Analog Noise Cancellation System

Project Proposal and Required Components

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***Abstract*—This project designs a simple analog noise-cancelling headphone circuit that reduces ambient noise using phase inversion. A microphone captures external sound, which is inverted and combined with the audio signal to cancel unwanted noise(destructive interference). The circuit uses basic analog components for a low-cost, real-time, and power-efficient solution.**

I. Introduction

Noise pollution has become a significant issue in today's environment, affecting concentration, productivity, and hearing health. Headphones that can actively reduce unwanted ambient noise provide an effective solution. The aim of this project is to design and implement an Analog Noise Cancelling Headphone Circuit that can minimize background noise by generating an inverse sound wave, improving listening quality without increasing volume.

II. Problem Statement

Conventional headphones only block external sounds passively using padding or tight ear cups. However, low-frequency noises like engine hum or fan sounds can still pass through. Digital active noise cancellation (ANC) systems exist but are often complex and expensive. This project focuses on developing a low-cost analog noise cancelling system that effectively reduces ambient noise using phase-inverted signals. The goal is to enhance audio clarity and user comfort, especially in noisy environments such as classrooms, public transport, or workplaces.

III. Proposed Approach

A. Overview of Approach

The circuit will pick up external noise through a microphone, invert it, and add it to the audio signal, so that unwanted sounds cancel out at the listener's ear. The design begins with an external microphone that captures surrounding noise, which is then passed through a pre-amplifier to boost the signal strength. The amplified noise is routed through an all-pass filter that introduces a controlled phase delay without altering its amplitude. This delay compensates for the physical time difference between when the ambient noise reaches the microphone and when it reaches the ear. The delayed noise signal is then inverted and combined with the original music signal using a summing amplifier, which includes a potentiometer to fine-tune the amplitude for optimal cancellation.The setup is duplicated for the left and right channels to create a stereo system, with microphones mounted externally on each ear cup.

B. Components and Blocks

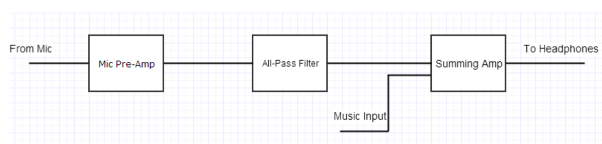

Fig. 1. Block Diagram

The proposed system consists of five major functional blocks integrated on a single PCB for stereo analog noise cancellation. Each block performs a specific task and contributes to the overall noise-cancelling operation as described below:

- **Microphone Block (Input Unit):**
  - Component: ECM-60PC-R Electret Microphone
  - Function: Captures external ambient noise near the headphone earcups. The output signal is AC-coupled and filtered to remove DC bias and high-frequency noise.
- **Pre-Amplifier Block:**
  - Component: LM-741 Op-Amp configured as a non-inverting amplifier
  - Function: Amplifies the weak microphone signal to a level suitable for processing. Gain is set based on resistor ratio to stabilize low-frequency response.
- **All-Pass Filter (Phase Delay Block):**
  - Component: LM-741 Op-Amp with RC network
  - Function: Introduces a controlled delay to synchronize the inverted noise signal with the original ambient sound reaching the ear, ensuring proper phase alignment for effective cancellation.
- **Summing Amplifier Block:**
  - Component: LM-741 Op-Amp configured as inverting summing amplifier

- Function: Combines the inverted noise signal with the main audio signal. A potentiometer adjusts the gain to fine-tune the level of noise cancellation.

- **Output Stage (Headphone Driver Block):**
  - Component: 3.5 mm audio jack with current-limiting resistor.
  - Function: Delivers the processed noise-cancelled audio signal safely to the headphones, protecting them from overcurrent and distortion.

C. Advantages of the Proposed Approach

The proposed analog noise-cancellation system offers several key advantages over existing digital approaches. It is a low-cost and power-efficient solution, utilizing standard op-amps and passive components without the need for complex DSPs or microcontrollers. The purely analog design enables real-time operation with negligible delay, making it suitable for headphones and similar audio applications. It is particularly effective for low-frequency noise suppression (below 1 kHz), addressing common environmental sounds such as fans and engines. The system is also portable and easily scalable, operating reliably on a simple ±9V supply, with stereo implementation achieved by duplicating the single-channel circuit. Additionally, the project provides educational value, reinforcing practical understanding of analog signal processing and active noise-cancellation techniques.

IV. Working of the Circuit

- The system begins by capturing sound through a microphone. The microphone module used is the ECM-60PC-R, which, according to its datasheet, operates with a bias voltage ranging from 4.5 V to 12 V DC. This bias voltage is supplied through a regulated DC power source, as shown in Figure 2.

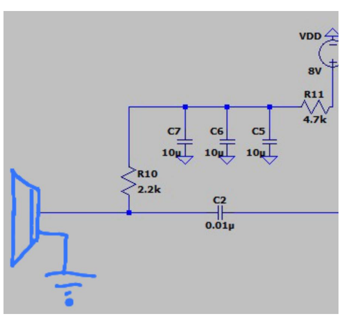

Fig. 2. Biasing and filtering circuit for the ECM-60PC-R electret microphone.

To ensure a clean audio signal, a low-pass filter is used to remove electronic noise from the power supply. In electret microphone circuits, the DC bias voltage is provided via a resistor (R10), but the supply often contains high-frequency fluctuations or ripple from the power source, nearby electronics, or switching regulators. These fluctuations can couple into the microphone signal, introducing noise. By using capacitors (C5, C6, C7) and a resistor (R11) to form a low-pass filter, high-frequency components of the supply are shunted to ground, allowing only smooth DC voltage to reach the microphone. This ensures the captured audio remains clean and free from power supply noise. Assuming $V_{DD} = 8$ V, $R_{11} = 4.7$ kΩ, $R_{10} = 2.2$ kΩ, and mic current $I_{MIC} \approx 0.5$ mA:

$$
\begin{aligned}
V_{R11} &= I_{MIC} \cdot R_{11} = 0.5 \text{ mA} \times 4.7 \text{ k}\Omega = 2.35 \text{ V} \\
V_{\text{filtered}} &= V_{DD} - V_{R11} = 8 - 2.35 = 5.65 \text{ V} \\
V_{R10} &= I_{MIC} \cdot R_{10} = 0.5 \text{ mA} \times 2.2 \text{ k}\Omega = 1.1 \text{ V} \\
V_{\text{mic}} &= V_{\text{filtered}} - V_{R10} = 5.65 - 1.1 = 4.55 \text{ V}
\end{aligned}
$$

Thus, the microphone receives a DC bias of approximately 4.5 V.

- Now, after the mic captures the ambient noise, the microphone preamp stage is used to amplify the small audio (noise) signal from the mic to a level suitable for processing. It also reduces the DC component, which could create an offset and interfere with the noise-cancelling operation. Essentially, it ensures that the AC audio signal is strong and clean enough for the next stages while ignoring unwanted DC. Following circuit shows the preamp.

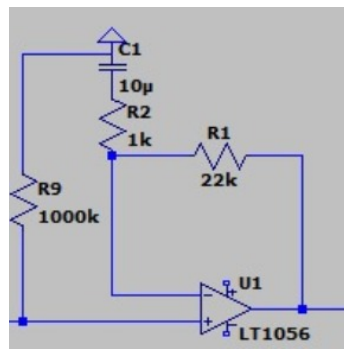

Fig. 3. Pre-Amp Stage

This pre-amplifier circuit has a frequency-dependent gain. It acts as a unity-gain (gain of 1) buffer for DC signals and a non-inverting amplifier with a gain of 23 for AC signals. The capacitor, C1, is essential for this function; it blocks the amplification of unwanted DC offsets from the microphone, preventing the op-amp from saturating, while allowing the AC audio signal to pass through and be amplified. The large $R_9 = 1$ MΩ resistor, R_9, serves as a pull-down resistor, providing a stable DC path to ground for the op-amp's input and setting a high input impedance. This high impedance is crucial to ensure maximum signal transfer from the microphone without distorting it.

- Now that the noise is amplified, An all-pass filter is used in a noise-cancelling circuit to introduce a delay in the noise-cancelling signal without affecting its amplitude. This delay is necessary because the unwanted noise takes a finite amount of time to travel through the air

from the source to the listener's ear, while the corresponding electrical signal from the microphone reaches the circuitry almost instantly. To ensure effective noise cancellation, both signals must arrive at the ear at the same time. Ordinary filters, such as low-pass or high-pass, can introduce delay but also distort the signal's amplitude across frequencies, which would reduce the accuracy of cancellation. In contrast, an all-pass filter maintains a constant gain of unity for all frequencies while shifting the phase of the signal, effectively creating a time delay without altering its magnitude. This makes it ideal for synchronizing the electronically generated anti-noise signal with the actual noise, enabling proper destructive interference.
The Delay provided will depend on the distance from mic to speaker(ear piece) we will first measure the distance from the microphone to the ear, which is d. The time delay for the sound wave to travel this distance is given by:

$$d = v \cdot t \quad \Rightarrow \quad t = \frac{d}{v}$$

where $v = 340$ m/s is the speed of sound. Now from this time delay we can calculate phase lag in degrees and then decide what frequencies to cancel out

$$phaselag(deg) = t \cdot f \cdot 360$$

after calculating phase lag , we can find what will be the values of resistor and capacitor in all pass filter

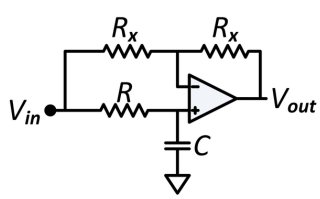

Fig. 4. All Pass Filter

- The final stage of the circuit combines the music signal with the processed noise-cancelling signal and inverts the resulting sum using a classic op amp summer which uses inverted configuration. A key part of this stage is tuning the amplitude of the noise-cancelling signal so that it matches the amplitude of the music or ambient sound, which is essential for effective noise cancellation. A potentiometer is included to allow fine adjustment of the noise-cancelling signal's gain. After setting up the system, this potentiometer is adjusted until the noise is audibly reduced, a process that can seem subjective because audio signals are difficult to quantify directly with instruments. The music signal is provided through one channel of a standard 3.5 mm audio jack, making it easy to integrate into the circuit.
Finally we will be adding music+noise+inverted noise which will ultimately give music in speaker or headphones.
Final circuit would look like the figure given below(the schematic was made in LT SPICE).

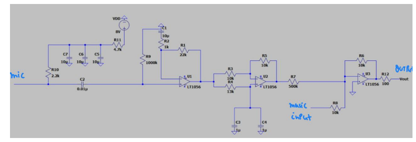

Fig. 5. Full Schematic

The above figure uses an LT1056 op-amp; due to availability and cost constraints, an LM741 may be used instead (note: the 741 requires dual ± supply rails and has lower performance).

V. List of Components

To build the full system in stereo, you will need:

- 1 × pair of over-ear headphones
- 6 × LT1056 Op-Amp (Although the figure shows LT1056, LM741 can be used as a low-cost and easily available alternative)
- 2 × ECM-60PC-R Electret Microphone
- 2 × 3.5 mm Audio Jacks

Capacitors:

- 2 × 0.01 µF
- 4 × 1 nF
- 8 × 10 µF

Resistors:

- 2 × 100Ω
- 2 × 1 kΩ
- 2 × 2.2 kΩ
- 2 × 4.7 kΩ
- 8 × 10 kΩ
- 2 × 13 kΩ
- 2 × 22 kΩ
- 2 × 1 MΩ

Others:

- 2 × 500 kΩ Potentiometer
- Connecting wires
- A power supply (±8 V or 9 V) capable of at least 30 mA
- Breadboard for building and testing
- Oscilloscope for testing
  Note: *The values of capacitors and resistors may change as per our requirements

VI. Work Division

- Member 1: Design and test the microphone and pre-amplifier circuits on both the breadboard and PCB.
- Member 2: Design and test the all-pass filter circuit on both the breadboard and PCB.
- Member 3: Design and test the summing amplifier and output stage on both the breadboard and PCB.

REFERENCES

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