EE 344 Design Review Report
Wideband Audio Acquisition using an Electret Microphone

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1 Objective

Conventional audio acquisition circuits using an electret microphone use a DC blocking capacitor at the input to prevent the biasing current to pass along with the audio signal to subsequent amplification and processing stages [1]. However, this capacitor also filters out much of the low frequency signal [2]. Our goal is to replace the capacitor and come up with an alternative mechanism to compensate for the bias current in the signal which does not eliminate lower frequencies. We introduce a microcontroller based circuit which continuously monitors the signal and compensates for DC offsets at the input, thereby reducing the lower cutoff frequency of the circuit. In addition to bias current compensation we also introduce gain control which uses microcontroller feedback to adjust signal amplification level so that the microphone is robust to variations in loudness of the input audio signal. The DC compensated and gain controlled audio will finally be transmitted via a bluetooth module for further processing or storage.

2 Design Description

2.1 DC Compensation

The conventional design of a circuit for audio acquisition from an electret microphone involves coupling of a DC blocking capacitor and an amplifier [1][3]. Our design eliminates the DC blocking capacitor. Instead, we connect the current signal directly to an amplifier.
To counter the DC bias present in the current signal, we add a constant voltage and resistance pair that removes the majority of the offset. Despite this, there may still be fluctuations in the DC bias due to temperature changes. To address this, we have implemented a feedback system that uses a μC and a DAC. The μC runs a successive approximation algorithm that tracks the signal's maxima and minima to continuously update the average signal value and subtracts it from the DC bias current to maintain the desired DC value.

2.2 Gain Control

After the DC bias compensation of the current signal, it is then directed through the feedback resistor of a low-noise op-amp amplifier. To automatically adjust the gain of the signal, we have incorporated a digital potentiometer as the feedback resistor. This allows us to dynamically adjust the gain using the μC. The output of the op-amp is a DC-offset-free gain-adjusted signal, which is then converted to a digital form by an ADC and fed into the μC. This digital signal serves three crucial purposes:

1. It is used to continuously generate the feedback necessary for gain control.
2. It is used by the μC to further fine-tune the DC bias compensation to ensure a stable and accurate output.
3. It is transmitted to another device via bluetooth.

2.3 Signal Output

The ADC output is passed into the μC which then sends it to a Bluetooth module so that it can be transmitted to an external device.

2.4 Stable Power Supply

Two key voltages in our design need to be made as noise free as possible. These are the **constant offset current source** to eliminate the bulk of the DC bias, and the **microphone biasing voltage** applied to the non-inverting terminal of the op-amp. We will use a voltage regulator to convert voltage supplied by the battery to a stable value. Further the PCB design will be made so as to separate the digital and analog ground planes, thereby protecting the analog circuitry from digital noise.

3 Project Timeline

We shall adhere to the following timeline as we proceed with the project:

- **24 January 2023:** Clearly define the objectives of the project as outlined in the problem statement. Develop a solid understanding of the theoretical concepts involved. Generate and finalize a detailed design plan, complete with necessary schematics. Determine the specific physical components needed to successfully execute the project in its entirety.
- **14 February 2023:** Create comprehensive schematics that thoroughly illustrate the audio acquisition and automatic gain control circuitry. Utilize a micro-controller circuit to implement DC bias compensation and thoroughly test all components on a breadboard prototype to ensure proper functionality.
- **14 March 2023:** Complete the PCB design layout using CAD software, including all necessary circuitry to support audio acquisition and automatic gain control with a microcontroller at its core. Additionally, incorporate an extended circuit to enable seamless Bluetooth interfacing, ensuring all elements of the project are fully integrated.
- **21 March 2023:** Conduct thorough testing of the fully-integrated PCB, utilizing various methods to ensure all elements of the design and components are functioning correctly and identify any potential issues or flaws in the design.
- **4 April 2023:** Enclose the entire system in a durable, portable external housing, securely and neatly organizing all wired components. Address any issues or concerns that arose during testing and verification, ensuring all deliverables are met and the project is completed to a high standard.

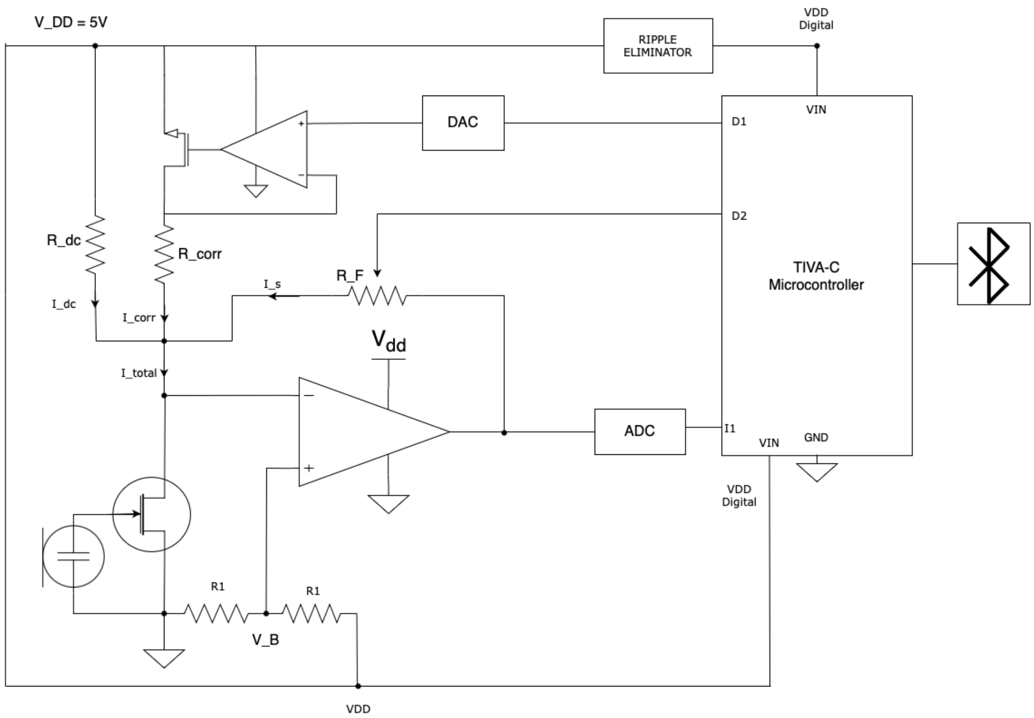
4 What Distinguishes Our Project

We will primarily distinguish our design in the following two aspects:

1. Bias Compensation Algorithm : The μC will average the incoming signal over some time window. If the average is different from the desired DC value, a compensating current signal is sent via the DAC.
2. Gain Control Algorithm: We estimate the peak amplitude of the signal over a time window and if it falls below a desired threshold we increase the signal gain. We must ensure that gain changes are done gradually so that the frequency characteristics of the signal are not severely affected.

There are several approaches for both and we will try to implement and compare some of them. We are yet to decide on details of the algorithm. The hardware design is mostly similar. However, we will design our schematics and PCB layouts independent of other teams.

5 Block Diagram



In the above circuit, the capacitor in the electret microphone converts the incoming sound signal into a voltage signal at the input of the gate of the FET [1]. The voltage at the drain is set to V_B due to the negative feedback opamp configuration, and a current $I = I_{bias} + i_{in}$ flows into the drain of the FET, where i_{in} is the small signal component and carries the information about the sound signal, and I_{bias} needs to be compensated [1][2].
The voltage at the output of the opamp can be written as:

$$V_{out} = V_B + R_F(I_{bias} + i_{in} - \frac{V_C - V_B}{R_C} - \frac{V_{control} - V_B}{R_{control}})$$

Here we bring in compensating currents from the sources V_C and $V_{control}$ to get rid of the bias current. The current from V_C cancels most of the bias current and is fixed. $V_{control}$ is a variable output of the micro-controller and handles small variations in the bias current. The micro-controller uses a digitized version of the opamp output as input to control the gain R_F and decide $V_{control}$ in a feedback loop. The exact details of the control logic will be decided later. The digitized signal is also transmitted to an external device through a Bluetooth module, where further operations may be performed on the signal.

6 Bill of Materials

- CMA-4544PF-W: A set of Electret Microphones for audio acquisition [4]
- TIVA-C Launchpad: An appropriate programmable micro-controller with in-built ADC and sufficient I/O bandwidth and computation power to process input signals [5].
- LAUNCHXL CC2640R2F: Bluetooth micro-controller interface which accepts digital input from the micro-controller and transmits it over a wireless channel to a computer or an audio device [6].
- TPL0102-EP: Digital Potentiometer [7]
- MCP4921: A DAC with SPI Interface to efficiently convert Digital input to Analog output for DC bias compensation [8].
- TI TLV2472: Reliable Operational Amplifiers which support rail-to-rail operation for precise acquisition of signals [9].

7 References

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