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DIY Construction of a First-Order Ambisonic Microphone

Klaudia Szwaba, Otylia Wójcik, Marek Nijakowski, and Piotr Pawlukiewicz

Gdańsk Univeristy of Technology, Department of Multimedia Systems
Gdańsk, Poland

Correspondence should be addressed to Klaudia Szwaba (s193110@student.pg.edu.pl)

ABSTRACT

This paper presents a comprehensive overview of the design and construction process of a DIY first-order ambisonic microphone based on TSB-2555 electret capsules and low-noise preamplifiers utilizing OPA1642 operational amplifiers in the "Alice" topology. The goal is to create a low-cost yet high-performance spatial recording solution suitable for immersive applications. The microphone captures a full-sphere sound field in Ambisonic A format using four capsules arranged in a tetrahedral layout. The paper discusses the capsule characteristics, amplifier circuit design, enclosure considerations, and stages of troubleshooting. Assembly and calibration are scheduled for May 2025, with initial functional tests planned for the same month..

1. Introduction

Ambisonics is an advanced spatial audio technique that enables the recording and reproduction of three-dimensional sound fields using spherical harmonics. Unlike stereo or even surround sound techniques, ambisonics allows for manipulation and rendering of the sound field independently of loudspeaker layout.
First-order ambisonics (FOA) requires four channels: W (omnidirectional), X, Y, and Z (bidirectional components along the three axes). These channels are typically derived from four capsules arranged tetrahedrally.
Due to design complexity and required precision, commercial ambisonic microphones are expensive and often inaccessible to hobbyists and students.
Our project proposes a DIY approach to FOA microphone construction using affordable components while maintaining high fidelity and quality.
The main goals include modularity, low cost, compliance with professional audio standards, and usefulness in both research and art.
The project is being developed at Gdańsk University of Technology as a research and educational platform. It also supports artistic exploration in immersive sound recording and playback.

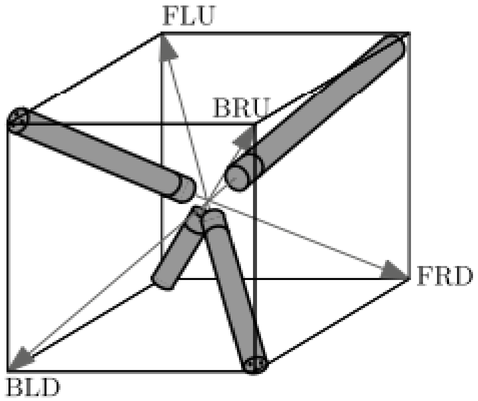

Figure 1. Tetrahedral array with four cardioids

2. Capsules and Tetrahedral Configuration

2.1 TSB-2555 Capsule Characteristics

The TSB-2555 is a high-quality electret capsule from VAMISOUND, selected for its cardioid response and high sensitivity (−42 dB). It offers a wide frequency response (50 Hz – 20 kHz), low self-noise, and stable directivity. Importantly, the capsule lacks an internal JFET buffer, making it incompatible with typical electret preamp modules but ideal for use with a custom low-noise amplifier.
Its compact dimensions allow tight placement, which is crucial for minimizing phase errors in tetrahedral configurations. Precise mechanical construction is required to maintain spatial coherence.

2.2 Tetrahedral Layout

The capsules are mounted on the faces of a regular tetrahedron, facing outward at equal angles. This layout provides uniform coverage of the 3D sound field and enables derivation of W, X, Y, Z signals via linear combinations of capsule outputs. The symmetric geometry helps preserve phase and level balance, which is essential for accurate ambisonic encoding.
The enclosure was designed to support this geometry, with millimeter-level tolerances to ensure spatial accuracy.

3. Electronics and Preamplifier Design

3.1 Early Development and Noise Issues.

Initial attempts used ready-made electret amplifier modules. However, lab testing revealed excessive noise and low output levels. Various potential causes were considered: poor shielding, impedance mismatch, unstable polarization, grounding issues. Numerous components were tested — cables, ferrite beads, shielding, passive modifications — all without success. Eventually, the root cause was identified: the modules were designed for capsules with internal JFET buffers, which the TSB-2555 lacks.

3.2 “Alice” Amplifier with OPA1642

A modified version of the “Alice” amplifier, originally designed for professional condenser microphones, was adopted. Our version uses the Texas Instruments OPA1642 — a dual low-noise op-amp (5.1 nV/√Hz) with low distortion and rail-to-rail output.
The preamp circuit includes:

- an input FET stage for impedance matching and polarization
- a single-opamp differential output stage
- phantom power compatibility (48V)
  Currently, the PCB shape is being reconsidered for better integration into the enclosure — including vertical mounting and width reduction.

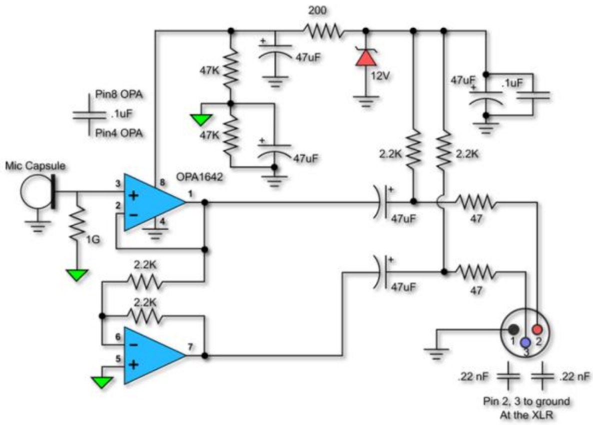

Figure 2. schematic of Alice amplifier with OPA1642

4. Enclosure Design and Prototyping

The mechanical housing plays a key role in capsule positioning, shielding, and field usability. The first prototype was 3D-printed in PLA using a model created in Autodesk Fusion 360 and features:

- tetrahedral mounts for the capsules
- internal channels for shielded wiring
- space for four separate preamp modules and XLR connectors
  As this prototype was designed around an earlier amplifier layout, a new version of the enclosure is currently in development.

5. Testing and Evaluation (Planned)

For May 2025, the following tests are scheduled:

- frequency response measurements (pink noise, swept sine)
- self-noise measurements (in an anechoic or damped room)
- interchannel and phase consistency tests
  The signals will be recorded via a multichannel interface and processed in Reaper using plugins for A-to-B format conversion.

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6Design Modularity and Future Work

The system is highly modular — each capsule–preamp–output path can be swapped out. This allows testing of:

- different capsule types (cardioid vs subcardioid)
- different preamps (transformer-based vs opamp-based) Prototype preamp PCBs for other capsules are also under evaluation. The goal is to reduce system size while maintaining quality — primarily by redesigning the amplifier boards.

7. Conclusions

This project addresses the practical challenges of building a DIY first-order ambisonic microphone using TSB-2555 capsules and OPA1642-based amplifiers. Though assembly and testing are still in progress (as of May 2025), it already solves key compatibility, noise, and spatial accuracy issues.
By emphasizing modularity and accessibility, the project contributes to the DIY 3D audio community and provides a replicable platform for further experimentation.

References

[1] F. Zotter, M. Frank, “*Ambisoncs, A Practical 3D Audio Theory for Recording, Studio Production, Sound Reinforcement, and Virtual Reality”* (2019).

[2] TSB-2555BXZ3-GP datasheet

[3] “OPA-Alice” microphone electronics datasheet