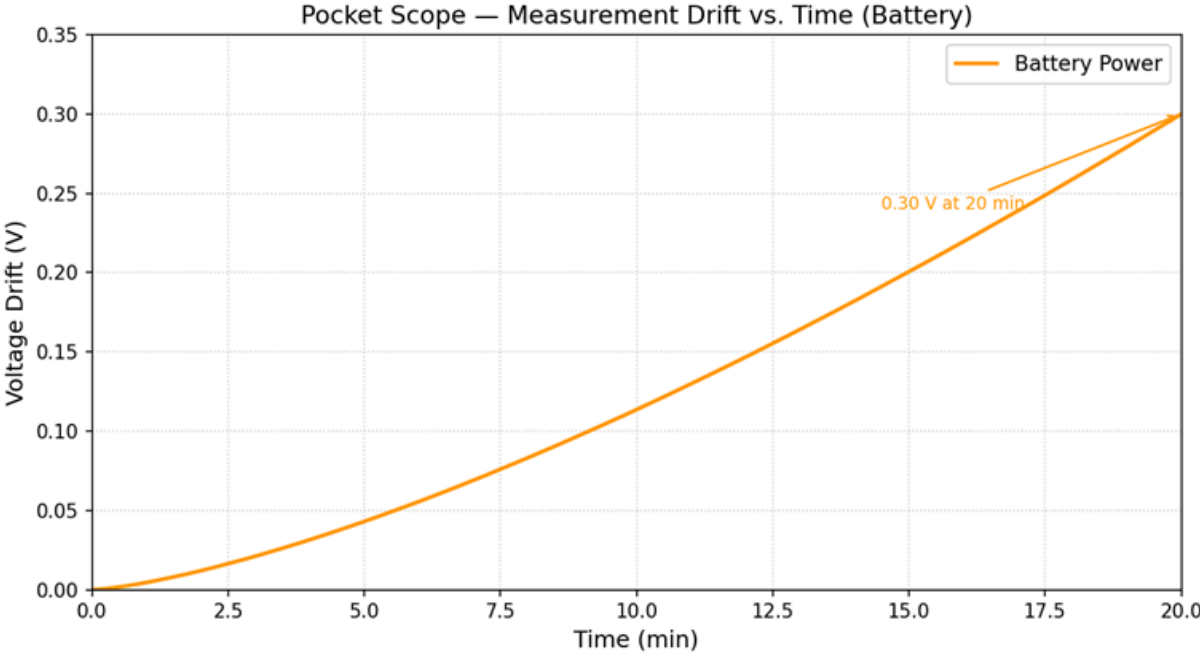


Figure 6. Showcases battery voltage drop over time



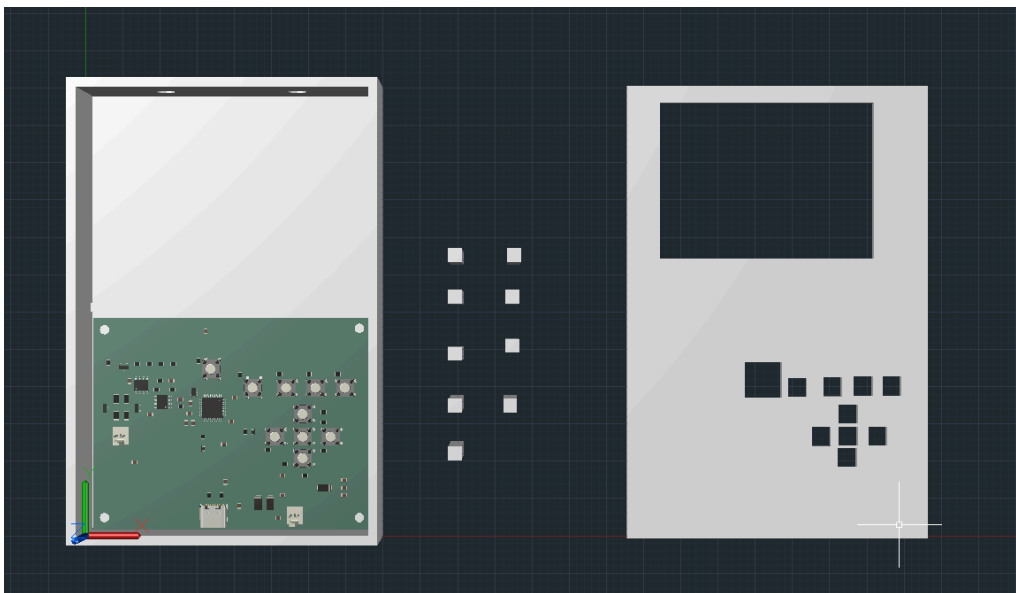
Figure 7. Battery pack voltage after protection diode

## 2.5 Physical Chassis

### 2.5.1 Procedure

The design of the case for the PocketScope was done in AutoCAD, since this software is free to University of Illinois students and is compatible with the available 3D printer in the lab. The main goal of the physical design is to provide a space for the three large components: PCB, LCD screen, and battery, while staying within the sizing constraints given in the introduction: a footprint less than 150x175x50mm.

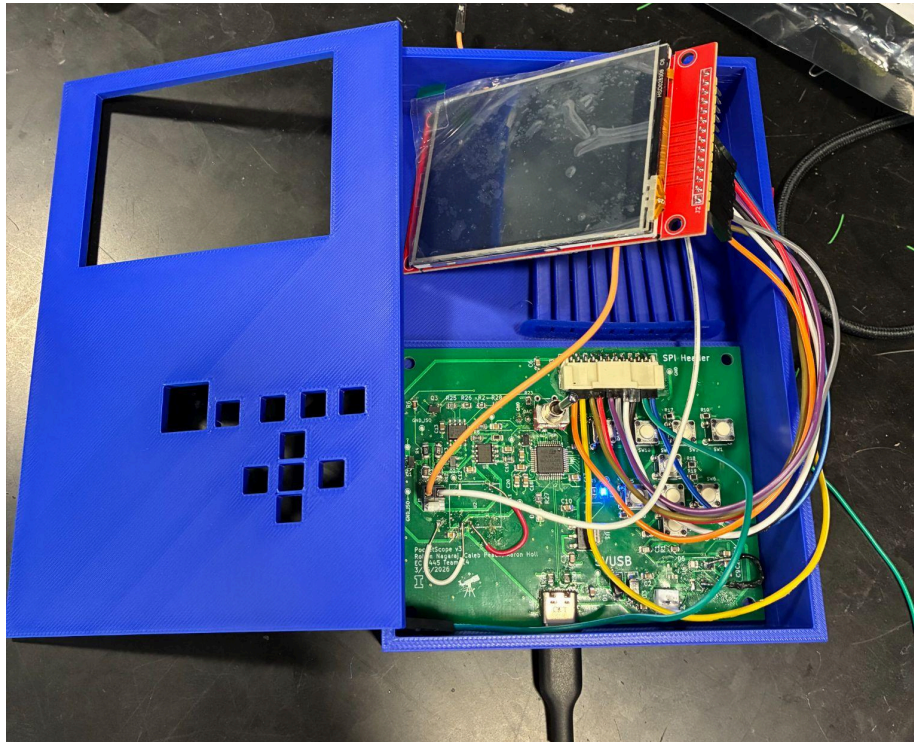
### 2.5.2 Details



**Figure 8. AutoCAD Model of Chassis**

The final design for the chassis is shown above in Figure (X), with the base, buttons, and lid shown from left to right. An imported model of the PCB is also present for scale. The final footprint of the assembled device was 100x150x35mm, with 3mm walls around the base and 3mm thick lid. In the lid are nine 6x6mm holes for the buttons, one 12x12mm hole for the reset switch, and one 71x51.5mm for the LCD display. The base also features a 15x7mm hole for the USB-C port and two 3mm radius holes for the voltage sensing wires.

### 2.5.3 Verification



**Figure 9. Final Print of Chassis with Components**

The testing of the case involved designing a model in AutoCAD, printing it with the 3D printer, and finally assembling the device to understand how well it supported the other subsystems and components. Overall, we went through five prototypes before landing on the final iteration, where each of the previous models either did not fit all of the components or sacrificed on footprint. One major revision from the original plan was to move away from using solid metal prongs for the voltage sensing and instead opting for traditional wires. This was informed by the complexity of implementing an adjustable rail for the prongs as well as being unable to find sturdy and cheap prongs in our price range. Standard wires solve the problem of adjustability in a simpler fashion and are guaranteed to be compatible with nearly any project that a consumer would be working on. A useful change that did not make it into the final design would be screwholes for mounting the lid, as the batteries cannot be replaced in the current design without removing the adhesive.

### 3. Cost

Assuming an annual salary of 90,000 (typical for a UIUC graduate working in Illinois) [4], we have an hourly rate of about \$43.30 per partner. For 16 weeks in a semester, we can assume each partner dedicates about 4 hours/week to the project, giving 80 hours total. The cost per partner therefore is  $43.3 \times 2.5 \times 64 = \$ 6928$ . Multiplying by 3 to account for the three partners, we come to a total labor cost of \$20784. For the parts, looking at Appendix A showing the bill of materials, we see that the total cost was \$46.59. This brings our total labor cost to **\$20830.59**.

## 4. Conclusion

The PocketScope project was an attempt to bring lab oscilloscope functionality to the consumer's pocket, and in several important ways it succeeded. Reviewing the high-level requirements laid out in the introduction, we see that the final product had a footprint smaller than 150x175x50 mm, it supported voltage waveforms in the [0,20] volt range, it performed real-time FFT analysis, and could detect three waveforms: sine, square, and sawtooth. These features are critical to the success of the project and demonstrate the usefulness of such a tool. A battery powered oscilloscope that can be stored in your pocket and used to quickly test a malfunctioning device or project is a powerful diagnostic tool that currently doesn't exist with an entry-level price tag.

However, although it displays great promise, the current iteration of the PocketScope would not be a viable product to sell or mass-produce. Looking at the other high-level requirements, we see that the project did not support high voltage or negative voltage measurements, signal generation, and a machine learning algorithm for advanced waveform fitting. Furthermore, the project goals were adjusted to discard current sensing as a result of problems with the sensing circuit on the PCB. These problems are prohibitive to mass-production since many devices and projects will require testing voltages above the 20 volt threshold, and virtually all of them would require negative voltage sensing. Additionally, the physical chassis for the device is not strong enough to withstand continued use and would serve the consumer better if it could be made even smaller.

For future implementations of the project, the main workload would come from addressing the shortcomings mentioned above. Adjusting the PCB design to ensure it supports high voltage by adding isolation, fixing the current sensing circuit, and refactoring the machine learning code or increasing the power of the microprocessor to support better wave detection. The physical case should also be composed of stronger material than 3D-printed plastic and the buttons could be mounted more securely to the PCB.

The PocketScope was designed to increase the accessibility of diagnostic tools for hobbyists and students, fulfilling the ethical duty to assist the public in reaching a higher understanding of technology. To ensure safety, the device must mitigate the risks of electric shock from its voltage input and thermal runaway from the battery pack. We adhered to IEC 61010-1 for laboratory safety and IEC 62133 for battery compliance to prevent injury during field use. Additionally, in accordance with the IEEE Code of Ethics (1.1) [5], we prioritized public safety by clearly labeling the voltage limits of the non-isolated sensing prongs and ensuring our 12-bit accuracy claims are honest to prevent diagnostic errors by technicians.

## 5. References

- [1] Micro Center. *SDS1104X-E Super Phosphor Digital Oscilloscope*. Retrieved from [https://www.microcenter.com/product/510480/SDS1104X-E\\_Super\\_Phosphor\\_Digital\\_Oscilloscope?storeID=025](https://www.microcenter.com/product/510480/SDS1104X-E_Super_Phosphor_Digital_Oscilloscope?storeID=025)
- [2] The Home Depot. *Vrbgify 3-in-1 handheld oscilloscope multimeter DDS generator, 2-channel, 10MHz, 50MSa/s*. Retrieved from <https://www.homedepot.com/p/Vrbgify-3-in-1-Handheld-Oscilloscope-Multimeter-DDS-Generator-2-Channel-10MHz-50MSa-s-10000-Counts-Voltage-Current-More-343SA04-427D/33507899?source=shoppingads&locale=en-US&fp=ggl>
- [3] The Home Depot. *Klein tools 600 volt digital multi meter manual ranging MM325*. Retrieved from [https://www.homedepot.com/pep/Klein-Tools-600-Volt-Digital-Multi-Meter-Manual-Ranging-MM325/320822947?source=shoppingads&locale=en-US&fp=ggl&pla=&mtc=SHOPPING-BF-CDP-GGL-D27E-027\\_011\\_ELECTRICAL\\_ACCESSORIES-NA-NA-NA-PMAX-NA-NA-NA-NA-NBR-NA-NA-NEW-NA\\_Priority2024Ended&cm\\_mmc=SHOPPING-BF-CDP-GGL-D27E-027\\_011\\_ELECTRICAL\\_ACCESSORIES-NA-NA-NA-PMAX-NA-NA-NA-NA-NBR-NA-NA-NEW-NA\\_Priority2024Ended-21843354617--&gclsrc=aw.ds&gad\\_source=1&gad\\_campaignid=21843375815&gbraid=0AAAAADq61Uek\\_3kUVYNx8ipspNTlnaWKN&gclid=Cj0KCQiA7rDMBhCjARIsAGDBuEDIYXppELcl956dHNq6YBzuftJrSYu3N8N3rJukhYRGhoZcQjY4-OoaAqL8EALw\\_wcB](https://www.homedepot.com/pep/Klein-Tools-600-Volt-Digital-Multi-Meter-Manual-Ranging-MM325/320822947?source=shoppingads&locale=en-US&fp=ggl&pla=&mtc=SHOPPING-BF-CDP-GGL-D27E-027_011_ELECTRICAL_ACCESSORIES-NA-NA-NA-PMAX-NA-NA-NA-NA-NBR-NA-NA-NEW-NA_Priority2024Ended&cm_mmc=SHOPPING-BF-CDP-GGL-D27E-027_011_ELECTRICAL_ACCESSORIES-NA-NA-NA-PMAX-NA-NA-NA-NA-NBR-NA-NA-NEW-NA_Priority2024Ended-21843354617--&gclsrc=aw.ds&gad_source=1&gad_campaignid=21843375815&gbraid=0AAAAADq61Uek_3kUVYNx8ipspNTlnaWKN&gclid=Cj0KCQiA7rDMBhCjARIsAGDBuEDIYXppELcl956dHNq6YBzuftJrSYu3N8N3rJukhYRGhoZcQjY4-OoaAqL8EALw_wcB)
- [4] Grainger College of Engineering, University of Illinois Urbana-Champaign. *Electrical Engineering*. Retrieved from <https://grainger.illinois.edu/academics/undergraduate/majors-and-minors/electrical-engineering>
- [5] IEEE. *IEEE Policies: Section 7 – IEEE Board of Directors*. IEEE. Retrieved from <https://www.ieee.org/about/corporate/governance/p7-8>

## Appendix A- Bill of Materials

Designator	Footprint	#	Value	Supplier Links	Price	
C10, C14	805	2	10uF		\$0.00	
C12, C13, C15, C16, C17, C18, C19, C20, C5, C6	805	10	1uF		\$0.00	
C7, C8	805	2	470pF		\$0.00	
D2	805	1	LED		\$0.00	
J1	Molex_KK-254_AE-6410-02A_1x02_P2.54mm_Vertical	1	Input Signal		\$0.00	
J3	USB_C_Receptacle_GCT_USB4105-xx-A_16P_TopMnt_Horizontal	1	USB_C_Receptacle_USB2.0_16P	<a href="https://www.digikey.com/en/products/detail/gct/USB4085-GF-A/9859662">https://www.digikey.com/en/products/detail/gct/USB4085-GF-A/9859662</a>	\$0.87	
J5	Molex_Mega-Fit_76829-0108_2x04_P5.70mm_Vertical	1	LCD Display Connector		\$0.00	
Q1, Q2	SOT-23	2	AO3400A	<a href="https://www.digikey.com/en/products/detail/alpha-omega-semiconductor-inc/AO3400A/1855772">https://www.digikey.com/en/products/detail/alpha-omega-semiconductor-inc/AO3400A/1855772</a>	\$0.92	
R10, R11, R17, R18, R19, R20, R21, R22, R23, R24	805	10	10k		\$0.00	
R12	1206	1	1.1M		\$0.00	
R13	1206	1	10k		\$0.00	

R14, R9	805	2	330		\$0.00	
R15, R16	805	2	5.1k		\$0.00	
R3	1206	1	1M		\$0.00	
R4	1206	1	82k		\$0.00	
R5	805	1	1k		\$0.00	
R7	805	1	100k		\$0.00	
R8	805	1	51k		\$0.00	
SW1	SW_TH_Tactile_O mron_B3F-100x	1	BTN0	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.24	
SW10	SW_TH_Tactile_O mron_B3F-100x	1	BTN7	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.24	
SW2	SW_TH_Tactile_O mron_B3F-100x	1	BTN1	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.24	
SW3	SW_TH_Tactile_O mron_B3F-100x	1	BTN2	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.24	

SW4, SW7, SW8	SW_TH_Tactile_O mron_B3F-100x	3	BTN3	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.72	
SW5	SW_TH_Tactile_O mron_B3F-100x	1	BTN4	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.24	
SW6	SW_TH_Tactile_O mron_B3F-100x	1	BTN5	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.24	
SW9	SW_TH_Tactile_O mron_B3F-100x	1	BTN6	<a href="https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150">https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/B3F-1000/33150</a>	\$0.24	
U2	NXE1S0505MC_M UR	1	NXE1S 0505M C-R7	<a href="https://www.digikey.com/en/products/detail/murata-power-solutions-inc/">https://www.digikey.com/en/products/detail/murata-power-solutions-inc/</a>	\$3.05	

				<a href="#">NXE1S0505MC-R7/5047358?s=N4IgtTCBcDalHIA0CiBGAYgBgKzYLIGEBaAJQHYAdckAXQF8g</a>		
U3, U5	SOIC-8_3.9x4.9mm_P1.27mm	2	AD8606ARZ	<a href="https://www.digikey.com/en/products/detail/analog-devices-inc/AD8606ARZ/751185">https://www.digikey.com/en/products/detail/analog-devices-inc/AD8606ARZ/751185</a>	\$10.36	
U6	WSON-6-1EP_2x2mm_P0.65mm_EP1x1.6mm_Thermal Vias	1	LP5912-3.3DRV	<a href="https://www.digikey.com/en/products/detail/texas-instruments/LP5912-3-3DRVR/6005673?gclid=aw.ds&amp;gad_source=1&amp;gad_campaignid=17922795960&amp;gbraid=0AAAAADrbLjS1j_EWe_tBE2wjnBK-Oywm&amp;gclid=CjwKCAiA-MBhAKEi">https://www.digikey.com/en/products/detail/texas-instruments/LP5912-3-3DRVR/6005673?gclid=aw.ds&amp;gad_source=1&amp;gad_campaignid=17922795960&amp;gbraid=0AAAAADrbLjS1j_EWe_tBE2wjnBK-Oywm&amp;gclid=CjwKCAiA-MBhAKEi</a>	\$1.18	

				<a href="#">wASBmsB CAQ8rH1k sgVambrB irD9Jr3d3 SL3aP0oo 8QoxeL7h AT8Niqj9A S9hoCX4c QAvD_Bw E</a>		
U7	SOT-23-5	1	SN74L VC1G1 4DBV	<a href="https://www.digikey.com/en/products/detail/texas-instruments/SN74LV&lt;br/&gt;C1G14DB&lt;br/&gt;VR/38572&lt;br/&gt;4">https://www.digikey.com/en/products/detail/texas-instruments/SN74LV C1G14DB VR/38572 4</a>	\$0.12	
U8	LQFP-48_7x7mm_ P0.5mm	1	STM32 G473C ETx	<a href="https://www.digikey.com/en/products/detail/stmicroelectronics/STM32G4&lt;br/&gt;73CET6/1&lt;br/&gt;0326771">https://www.digikey.com/en/products/detail/stmicroelectronics/STM32G4 73CET6/1 0326771</a>	\$7.74	
--	LCD Display	1	Adafruit Industries LLC 4311	<a href="https://www.digikey.com/en/products/detail/adafruit-industries-llc/4311&lt;br/&gt;/1031391&lt;br/&gt;4?gclid=aw.ds&amp;gad_source=1&amp;gad_campaignid=20">https://www.digikey.com/en/products/detail/adafruit-industries-llc/4311 /1031391 4?gclid=aw.ds&amp;gad_source=1&amp;gad_campaignid=20</a>	\$19.95	

				<a href="#">22838772</a> <a href="#">0&amp;qbraid=</a> <a href="#">0AAAAADr</a> <a href="#">bLlqGkNG</a> <a href="#">8AON46x</a> <a href="#">HZcF2CVR</a> <a href="#">nZx&amp;gclid</a> <a href="#">=Cj0KCQj</a> <a href="#">AtfXMBhD</a> <a href="#">zARIsAJ0j</a> <a href="#">p3CLPaq8</a> <a href="#">6xL0jHVQ</a> <a href="#">NO29bb3</a> <a href="#">WZvOZM8</a> <a href="#">WfpdJCUh</a> <a href="#">8Rwz6MF</a> <a href="#">v0nwkuL9</a> <a href="#">0YaAqYuE</a> <a href="#">ALw_wcB</a>		
					\$46.59	

## Appendix B - Design Document RV Tables

Table 1: Sensing RV

Requirements	Verification
Have a tolerance of $< 1\%$ on voltage measurements	<ul style="list-style-type: none"><li>- Use a waveform generator to generate 1V, 5V, 20V, and 120V on the input terminals of PocketScope</li><li>- Run a debugger on the PocketScope and inspect what the voltage readings are. It should be less than 1% difference from what was selected on the waveform generator (or, if the waveform generator specifies a tolerance, it should be within 1% above this tolerance. Ideally, a waveform generator with a very low tolerance should be chosen)</li></ul>
Support up to 170V input	<ul style="list-style-type: none"><li>- Put the PocketScope into High Voltage mode by pressing the appropriate button.</li><li>- Use a power supply to generate a signal starting at 20 V, and connect this to the terminals of the PocketScope.</li><li>- View the waveform on the PocketScope display and slowly increase the voltage magnitude from 20 V to 170 V, watching for any errant readings.</li></ul>
Support up to .5 A input	<ul style="list-style-type: none"><li>- Put the PocketScope into Current Sensing mode by pressing the appropriate button.</li><li>- Use a power supply to generate a signal starting at 100 mA and connect this to the terminals of the PocketScope.</li><li>- View the waveform on the PocketScope display and slowly increase the current magnitude from 100 mA to 500 mA, watching for any errant readings.</li></ul>

**Table 2: User Interface RV**

Requirements	Verification
Subsystem must draw less than 1.5 Watt of power	<ul style="list-style-type: none"><li>- The system can operate on a single 5 V supply. Thus connect a power supply to the PocketScope and monitor how much current is being drawn by the power supply under heavy computational conditions to verify it draws less than 1.5 W of power</li></ul>

**Table 3: Signal Generator RV**

Requirements	Verification
Amplitude: 0 to 5 V range	<ul style="list-style-type: none"><li>- Utilizing a full-size lab oscilloscope, connect one of the channels to the output prongs of the Pocketscope. Set the display range to [0,5] volts. Turn on the signal generation function of the Pocketscope and watch the oscilloscope to ensure that the voltage magnitude varies appropriately as you adjust the output. The maximum output should fall within the [4.8,5.2] V range.</li></ul>
Frequency: 0 to 100 kHz	<ul style="list-style-type: none"><li>- Utilizing a full-size lab oscilloscope, connect one of the channels to the output prongs of the Pocketscope. Turn on the signal generation function and watch the oscilloscope as you vary the frequency from the Pocketscope to watch the signal stretch and contract. The maximum output should fall in the [99, 101] kHz range.</li></ul>
Duty Cycle: 0 to 100%	<ul style="list-style-type: none"><li>- Utilizing a full-size lab oscilloscope, connect one of the channels to the output prongs of the Pocketscope. Turn on the signal generation function and generate a square wave. Watch the oscilloscope as you vary the duty cycle from 0 to 100% and see that the</li></ul>

Requirements	Verification
	percentage of high voltage output time increases compared to low output, ending with a simple high voltage output at 100%.
Phase: 0 to 360 degrees	<ul style="list-style-type: none"> <li>- Utilizing a full-size lab oscilloscope, connect one of the channels to the output prongs of the Pocketscope. Turn on the signal generation function and watch the oscilloscope as you vary the phase from the Pocketscope to watch the signal shift to the right. The signal should successfully return to its original location after the full 360 degrees.</li> </ul>

**Table 4: Compute RV**

Requirements	Verification
Perform a 512-point FFT transform in <100 ms (to keep up with frame rate)	<ul style="list-style-type: none"> <li>- Connect a debugger to the STM running ADC drivers.</li> <li>- Call a get timer function before and after FFT calls, and use the debugger to read these values.</li> <li>- Ensure the timer value is &lt;100ms apart.</li> </ul>
Perform accurate line matching algorithms with less than 10% error on the measured outputs	<ul style="list-style-type: none"> <li>- Set up a waveform generator with one of the signals to be predicted (noting the period, amplitude, etc of the output).</li> <li>- Plug the output terminals of the waveform generator into the input terminals of the PocketScope.</li> <li>- Inspect the output on the LCD display and verify that the predicted fit is within the expected tolerance</li> </ul>

**Table 5: Battery RV**

Requirements	Verification
Must be able to charge the battery while in use	<ul style="list-style-type: none"><li>- Turn on the PocketScope and let the battery deplete to around 50% charge.</li><li>- While looking at the on-screen battery life display, plug the usb-c charging cord into the PocketScope.</li><li>- Use a lab oscilloscope to generate a signal, measure the signal with the PocketScope, and watch to see if the battery life increases or continues to deplete while in use.</li></ul>
Must add battery disconnection circuit to prevent fire hazard in the case of overdrawing power	<ul style="list-style-type: none"><li>- Intentionally draw battery power into an electronic load and verify the battery disconnects after it starts to draw over 1 W of power</li></ul>
Must add overcharge protection to prevent fire hazard	<ul style="list-style-type: none"><li>- Verify the battery is not being charged when at full capacity by using a voltmeter to verify the charging circuit is at 0 V when plugged into USB-C power</li></ul>