

Electric Drum Hit Localization Using Time Difference of Arrival Analysis

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Team No. 42

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1. Introduction

1.1. Problem and Solution

Electronic drums use sensors to detect strikes and trigger recorded sounds. However, systems that classify strikes into only a few predefined zones reproduce only part of the variation available on an acoustic drum. Strike position changes an acoustic drum's sound continuously from its center to its rim. Detecting position with greater resolution would allow an electronic drum to represent this variation more closely. Configurable mapping of strike positions to MIDI notes would also give users greater control over sound selection in external software, and allow for greater manipulation than typical single-zone electronic drums.

Our project uses an array of inexpensive piezoelectric sensors to estimate strike position on a 13-inch mesh drum head. The sensors detect the mechanical disturbance at different times, allowing time difference of arrival analysis to estimate the strike location. Analog preprocessing circuitry conditions the sensor outputs for acquisition by an STM32 microcontroller, which estimates the strike's radial zone and transmits the corresponding MIDI note over USB. The design targets at least ten radial zones using a small sensor array rather than a dedicated sensor for each zone. Assigning distinct MIDI notes to these zones allows the host software to select different sounds based on strike position.

1.2. Visual Aid

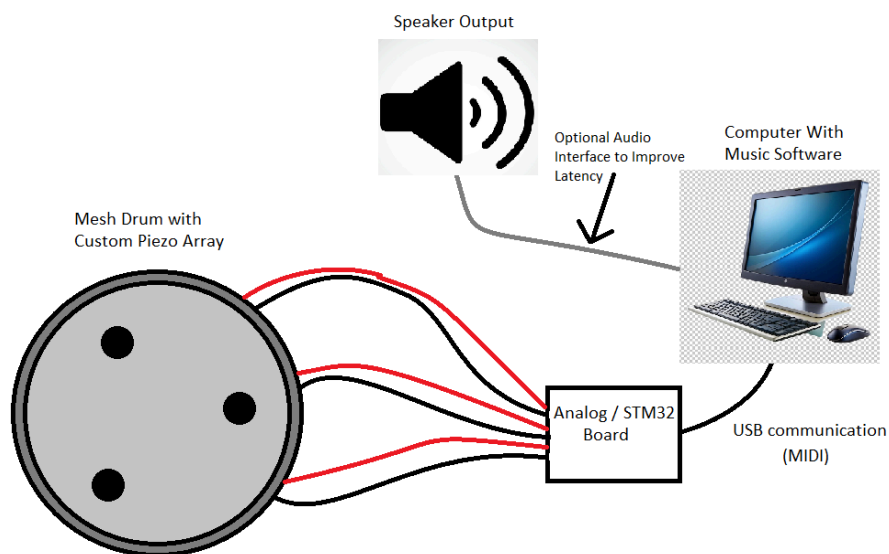


Figure 1. Intended use of the electric drum hit localization system.

The user strikes the mesh drum head with a drumstick. The device estimates the strike position and sends the corresponding MIDI note to a host computer through USB. Software on the computer maps the received note to a drum sound and plays it through the host's audio output. The USB connection also supplies power to the device.

1.3. High-level requirements list:

- The system shall distinguish between at least ten radial zones on a 13-inch-diameter drum surface with at least 90% accuracy over a minimum of ten test strikes per zone.
- The combined MCU processing and USB transmission latency, measured from the first detected piezo threshold crossing to completion of the corresponding USB-MIDI transfer, shall not exceed 15 ms for at least 95% of test strikes.

- The device shall be recognized by a host computer as a USB-MIDI interface in ten consecutive connection attempts and shall transmit the MIDI note assigned to each detected strike zone.

2. Design

2.1. Block Diagram:

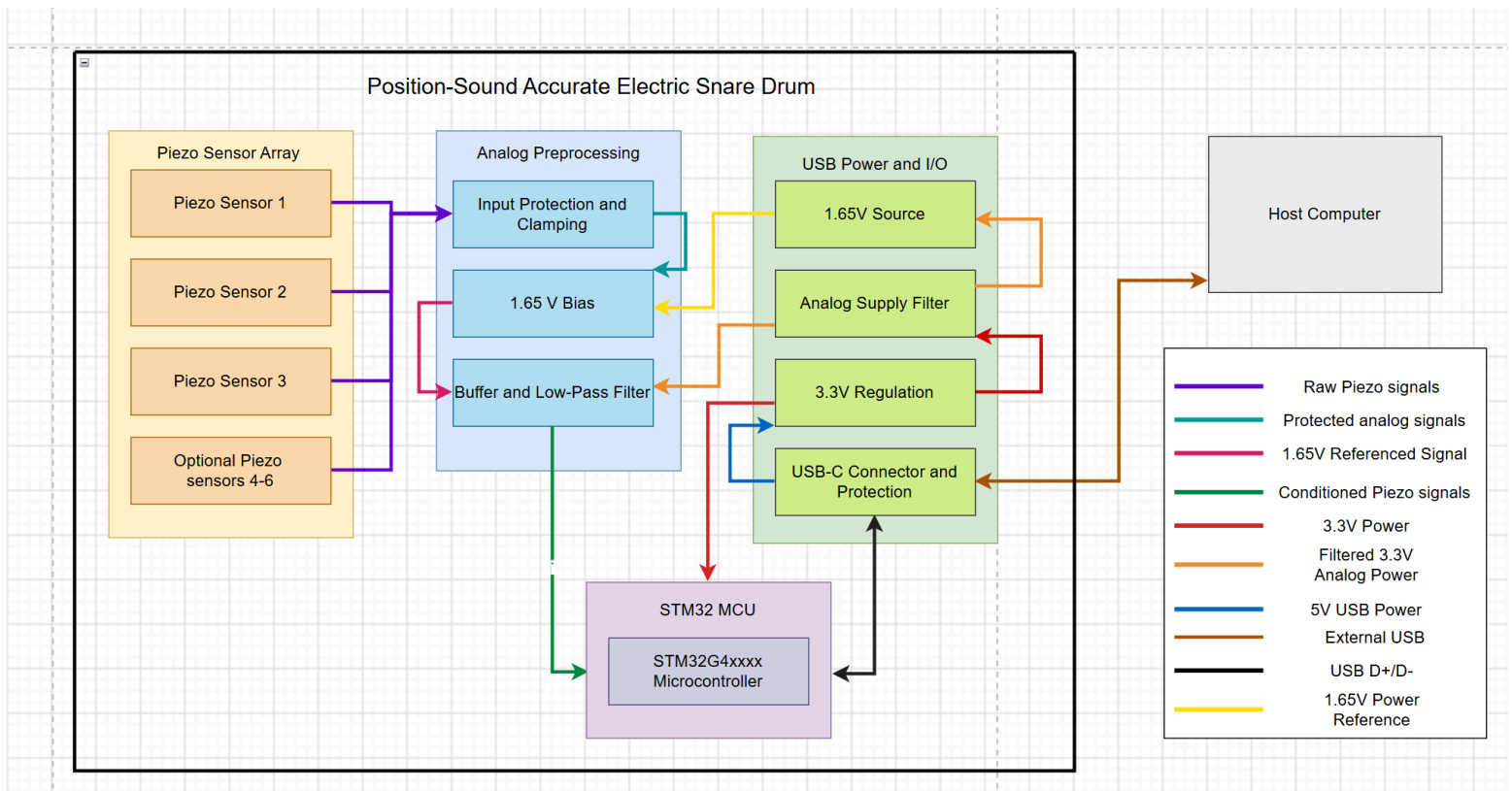


Figure 2. System block diagram showing sensor signals, power distribution, and USB communication.

The system consists of four subsystems: the piezoelectric sensor array, analog preprocessing circuitry, STM32 microcontroller, and USB Power and I/O subsystem. The sensor array converts mechanical disturbances from drum strikes into independent analog signals. The analog preprocessing circuitry protects, biases, and filters these signals for acquisition within the MCU's 0–3.3 V ADC input range. The MCU acquires the conditioned signals, estimates strike position, and maps the detected radial zone to a MIDI note. The USB Power and I/O subsystem supplies regulated power and provides the physical connection through which the MCU communicates with the host computer.

2.2. Physical Design (if applicable):



Figure 3. Physical arrangement of the drum and mounting structure with adjustable sensor mounts. Current implementation of piezo mounting and PCB mounting may be different from the realized mount.

The device uses a 13-inch acoustic snare drum with its acoustic head replaced by a silent mesh head. The drum shell provides the mechanical structure and space for mounting the sensors and electronics. The proposed sensor mounts use 3D-printed slots with 90-degree brackets secured through the drum's existing

tuning-lug hardware. Slots in the mounts allow sensor positions to be adjusted during testing. Sensor coordinates will be measured after the mounting arrangement is finalized and supplied to the localization algorithm. Wiring connects each sensor to an independent analog preprocessing channel on the PCB. The PCB provides four populated conditioning channels, with an additional connector reserved for two optional sensor inputs.

2.3. Piezo Sensor Array Subsystem

The piezoelectric sensor array converts mechanical disturbances from strikes on the mesh drum head into electrical signals. Spatially separated sensors detect each disturbance at different times, providing the measurements needed for strike localization. This subsystem supports the high-level requirement of distinguishing at least ten radial strike zones.

The initial implementation uses four piezoelectric sensors, each connected to an independent analog preprocessing channel through J3. Each sensor has a signal connection and a ground return. J5 is reserved for two optional sensor inputs and is not populated in the initial implementation. Piezoelectric sensors require no external excitation supply, simplifying the wiring and avoiding an additional power requirement.

The proposed arrangement distributes the sensors around the drum at equal nominal distances from its center. Adjustable mounts allow their positions to be refined during testing. Once the positions are selected, the coordinates of each sensor will be measured relative to the drum center and recorded for use by the localization algorithm. The mounts must retain these positions during repeated strikes because sensor movement would change the relationship between arrival-time differences and strike location.

Each sensor produces a bipolar, strike-dependent voltage. Its output connects to the input protection and conditioning circuitry rather than directly to the MCU. The analog preprocessing subsystem provides the protected, biased signals used for ADC acquisition.

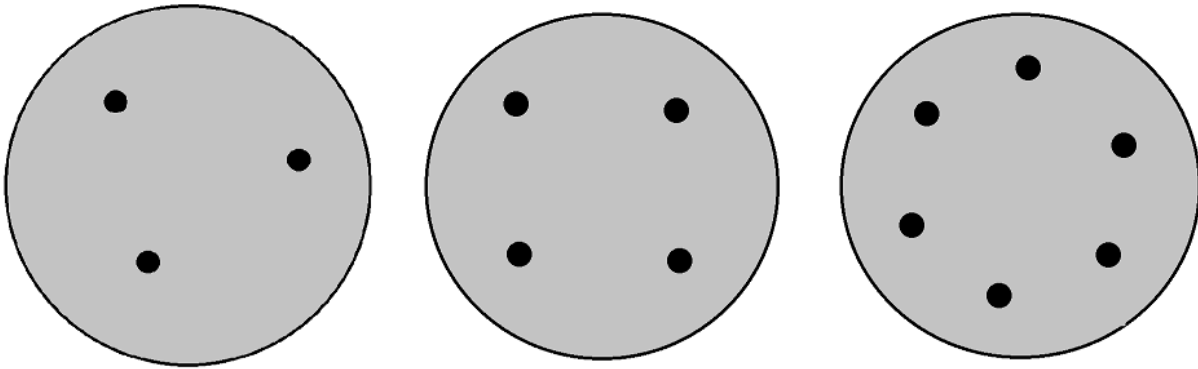


Figure 4. Center: Current sensor architecture Left / Right: Potential alternative piezo orientations. This image is not an accurate representation of every sensor array that could be utilized for this project.

The array shall provide four independently connected sensor signals to the analog preprocessing subsystem.	Connect all four sensors and power the board. Use an oscilloscope connected to testpoints labeled ADCx to observe each corresponding conditioned output relative to GND while striking the drum. Verify that each channel produces a response.
Each sensor's position shall be measured relative to the drum center with ± 1 mm measurement uncertainty.	Use a ruler or caliper and a coordinate reference through the drum center to measure each sensor's center position. Record the coordinates and measurement uncertainty in a table for use by the localization algorithm
The mounts shall restrict sensor displacement to ≤ 1 mm after 100 drum strikes.	Measure and record each sensor's position before testing. Apply 100 strikes distributed across the drum head. Measure the positions again using the same reference. Record the before-and-after coordinates and verify each sensor moved no more than 1 mm.
The array shall produce detectable responses on at least 3 sensor channels for at least 90% of test strikes in each radial zone.	Connect the sensors to the preprocessing circuitry. Record all four conditioned outputs simultaneously using an oscilloscope or MCU data capture. Apply ten strikes in each of the ten radial zones. Count a strike as successful when all three main channels cross the detection threshold used by the MCU. Record successful strikes per zone; verify at least nine of ten succeed in each zone.

2.4. Analog Preprocessing Subsystem

The analog preprocessing subsystem converts the bipolar piezoelectric outputs into signals suitable for the STM32 ADC. It provides four independent conditioning channels containing input protection, biasing, buffering, and filtering. Preserving the relative arrival times of these signals supports the high-level requirements for radial-zone classification and low processing latency.

Each sensor input includes a 1 k Ω series resistor and a BAT54S Schottky protection diode array. A 1 M Ω resistor is used for ground reference. The 1 k Ω series resistor limits protection-diode current. Capacitive coupling allows the strike-dependent signal to be referenced to the 1.65 V bias supplied by the USB power and I/O subsystem. A 1 M Ω resistor is used for connecting the piezo signal to the bias before amplification and filtering.

A TLV9064 quad operational amplifier provides one buffer for each conditioning channel. Buffering isolates the high-impedance sensor network from the downstream filter and ADC inputs. The amplifier operates from the filtered 3.3V analog power supply. Conditioned signals operate near 1.65 V so that positive and negative excursions from the piezoelectric sensors can be acquired using the MCU's single ended 0 - 3.3V ADC inputs.

An RC filter is placed after each op amp channel, and acts as a low pass filter to reduce high-frequency content before acquisition by the MCU. Three resistors in parallel and a shunt 10 nF capacitor allow for tuning of the circuit as necessary in future revision of the circuit. Each response must be consistent across the channels to ensure that delays between channels are as minimal as possible.

Each conditioning channel shall have a no-signal output of 1.65 V $\pm$ 100 mV	Power the board without the sensor array connected. Use a DMM to measure each conditioned output relative to GND. Verify all channel readings are between 1.55-1.75V.
Each conditioning channel shall keep its ADC input signal within 0–3.3 V during drum strikes.	Use an oscilloscope to measure each conditioned output relative to GND. Apply light, moderate, and strong

	strikes at the center, middle radius, and near the rim. Verify for each strike impulse response that the observed voltages for each channel remain within 0 - 3.3V.
The conditioned channels shall introduce no more than 10 μ s of relative threshold crossing delay when driven by the same input waveform	Disconnect the sensors. Use a function generator to apply the same bipolar test pulse simultaneously to all four sensor inputs, with the generator ground connected to board GND. Adjust the amplitude to produce unclipped outputs that cross the MCU's detection threshold. Use an oscilloscope to measure the threshold-crossing times of the conditioned outputs. Repeat for ten pulses. Record the largest difference between channels for each pulse. Verify each difference is $\leq 10 \mu$ s

2.5. STM32 MCU Subsystem

The STM32 MCU subsystem acquires the conditioned sensor signals, estimates the radial strike position, and sends the corresponding MIDI note to the host computer. It directly supports the high-level requirements for 10 zone classification, processing and transmission latency, and USB-MIDI operation.

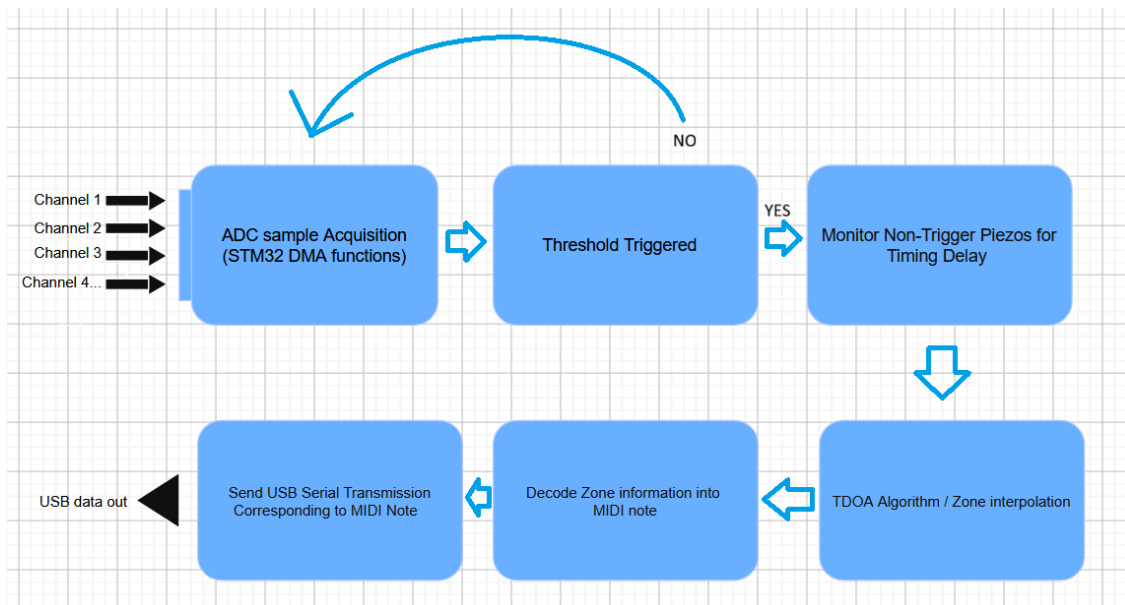
The design uses an STM32G473CET3 powered from the regulated 3.3V supply. Four conditioned sensor outputs connect to separate ADC inputs. Acquisition uses hardware-controlled timing at a minimum rate of 100 kS/s per active channel, corresponding to a sample interval of 10 μ s. The acquisition configuration must account for any timing offsets between channels so these offsets are not interpreted as differences in mechanical arrival time.

Firmware monitors the acquired signals for a strike-detection threshold crossing. Following detection, it collects the corresponding responses from the other sensors and determines their relative arrival times. The localization calculation uses these differences together with measured sensor coordinates and calibrated propagation behavior to estimate strike position. The estimated distance from the drum center determines which of the ten radial zones contains the strike.

For a 13-inch-diameter head, the usable radius is about 6 inches or 152.4 mm. Dividing this radius into ten equal zones gives a nominal zone width of

$$w = \frac{152.4 \text{ mm}}{10} = 15.24 \text{ mm}.$$

Each zone is assigned a distinct MIDI note. The MCU transmits the selected note through its native USB Full-Speed interface and the USB-C connection. The latency requirement covers acquisition following the first detected threshold crossing, localization processing, and transmission to the host. Sound generation and host audio playback are outside this latency measurement. The board also provides SWD connections for programming and debugging.



The MCU shall acquire each active sensor channel at ≥ 100 kS/s.	Run acquisition on all four channels. Use a hardware timer to measure the time required to collect 1,000 samples per channel. Verify the elapsed time is ≤ 10 ms
The MCU shall classify strikes into ten radial zones with $\geq 90\%$ overall accuracy. .	Use a removable rim-mounted positioning guide to locate test points at the midpoint of each radial zone. Move the guide clear before striking. Apply ten strikes per zone, distributed around different directions on the head. Record the intended zone and the zone reported by the MCU. Count missed detections as incorrect. Verify at least 90 of 100 strikes are classified correctly. Present the results in a table.
The MCU shall transmit the MIDI note	Connect the board to a computer running

assigned to each reported strike zone.	a MIDI monitor. During the zone-classification test, record the MCU's reported zone and the MIDI note received by the computer. Compare each received note with the configured zone mapping. Verify every recorded note matches its reported zone. Present the results in a table
The device shall enumerate as a USB-MIDI interface in ten consecutive connection attempts.	Connect the board to the host computer and verify it appears as a MIDI input device. Disconnect and reconnect it ten times. Record the enumeration result for each attempt. Verify all ten attempts succeed.
The time from the first detected sensor threshold crossing to completion of the corresponding USB-MIDI transfer shall be ≤ 15 ms for at least 95% of test strikes.	Connect the board to a host computer. Record a hardware-timer timestamp at the first detected threshold crossing and another in the USB transfer-complete callback. Calculate and store the elapsed time for each of 100 strikes. Retrieve the results after testing. Verify at least 95 of 100 measurements are ≤ 15 ms.

2.6. USB Power and I/O

The USB Power and I/O subsystem provides power to the microcontroller and analog preprocessing circuitry and connects the device to a host computer for USB-MIDI communication. It receives nominal 5 V power through a USB-C receptacle and produces a regulated 3.3 V supply. Stable power supports consistent signal acquisition and processing, while the USB data connection supports the high-level requirements for host recognition and MIDI transmission.

USB Interface and Input Protection

The USB-C receptacle, J1, carries VBUS, ground, and the USB 2.0 D+ and D- signals. Each configuration-channel pin has a nominal 5.1 k Ω pull-down resistor to identify the device as a power sink. The device operates from the standard USB supply without requiring USB Power Delivery. The D+ and D- differential signals connect to the STM32's native USB interface for Full-Speed communication at 12 Mbit/s, which enables the USB-MIDI interface.

A Würth 82400102 TVS array provides transient protection for the USB power and data connections. The TVS array allows for VBUS connection from the USB, and suppresses transients on the differential output of the USB. The VBUS protection is connected at the input, ahead of the TPS2553-1 current-limited switch. These components serve complementary purposes: the TVS array suppresses voltage transients, while the TPS2553-1 limits current during overload and short-circuit conditions.

The TPS2553-1 is configured for a nominal current limit of approximately 450 mA, with a maximum design limit of 500 mA. The minimum potential current limit was ~400 mA, which is still safely above the current estimate drawn by downstream devices. This setting provides margin above the expected operating current while shutting off after a typical delay of 7.5 ms if the condition is not removed. An external switch connected through J2 controls the enable input, and a pull-down resistor holds the switch disabled when the enable connection is open. The active-low fault output drives a DMP2045U PMOS, which will source current and voltage for a red LED when the TSP2553 has indicated an overload condition. A series resistor limits the LED current.

Voltage Regulation and Analog Supply

An LD1117S33 regulator converts the protected USB supply to 3.3 V. The complete MCU and analog circuitry are estimated to draw no more than 200 mA during normal operation. A conservative operating budget allocates 100 mA to the MCU and its active peripherals, 10 mA to the five green indicators, and 10 mA to the analog circuitry, bias reference, and remaining resistive loads, for a total of 120 mA on the 3.3 V rail. A 200 mA operating allowance provides additional margin, while the regulator is designed to supply up to 800 mA. The supply is designed to support 200 mA safely, while allowing for changes due to heat dissipation. A linear regulator was selected because the modest load allows a simple supply without introducing a switching converter's noise into the sensor acquisition circuitry. The SOT-223 package provides improved heat dissipation through its tab and connected PCB copper, though further design changes may need to be made after measuring actual heat dissipation from the first round PCB order.

The approximate regulator dissipation is

$$P_{reg} = (V_{in} - V_{out})I_{load}$$

At a nominal 5 V input, dissipation is approximately 0.34 W at the estimated 200 mA operating load and 0.51 W at the 300 mA design load. At the maximum specified input of 5.25 V, these values become 0.39 W and 0.585 W, respectively. These calculations informed the regulator package selection and provision of copper for heat dissipation.

A 10 μF tantalum output capacitor provides the capacitance and ESR required for regulator stability. Local ceramic capacitors provide bypassing at the power devices and loads. An MI0805K601R-10 ferrite bead separates the analog 3.3 V supply from the main digital supply. Together with local analog supply capacitance, it reduces high-frequency noise coupled into the analog circuitry while preserving a common ground reference.

The analog signal-bias reference is generated using two equal 10 k Ω resistors connected across the analog supply. The divider produces approximately half the supply voltage:

$$V_{bias} = V_{3.3VA} \frac{10k\Omega}{10k\Omega + 10k\Omega} = \frac{V_{3.3VA}}{2}.$$

At a nominal 3.3 V supply, this produces 1.65 V. Filtering at the divider reduces reference noise, and a TLV9001 voltage follower buffers the reference for the analog preprocessing channels. This reference allows the bipolar piezoelectric signals to be represented around the midpoint of the ADC input range.

The subsystem shall output 3.3 V ± 150 mV during normal operation.	Power the board through the USB port. Use a DMM to connect the regulator output relative to GND. Record input current and output voltage. Verify the output is between 3.15–3.45 V.
The subsystem shall maintain 3.3 V ± 150 mV with a continuous 200 mA output load and a brief 300 mA output load	Power the board through the USB port. Connect an electronic load between 3.3 V and GND. Use a DMM in current mode to measure the regulator output current, including the board and electronic load. Adjust the total output current to 200 mA and hold for one minute. Measure the output voltage with a second DMM. Repeat at 300 mA for five seconds. Record output current, USB input current, and output

	voltage. Verify both voltage readings are between 3.15–3.45 V.
The external switch shall enable the regulated supply when closed and reduce USB input current to ≤ 5 mA when open.	Power the board through the inline USB meter. Close the switch, and let the board initialize for 30 seconds. Open the switch and allow the supply to discharge for 15 seconds. Record the USB input current. Verify it is ≤ 5 mA.
The protection circuit shall disconnect downstream power within 20 ms of a sustained overload exceeding its trip threshold and remain off until the enable switch or input power is cycled.	Power the board through USB. Connect an electronic load between the TPS2553-1 protected 5 V output and GND. Use an oscilloscope to monitor output voltage and load current. Apply an overload above the selected trip threshold. Verify the output falls below 0.3 V within 20 ms of current limiting beginning. Remove the overload and verify the output remains off. Toggle the enable switch and verify power returns.
The red fault LED shall illuminate when overload protection trips and remain illuminated until the fault is reset.	Observe D9 during the preceding overload test. Verify it is off before the overload, illuminates when protection trips, and remains on after the added load is removed. Toggle the enable switch and verify D9 turns off.

2.7. Tolerance Analysis:

Easily the most difficult challenge in the design is the location precision needed to resolve 10 unique zones reliably. As detailed earlier, to accomplish distinction of 10 zones on a 13 inch drum, sub centimeter level accuracy is necessary. This means the sample rate of the ADCs will need to be sufficiently high. To address these concerns, the following procedure was conducted.

Two piezo sensors were mounted 10 inches apart on the drum head, and one was struck directly while both signals were monitored on an oscilloscope. The time delay between the two piezo signals was approximately 2.5ms. Using this time difference we can find the wavespeed:

$$v = \frac{d}{\tau}$$

$$v = \frac{0.254 \text{ m}}{2.5 \times 10^{-3} \text{ s}} \approx 101.6 \text{ m/s}$$

Our ADC has the capability to sample 5 channels at up to 4 Mhz, though this is the theoretical limit. We plan to start testing at ~100khz. In one sample cycle, the wave travels a known distance Δx .

$$\Delta x = \frac{1}{100 \times 10^3} \times 101.6 \text{ m/s} = 1.016 \text{ mm /sample}$$

This means that we will have $(15.24 / 1.016) = 15$ samples that we can use to resolve a certain zone, not including interpolation, which will give us higher precision. The preliminary calculation supports testing at 100 kS/S per channel. Localization accuracy will be verified through the ten-zone classification test.

3. Cost and Schedule

3.1. Cost Analysis

3.1.1. General Project Costs

	Costs
13 in Glarry Snare Drum	\$45
Mesh Drum Head	\$15
USB power meter	\$15
STM32 Dev Board	\$10
Electronic Parts	\$20.03 (detailed below)
Labor	(Hourly Rate) x (Overhead) x (members) x (projected hours) (\$35/hour) x 2.5 x 3 x 96 = \$25,200
Total (excluding labor)	\$105.03
Total	\$25,305.03

3.1.2. Electronic Parts Costs

Part / manufacturer and reference	Qty	Unit cost	Total cost	Incurred cost for project
2-pin JST XH header — JST B2B-XH-A — J2	1	\$0.10	\$0.10	\$0.10

8-pin IDC header and socket – Sullins SBH11-PBPC-D04-ST-BK / SFH210-PPKC-D04-ID-BK – J3	1	\$1.50	\$1.50	\$1.50
SPST rocker switch – E-Switch R1966ABLKBLKFF – external switch	1	\$1.56	\$1.56	\$1.56
10 nF, 100 V capacitors, 0805 – Samsung CL21B103KCANNNC – C5–C8, C25	5	\$0.10	\$0.50	\$0.00
2×3 section of 2.54 mm Berg strip – Amphenol BERGSTIK II equivalent – J4	1	\$0.243	\$0.24	\$0.00
1×3 section of 2.54 mm Berg strip – Amphenol BERGSTIK II equivalent – JP1	1	\$0.099	\$0.10	\$0.00
Jumper shunt – Sullins SPC02SVGN-RC – JP1	1	\$0.10	\$0.10	\$0.10
1 μ F, 50 V capacitors, 0805 – Samsung CL21B105KBFNNNG – C26, C28	2	\$0.14	\$0.28	\$0.00
1.91 k Ω , 0.5%, $\frac{1}{4}$ W resistors, 0805 – KOA Speer RK73H2ATTD1911D – R13, R16, R28, R31	4	\$0.10	\$0.40	\$0.00
1.5 k Ω , 1%, $\frac{1}{8}$ W resistors, 0805 – Stackpole RMCF0805FT1K50 – R14, R35, R29, R32	4	\$0.10	\$0.40	\$0.00
3.16 k Ω , 0.5%, $\frac{1}{4}$ W resistors, 0805 – KOA Speer RK73H2ATTD3161D – R15, R34, R30, R33	4	\$0.10	\$0.40	\$0.00
1 M Ω , 1%, $\frac{1}{8}$ W resistors, 0805 – Stackpole RMCF0805FG1M00 – R1–R4, R9–R12	8	\$0.10	\$0.80	\$0.00
1 k Ω , 5%, $\frac{1}{8}$ W resistors, 0805 – Stackpole RMCF0805JT1K00 – R5–R8, R26	5	\$0.10	\$0.50	\$0.00
Green LEDs – SunLED XZCDGK53W-8VF – D5–D7, D10, D11	5	\$0.48	\$2.40	\$2.40

Red LED – Kingbright APTD2012LSURCK – D9	1	\$0.30	\$0.30	\$0.30
10 μ F, 16 V tantalum capacitor – KYOCERA AVX TAJA106K016RNJ – C14	1	\$0.54	\$0.54	\$0.54
Ferrite bead – Laird MI0805K601R-10 – FB1	1	\$0.11	\$0.11	\$0.11
USB-C receptacle – GCT USB4105-GF-A-060 – J1	1	\$0.80	\$0.80	\$0.00
Tactile switches – C&K PTS645SL43SMTR92 LFS – SW1, SW2	2	\$0.39	\$0.78	\$0.00
100 Ω resistors, 0805 – YAGEO RC0805FR-07100RL cost equivalent – R25, R45–R47	4	\$0.10	\$0.40	\$0.00
Quad op amp – Texas Instruments TLV9064IPWT – U1	1	\$1.79	\$1.79	\$1.79
Latching current-limit switch – Texas Instruments TPS2553DBVT-1 – U5	1	\$1.36	\$1.36	\$1.36
Bias-buffer op amp – Texas Instruments TLV9001IDCKR – U6	1	\$0.40	\$0.40	\$0.40
Microcontroller – STMicroelectronics STM32G473CET3 – U9	1	\$9.87	\$9.87	\$9.87
4.7 μ F, 25 V capacitors, 0805 – Samsung CL21A475KAQNNNE – C9, C12, C16, C19	4	\$0.14	\$0.56	\$0.00
100 nF, 50 V capacitors, 0805 – YAGEO CC0805KRX7R9BB104 – C1–C4, C10, C11, C13, C15, C17, C18, C20–C24, C27, C29	17	\$0.098	\$1.67	\$0.00
Schottky diode arrays – onsemi BAT54SLT1G – D1–D4	4	\$0.15	\$0.60	\$0.00
PMOS – Diodes Incorporated DMP2045U-7 – Q1	1	\$0.44	\$0.44	\$0.00

100 kΩ, 5%, 1/8 W resistors, 0805 – Stackpole RMCF0805JT100K – R20, R21	2	\$0.10	\$0.20	\$0.00
1.5 kΩ, 1%, 1/8 W resistor, 0805 – Stackpole RMCF0805FT1K50 – R22	1	\$0.10	\$0.10	\$0.00
10 kΩ, 1%, 1/8 W resistors, 0805 – YAGEO AA0805FR-0710KL – R23, R24, R44	3	\$0.15	\$0.45	\$0.00
0 Ω resistor, 1/8 W, 0805 – Stackpole RMCF0805ZT0R00 – R27	1	\$0.10	\$0.10	\$0.00
3.3 V regulator – STMicroelectronics LD1117S33TR – U3	1	\$0.40	\$0.40	\$0.00
USB TVS array – Würth Elektronik 82400102 – U4	1	\$0.86	\$0.86	\$0.00
5.11 kΩ, 1%, 1/8 W resistors, 0805 – YAGEO AC0805FR-075K11L – R17, R18	2	\$0.10	\$0.20	\$0.00
60.4 kΩ, 1%, 1/4 W resistor, 0805 – KOA Speer RK73H2ATTD6042F – R19	1	\$0.10	\$0.10	\$0.00
Total electronic component cost			\$31.31	\$20.03
Reduction from course-provided and owned parts			\$11.28	
Estimated incurred cost for this project				\$20.03
Excludes shipping, tax, tariffs, sensors, PCB fabrication, drum, mounting materials and wire.				

USD. Quantity-1 prices, except 17 × 100 nF capacitors at the quantity-10 tier.

TA-provided, ECE shop and owned parts have zero new team expense.

Pricing details lists source links, selected equivalents and any estimated prices.

Source: All component prices were obtained from DigiKey Electronics and STMicroelectronics on October 2, 2026. Prices are subject to change [8].

1.1. Schedule:

	Task	Group Member(s)
Week (10/5)	Order missing parts	Kadin, Tim
Week (10/12)	Build breadboard demo, Assemble / Test PCB Rev 1 and make corrections for Rev 2	Kadin, Tim, Oscar Kadin, Tim, Oscar
Week (10/19)	Flash firmware / design TDOA algorithm	Oscar
Week (10/26)	Test alternate mounting architecture, Make final PCB revisions	Tim Kadin, Tim, Oscar
Week (11/2)	Design improvement / Debug	Kadin, Tim, Oscar
Week (11/9)	Design improvement / Debug	Kadin, Tim, Oscar
Week (11/16)	Finalize Design	Kadin, Tim, Oscar
Week (11/23)	Fall Break	
Week (11/30)	Demo	Kadin, Tim, Oscar
Week (12/7)	Final Paper	Kadin, Tim, Oscar

4. Discussion of Societal Impact, Engineering Standards, Ethics, and Safety Considerations:

4.1. Societal Impact

This project focuses on developing a low-material-cost electronic percussion sensing system that can improve the functionality and accessibility of electronic drums. Our multisensor implementation aims to provide greater strike-position resolution using a small number of inexpensive sensors. Our efforts may lay the groundwork needed for an open-source alternative to prosper. If successful, the design has the potential to give musicians realistic, configurable, and inexpensive electronic drum solutions.

Configurable MIDI mapping allows the device to work with different sound libraries and host software, giving musicians flexibility without tying them to a single manufacturer's ecosystem. This approach could benefit students, amateur musicians, educators, and independent music producers. Sharing the hardware design, software and test results could also allow others to reproduce and improve the system.

The environmental impact is expected to be limited, as construction consists of small electronic components powered by USB and a drum that may be reused. However, component manufacturing, PCB fabrication, plastic mounting materials, and eventual electronic waste still contribute to that impact. Reusing the drum and providing replaceable sensors and cables can reduce waste and extend the useful life of the system.

4.2. Engineering Standards

The design follows the USB Type-C cable and connector specifications, the USB 2.0 specification, and the USB device-class specification for MIDI devices. These standards define the connector configuration, electrical interfaces, and communication format needed for operation with a host computer.

The project is a low-voltage educational prototype and is not intended for commercial use or formal product certification. Nevertheless, the design must address electrical and mechanical safety. Testing with the intended host computer will demonstrate prototype compatibility without implying formal USB certification.

4.3. Ethics

The project follows the guidelines detailed by the IEEE and ACM codes of ethics by emphasizing safety, honesty in reporting results, and responsible engineering practices. The team will accurately report measured localization accuracy, latency, and compatibility, distinguishing experimental results from design goals and estimates. Failed detections and limitations will be included when evaluating performance.

External code, reference designs, and technical information will be appropriately attributed. Claims regarding originality, affordability, and improved realism will be supported by references or testing. If the design is released as an open-source project, its documentation will describe the operating requirements and known limitations so that others can use and develop it responsibly.

4.4. Safety Considerations

Electrical safety concerns include short circuits, regulator heating, and voltage transients generated by the piezoelectric sensors. The system operates from a nominal 5V USB power and uses a regulated 3.3V supply. USB transient protection and sensor input protection reduce the risk of component damage. The TPS2533-1 provides automatic power disconnection during a sustained overload, while the red fault indicator communicates that protection has activated.

Before initial power-up the team will inspect component orientation and solder joints and check for shorts between power and ground. Initial testing will use a current-limited supply. The regulator's temperature and output voltage will be monitored during load testing. Deliberate overload tests will use a separate USB power supply rather than a computer's USB power.

Mechanical safety concerns include loose mounts, movement of the PCB during strikes, and damaged or disconnected wiring. The PCB will be secured and insulated from conductive drum hardware. Wiring will be routed away from the striking surface and provided with strain relief. Sensor and PCB mounts will be inspected before use and checked after repeated strikes.

Assembly and testing will follow course laboratory safety guidelines including safe soldering practices and appropriate ventilation. Power will be disconnected

before wiring or mounting adjustments. Audio playback will begin at a low volume to reduce the risk of hearing damage.

5. Citations

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Appendix A - Current PCB designs

(Schematic figures are currently older than the figures from the BOM)

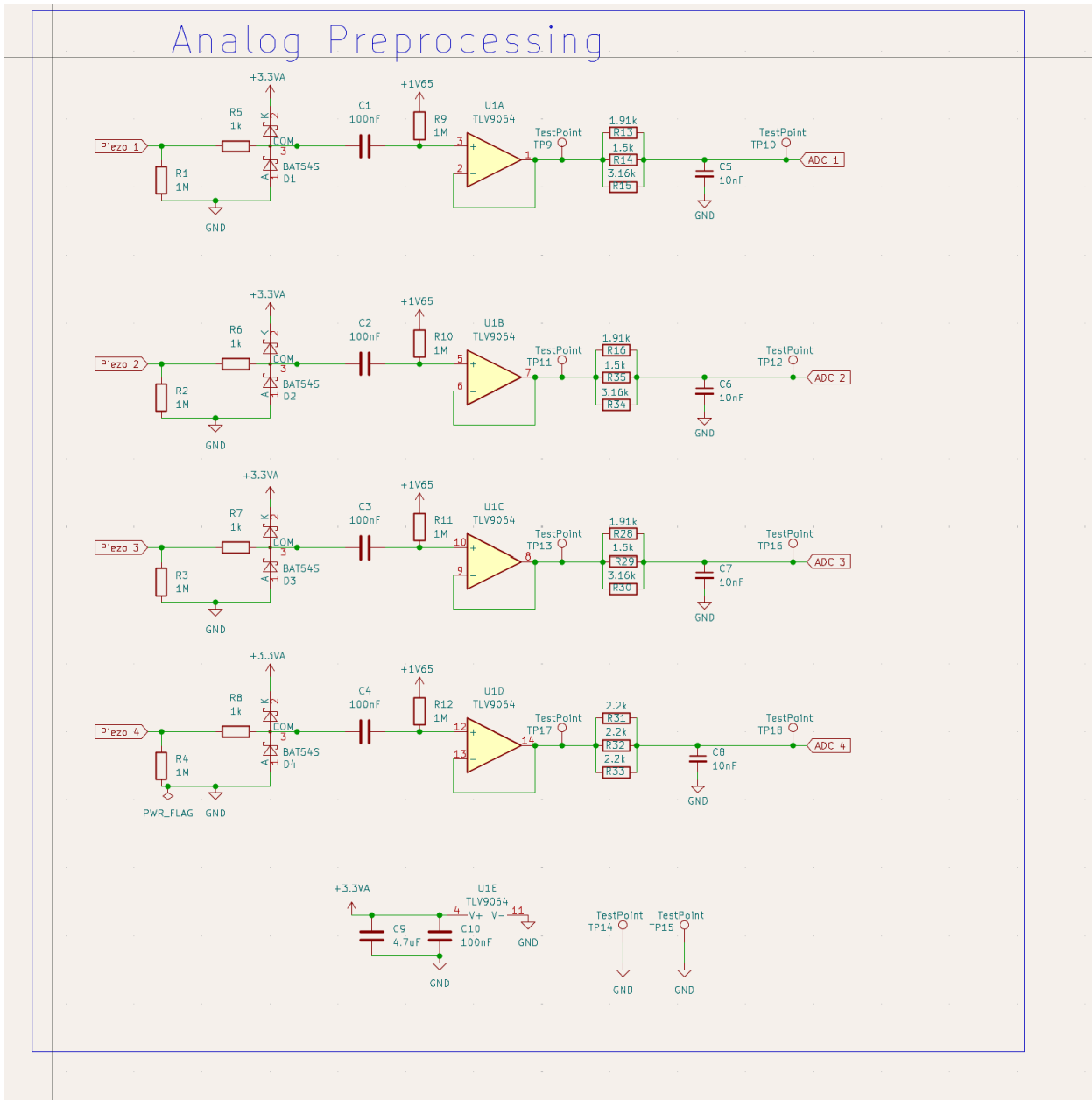


Figure A1. Schematic for the analog preprocessing subsystem. Piezo signals come in, are clamped for protection, and then are referenced through a 1.65V bias before buffering and filtering.

Figure A2. Schematic for the MCU subsystem. ADC channels are set for sensor acquisition, programming options are included, filter capacitors are shown, and leds are available for bring up.

