POCKETSCOPE PROJECT PROPOSAL

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Contents

1. Introduction

1.1 Problem

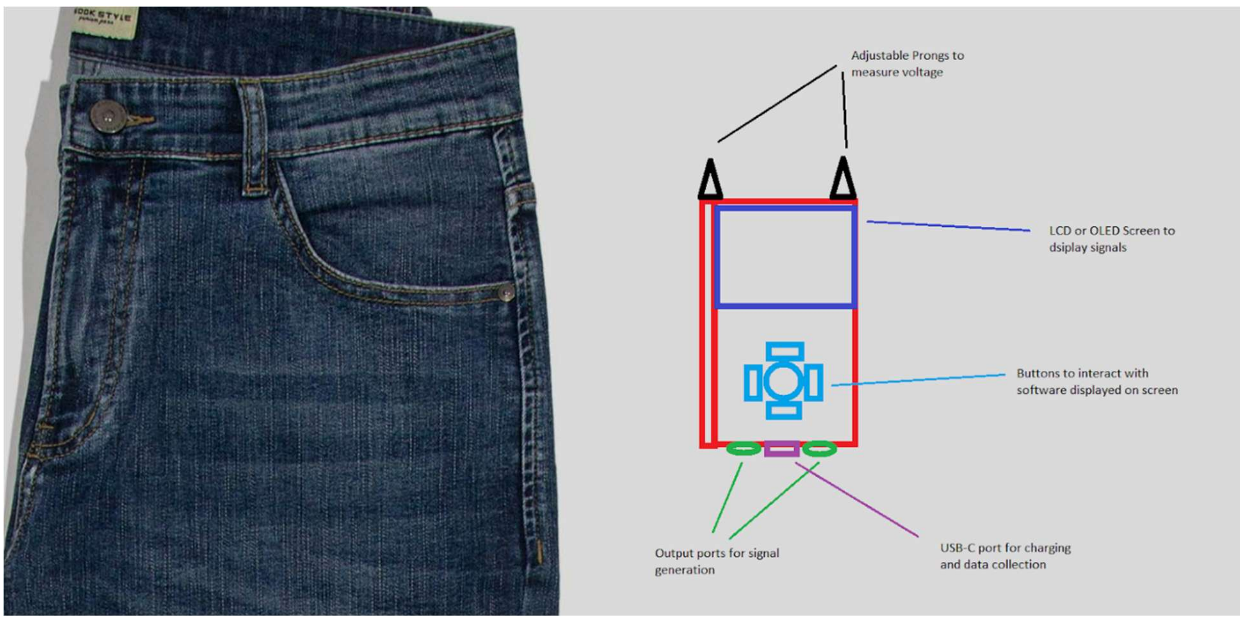
Currently there is no cheap and extremely portable oscilloscope that serves the needs of hobbyists and technicians. Oscilloscope functionality and signal generation is typically confined to laboratory instruments, which are prohibitively expensive to the average consumer since they are intended for university 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 and signal generator designed to give engineers, technicians, and students a powerful diagnostic tool in a truly portable form factor. The device enables high-resolution voltage-versus-time and current-versus-time measurements, real-time FFT analysis, waveform visualization, and onboard data storage with export capability. In addition to measurement, it functions as a signal generator capable of producing configurable waveforms, allowing users to both stimulate and analyze circuits with a single device.

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 both high-voltage measurements (up to approximately ±170 V with appropriate attenuation and protection circuitry) and high-precision measurements in the ±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.

1.3 Visual Aid



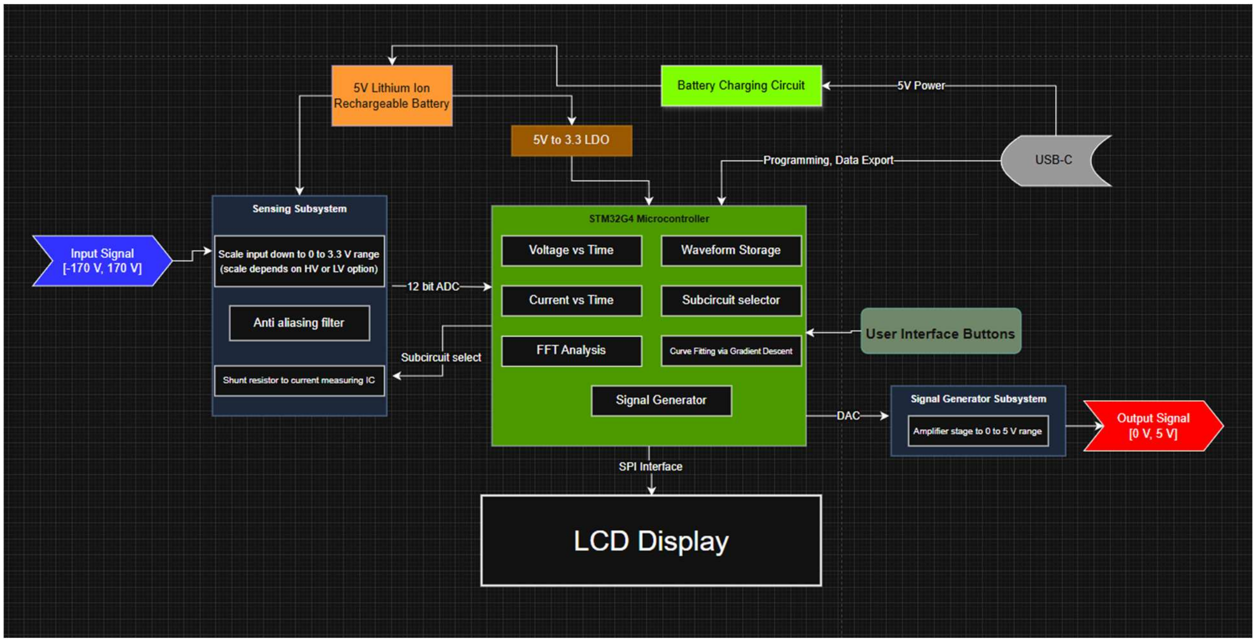
1.4 High Level Requirements

1) Averaging the size of men's and women's jeans pockets, we come to an average height of 7.4'' and an average width of 6.45''. Therefore, for the PocketScope to comfortably fit in an average pair of straight jeans, it must be no longer than 7'' on its longest dimension, and no wider than 6''. The depth of the oscilloscope can vary within 1'' to 2'' to fit within a standard pocket. (Pockets).
2) The PocketScope is intended for field use for technicians or hobbyists, therefore the battery must support at least 3 hours of use without needing to be recharged, as there may be no outlet available.
3) The PocketScope must have the following electrical specifications

- The device must operate in a high precision voltage measuring range of [-20 V, +20 V] and a low voltage measuring range of [-170 V, +170 V].
- The device must generate output signals within the [0 V, +5 V] range and support at minimum three waveform types: sine, square, and sawtooth, with user-adjustable amplitude, frequency, phase, and duty cycle.
- The device must perform onboard analytical processing, including real-time FFT-based spectral analysis and basic curve fitting, without requiring connection to an external computer.

2 Design

2.1 Block Diagram



2.2 Subsystems

2.2.1 Sensing Subsystem

Subsystem Overview

This system will take an input voltage from the conductive prongs on the device and scale down the signal to appropriate 0 to 3.3 V level for safe input into the microcontroller's ADC. Depending on if the signal is high or low voltage, the signal will be scaled differently but ultimately down to a 0 to 3.3 V level in order to maximize input voltage range and precision of the oscilloscope. The signal will first be scaled using a high impedance voltage divider followed by a summing op amp to get the signal above 0 V. The signal will then pass through an anti-aliasing filter to remove any unwanted noise above the 100 kHz bandwidth that the oscilloscope will be rated for. Then the filtered signal will be passed into the microcontroller's ADC pin for computation.

The filtered signal will also pass through a shunt resistor and into a current sensing IC, whose output will also be fed into an ADC pin in the microcontroller for current vs time measurements.

Subsystem Requirements

- Support up to 170V and 0.5 A of current
- For the given voltage range, the accuracy of the sensed voltage/current shouldn't be more than 1% away from the actual value.
    - Can test with 1V, 5V, 20V inputs
- Not damage the microcontroller when supplying an input voltage above the given range

2.2.2 User Interface Subsysem

Subsystem Overview

The User Interface Subsystem serves as the primary bridge between the technician and the internal measurement hardware, enabling real-time visualization of high-speed signals. This system will take user inputs via buttons and display important information to the user. All of the user inputs will interface with the compute unit via user interface buttons, and the outputs will be interfaced via serial peripheral interface (SPI) from the compute unit.

Subsystem Requirements

- This subsystem should take less than 1 Watt of power.
- This subsystem should support at least 5 buttons for users to interface with.
- This subsystem should have a refresh rate of at least 10 Hz.

2.2.3 Compute Subsystem

Subsystem Overview

The compute subsystem acts as the brain of the PocketScope. This subsystem inputs the high-speed signals from the sensing unit and performs digital signal processing (such as real-time FFT spectral analysis) on it. It then formats this processed data into a user-friendly graphical format to be sent to the User Interface Subsystem via SPI, while simultaneously managing the output parameters for the Signal Generator.

Subsystem Requirements

- This subsystem must provide at least two ADCs as inputs- one for voltage measuring and one for current measuring
- This subsystem must provide a 512-point FFT in <30 ms (to maintain the 30 hz refresh rate)

- This subsystem must be able to handle running a line-matching (ex: y=x) ML algorithm in <30 ms.

2.2.4 Signal Generator Subsystem

Subsystem Overview

This system allows the user to output the following waveforms at customizable frequencies, phase, duty cycle, and amplitude:

- Square Wave
- Triangle/Sawtooth Wave
- Sine Wave

These waveforms can be selected via the User Interface Subsystem and will be generated through the STM32G4's onboard DAC. That output will pass through a non-inverting op-amp configuration to scale the waveform to the battery's supply voltage of 5 V if the user desires. The output signal of the signal generator will be through the same contacts used to monitor analog signals through the oscilloscope function.

Subsystem Requirements

This subsystem should be able to generate the specified waveforms according to the following specs:

- Amplitude: 0 to 5V range
- Frequency: 0 to 50 kHz
- Duty Cycle: 0 to 100%
- Phase: 0 to 360 degrees

2.2.5 Battery Charging Subsystem

Subsystem Overview

This system allows the user to plug a USB-C cable into their PocketScope to allow for the battery to recharge. The 5 V power from the USB-C will go into a battery IC and the output will charge the battery. This will allow the PocketScope to operate on the go.

Subsystem Requirements

- Must be able to charge the battery while in use
- Must add battery disconnection circuit to prevent fire hazard in the case of overdrawing power
- Must add overcharge protection to prevent fire hazard

2.4 Tolerance Analysis

The sensing subsystem presents a significant technical risk because measurement accuracy is directly dependent on the integrity of the signal delivered to the MCU's 12-bit ADC. The analog front-end must attenuate high-voltage inputs (up to ±170 V), condition lower-voltage precision inputs (±20 V), and suppress EMI, switching noise, and environmental pickup before digitization. Any excessive noise, improper filtering, or impedance mismatch could reduce effective number of bits, distort waveform shape, and degrade FFT accuracy and curve-fitting reliability.

To quantify this risk, consider that in the ±20 V measurement range the total span is 40 V. With a 12-bit ADC (4096 levels) (4), the resolution is 40 V / 4096 or around 9.77 mV per LSB. To prevent visible waveform distortion or FFT degradation, total system noise should remain below about ±0.5 LSB, or roughly ±4.9 mV. The ADC's own quantization noise has an RMS value of approximately LSB / √12 or 2.8 mV RMS, meaning the analog front-end (resistors, op-amps, layout, and filtering combined) should contribute less than about 4 mV RMS of additional noise to stay within budget.

For comparison, resistor thermal noise is relatively small: even a 1 MΩ equivalent resistance over a 100 kHz bandwidth produces on the order of tens of microvolts RMS, which is far below the millivolt-level noise budget. This shows that the dominant risks are EMI pickup, op-amp noise, and improper filtering. Therefore, the sensing subsystem will use properly selected divider impedances, buffering amplifiers, and low-pass filtering with a cutoff slightly above the intended signal bandwidth to suppress high-frequency interference while preserving waveform fidelity.

3 Ethics and Safety

The PocketScope is 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 170V input range and thermal runaway from its lithium-ion battery. We will adhere 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), we will prioritize 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.

4 References

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