GRIGORE T. POPA UNIVERSITY OF MEDICINE AND PHARMACY IASI

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MUSTEM: A Dual-Modality System for Vibrotactile and Visual Translation of Music as an Assistive Technology

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1. Background & Motivation

THE CHALLENGE

- 430+ million deaf/HoH people worldwide (WHO, 2023)
- Music = cultural/emotional exclusion
- Emotional & structural understanding

CURRENT LIMITATIONS

- Amplification → insufficient
- Visual-only → lacks embodied exerience
- Vibration-only → limited frequency information

RESEARCH GAP

No integrated dual-modality approach

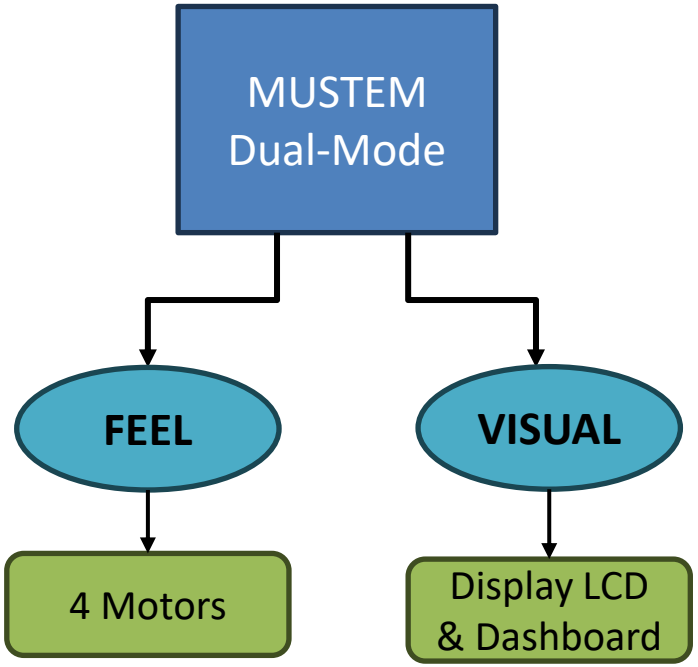
How to create a scientifically-grounded system?

2. The Proposed Approach

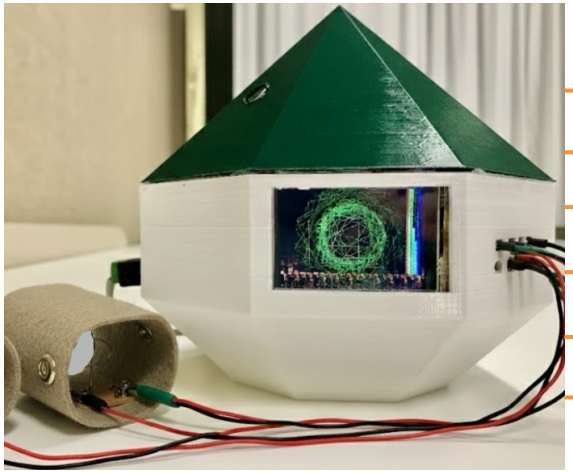
MUSTEM: **Mus**ic - **M**ultisensory **E**motional **T**ranslation

Complementary dual-modality

- Vibrotactile → Rhythm & Foundation
- Visual → Structure & Details (*non-arbitrary, math foundations*)
- Low cost



3. Methodology



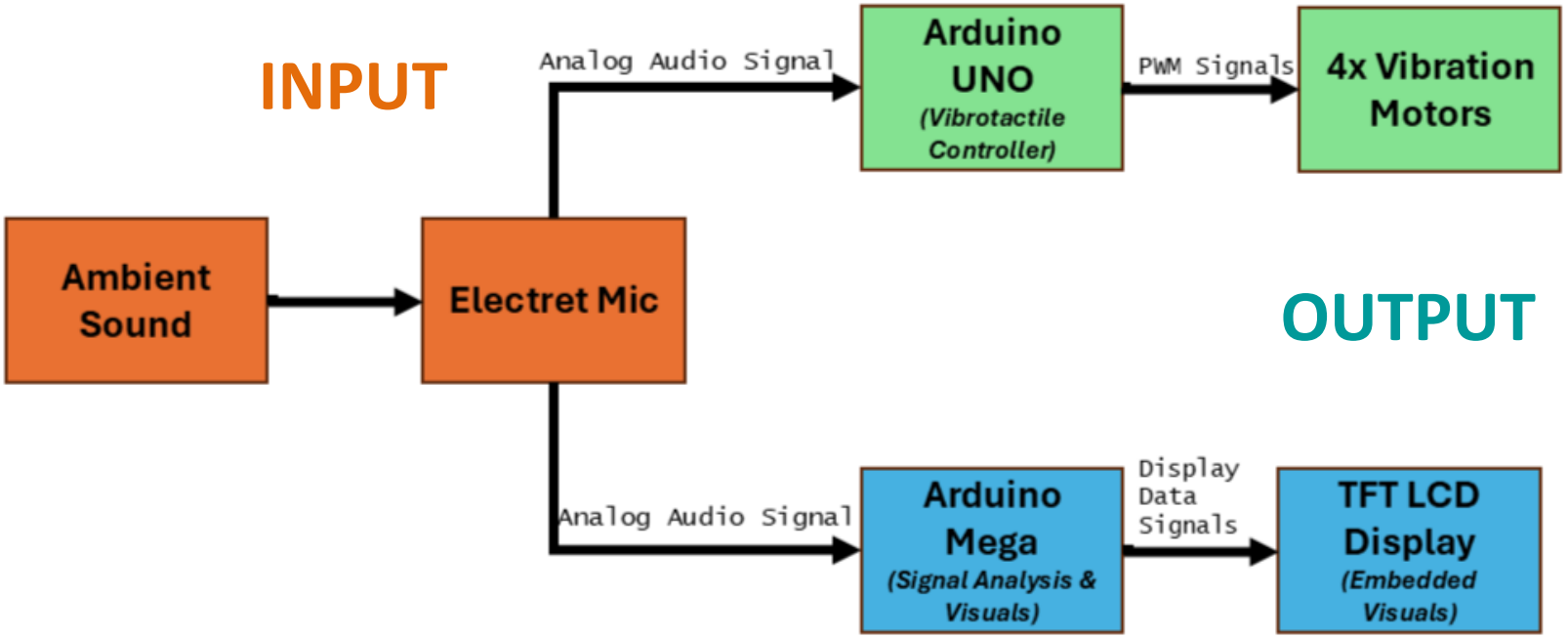
Main components:

- **1x** Arduino Mega 256
- **1x** Arduino UNO
- **4x** 3.3V vibration motor
- **1x** Display LCD TFT Shield 2.4"
- **1x** Electret Microphone
- **3D** Printer

1. **Psychoacoustic Loudness Scaling (*Steven's Power Law*)**
2. **Musically-Consonant Frequency Mapping**
3. **Nature-Inspires Generative Patterns**

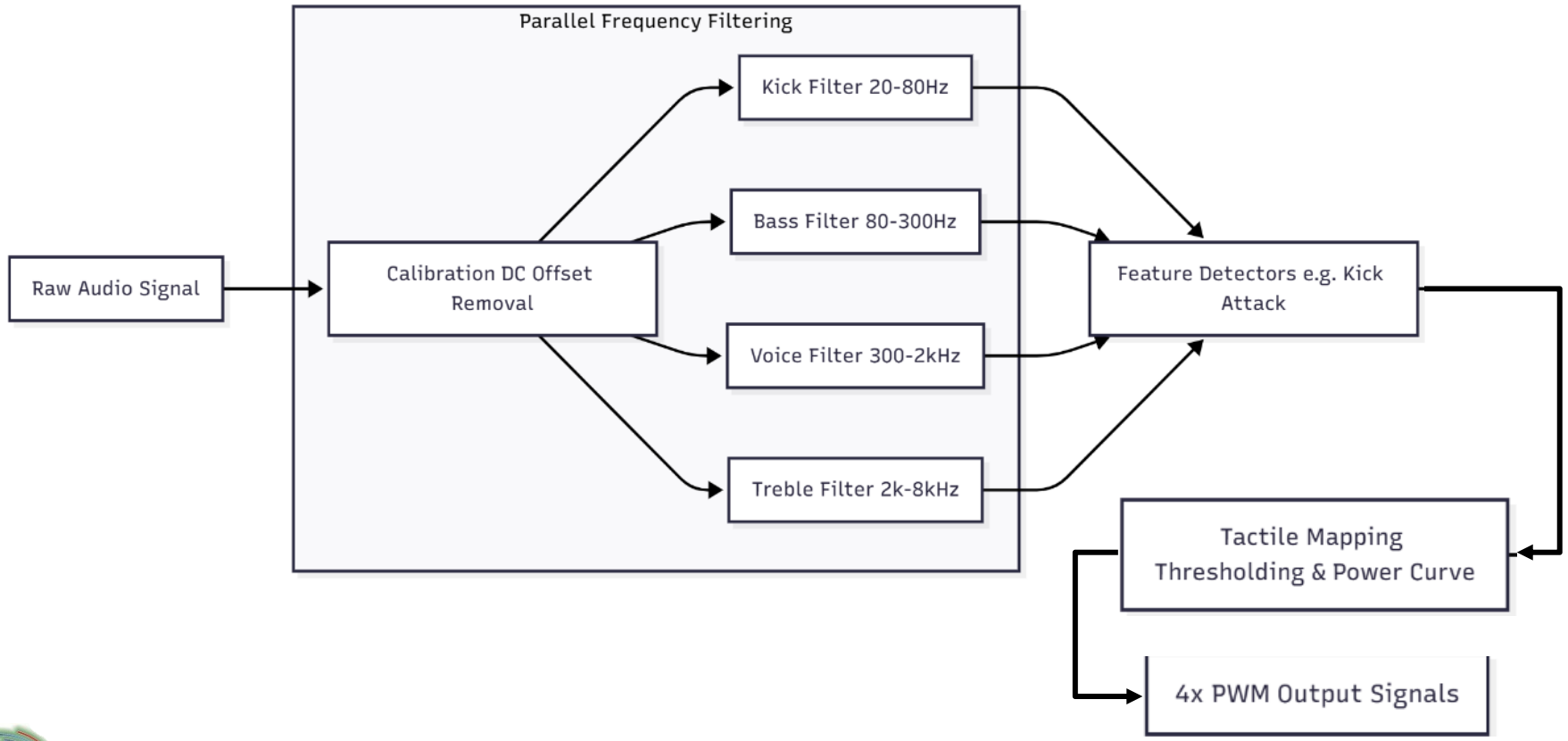
3. Methodology

3.1 System Architecture



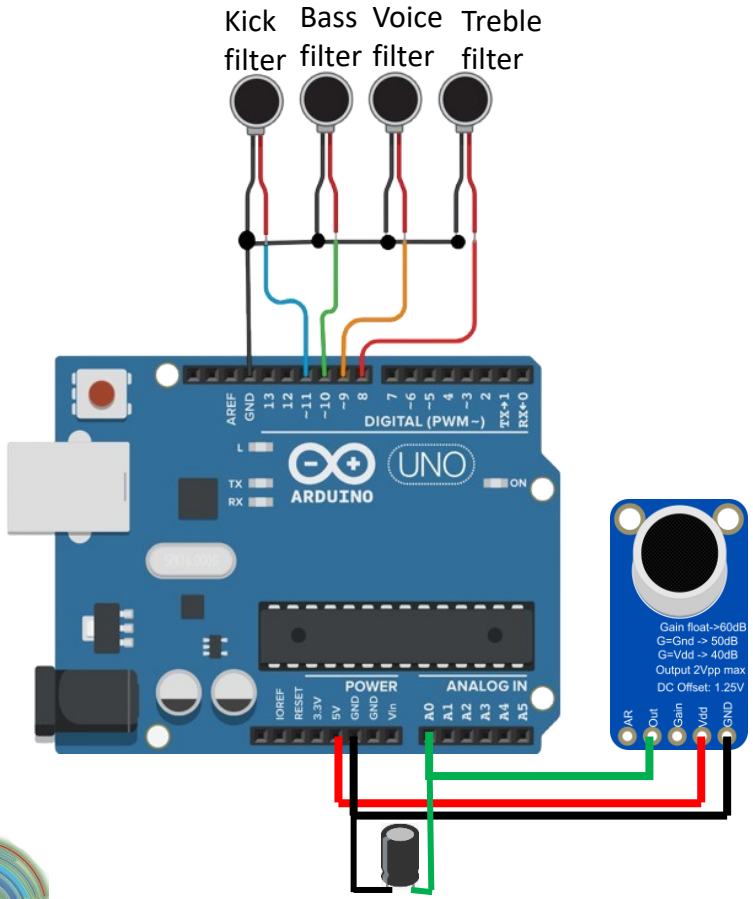
3. Methodology

3.2 Hardware Prototype & Vibrotactile System (Heuristic Audio Analysis)



3. Methodology

3.2 Vibrotactile System (Heuristic Audio Analysis)



Signal Processing:

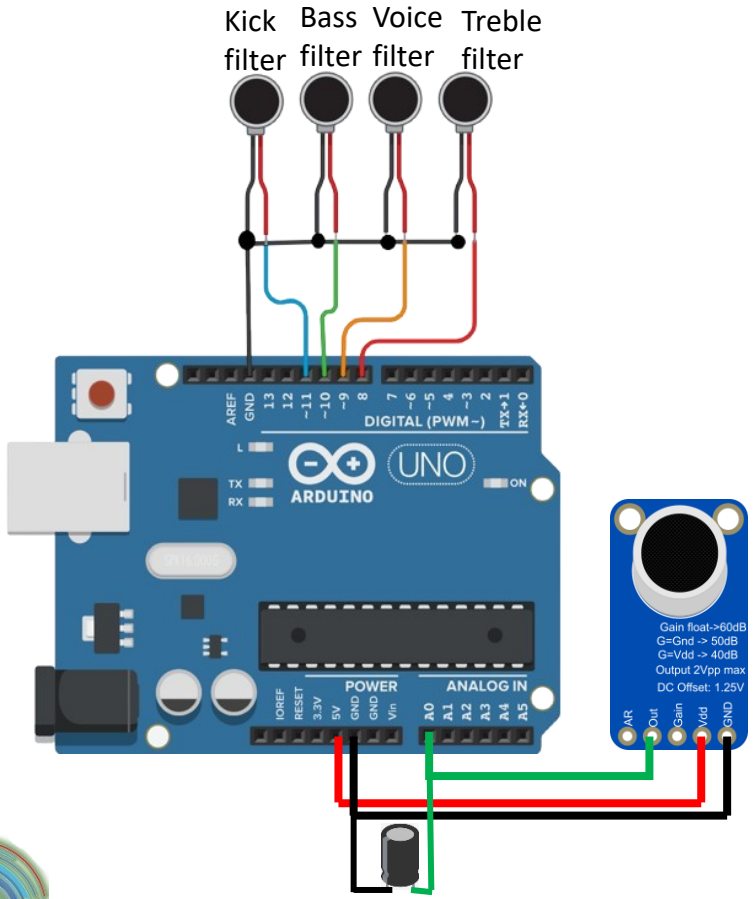
- EMA envelope ($\alpha = 0.3/0.1$)
- Stevens' scaling: $I = S\text{^}0.67$
- PWM output: $30 - 255$ $(8 - bit)$
- Latency: $< 60ms$

Perceptual Grounding:

- Fletcher-Munson aligned bands
- Spatial discrimination: $40cm$
- Just-noticeable difference: 3 PWM

3. Methodology

3.2 Vibrotactile System (Heuristic Audio Analysis)

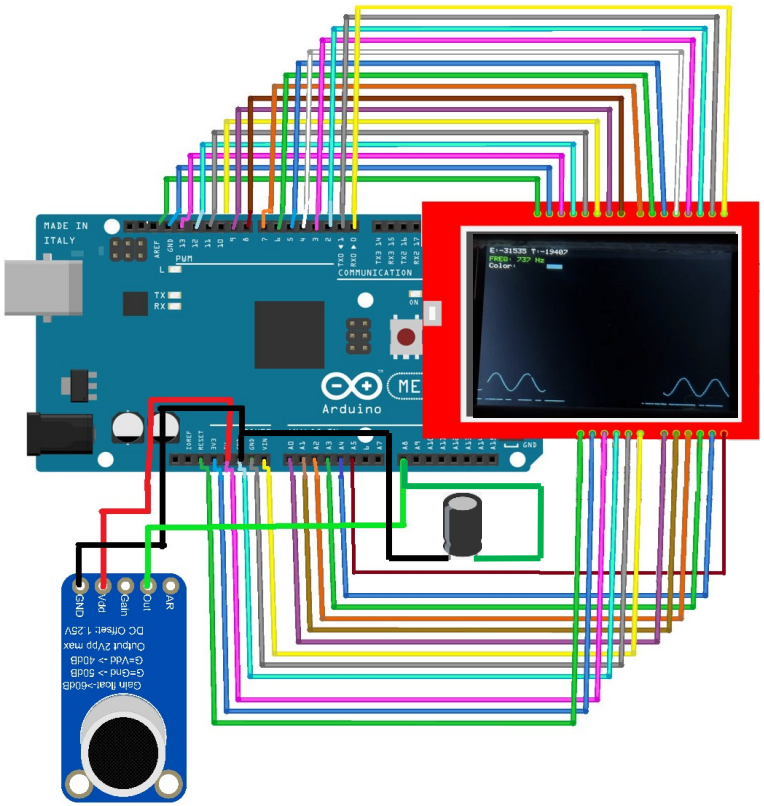


Frequency bands:

- Kick (main beats) → 20 – 80Hz
- Bass → 80 – 300Hz
- Voice/Melody → 300 – 2kHz
- Treble → 2kHz – 8kHz

3. Methodology

3.3 Visual Mapping and Display System (Arduino Mega & LCD Shield TFT)



FREQUENCY → COLOR	PATTERN GENERATION	INTENSITY SCALING
Log-Frequency (12-tone)	**Golden Angle Phyllotaxis**	**Stevens' Law (n = 0.67)**
$s = 12\log_2(f/55)$	$\theta[n] = n \times 137.5°$	$I = S^{0.67}$
$hue = (s/84) \times 360°$	$r[n] = c\sqrt{n}$	
[color wheel A1→A7]	*[spiral diagram]*	*[compression graph]*
Octave equivalence	Nature-inspired aesthetic	Perceptual comfort

3. Methodology

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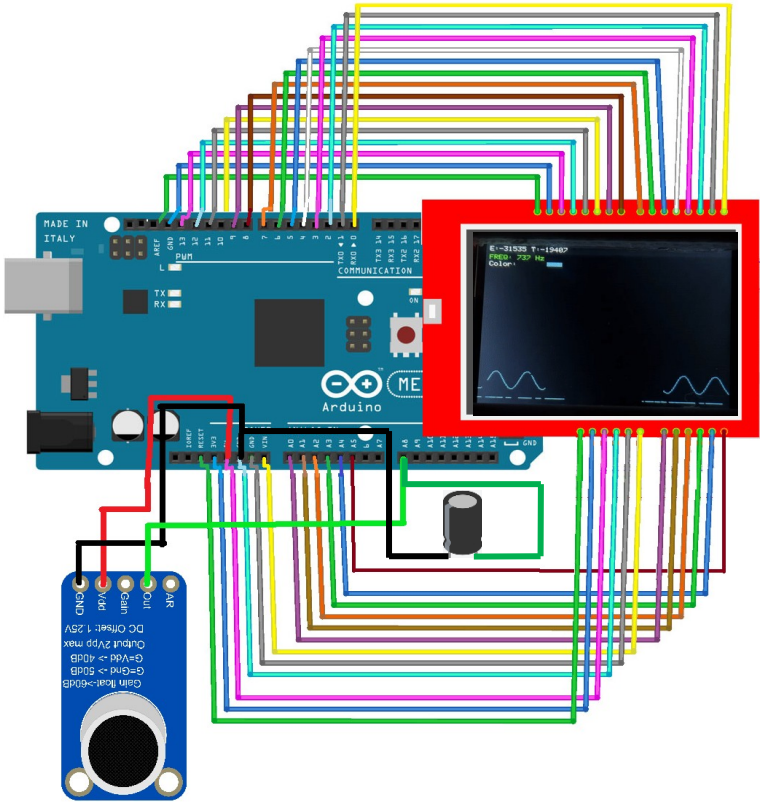
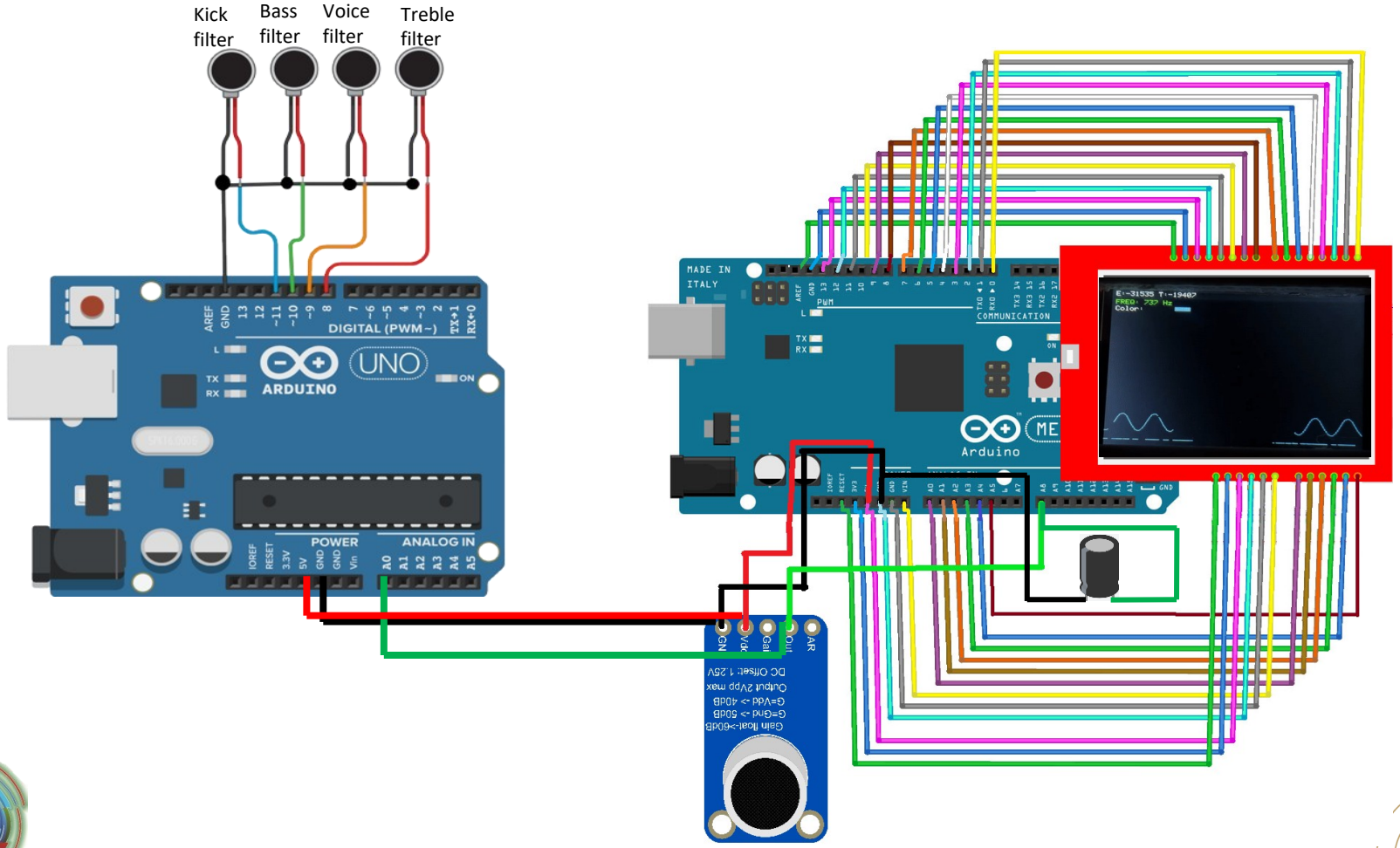


Band	Range	Center Freq	Visual Color
Sub-bass	20-60 Hz	40Hz	Deep Red
Bass (low)	60-80 Hz	70Hz	Orange
Bass (mid)	80-110Hz	95Hz	Yellow
Bass (upper)	110-165Hz	135Hz	Yellow-Green
Low-Mid	165-360Hz	250Hz	Green
Mid (Low)	360-630 Hz	500Hz	Cyan
Mid (Upper)	630-960 Hz	800Hz	Light-Blue
High-Mid	960-2400 Hz	1500Hz	Dark-Blue
Treble	2400+ *Hz*	6000Hz	Purple-Magenta

4. Results

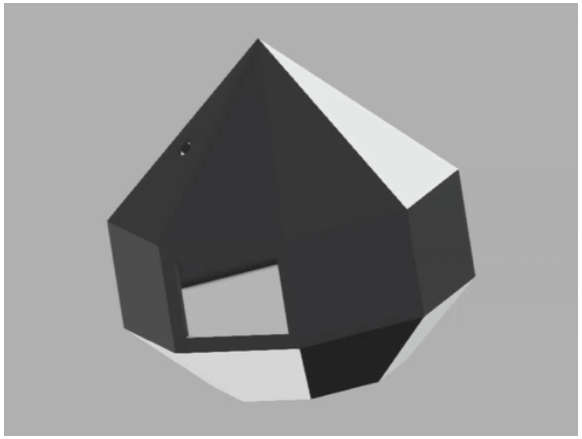
4.1 Visual Mapping and Vibrotactile System (Integration)

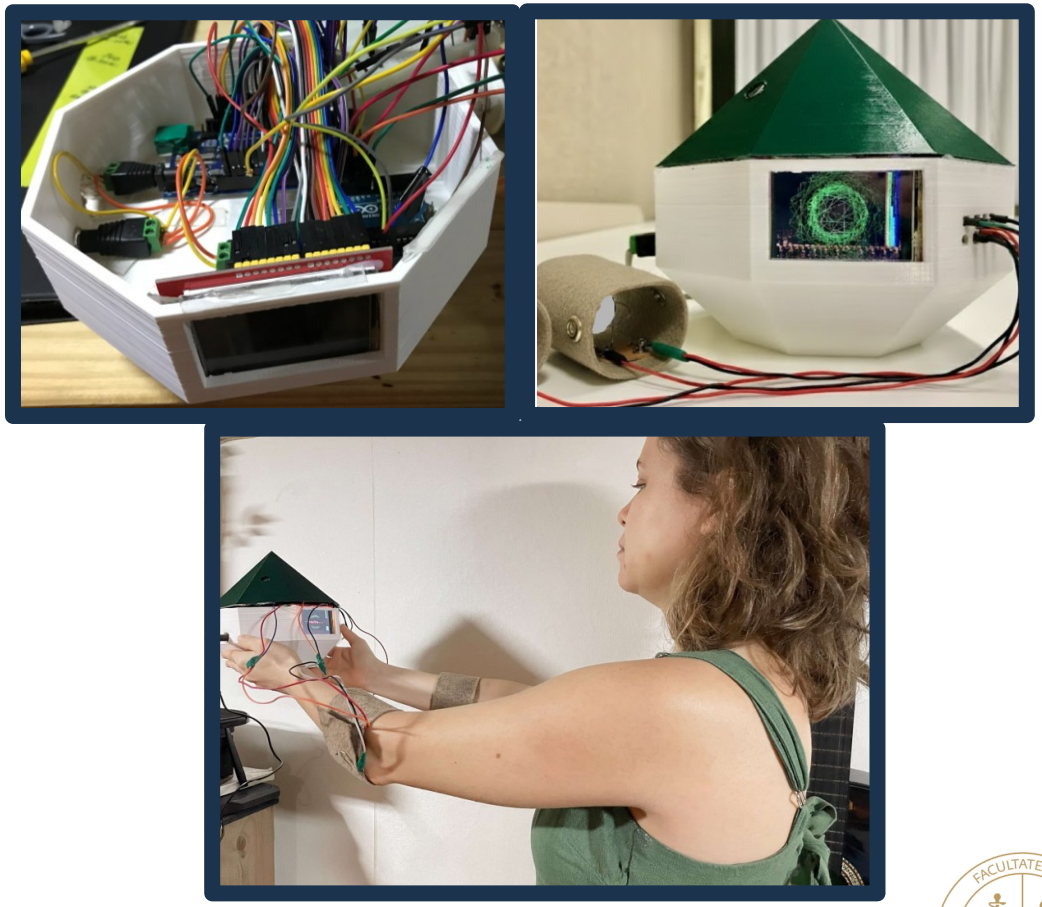


4. Results

4.2 From Design to Prototype: Integrated Hardware System

3D Printing





Demonstrations:

4. Results

4.3 High-Fidelity Assistive Dashboard: An Educational Interface

Demonstrations:

5. Limitations & Future Works

What We Know Works:

- ✓ Scientifically-grounded translation
- ✓ Real-time processing on affordable hardware
- ✓ Multi-modal sensory mapping (tactile + visual)
- ✓ Positive preliminary user feedback (N=7)

What Needs Refinement:

- Comprehensive user validation (IRB study ongoing)
- Noise robustness in many real-world environments
- Hardware scalability and manufacturing pipeline

VALIDATION

- ➢ IRB-approved study (N=30+, QUEST standardized)
- ➢ Multi-genre performance assessment
- ➢ Long-term usability evaluation

TECHNICAL EVOLUTION

- ➢ ARM Cortex-M4 (real-time ML inference)
- ➢ AI-based source separation
- ➢ Adaptive algorithms for diverse environments

Demonstrations:

That's all (for now)…