EE 344 Design Report
Wideband Audio Acquisition using Electret Microphone

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1 Objective

Our aim is to develop a real-time wideband audio acquisition, manipulation and playback device. The audio will be captured through an electret microphone. Standard two-terminal electret microphones have the FET output AC coupled to the subsequent amplification stage via a capacitor in order to block the DC bias current. The capacitor imposes a lower cutoff frequency on the captured audio signal. We would like to replace the capacitor with a microcontroller based circuit for DC bias compensation so that the signal's lower cutoff frequency can be reduced.

The circuit will also include Automatic Gain Control (AGC) implemented using a μC in order to maintain input signal to noise ratio (SNR), and thus maintain an optimal level of signal loudness. The DC compensated and gain controlled audio will finally be transmitted via a bluetooth module to an external device in real-time. This device can have applications in wideband audio capture as well as real-time audio playback.

2 Design Description

2.1 DC compensation

A typical circuit for audio acquisition from an electret microphone consists of a DC blocking capacitor coupled with an amplifier. We modify this design by directly connecting the captured current signal through an amplifier. In order to compensate the DC bias in the current signal, we add a constant voltage and resistance pair to remove the bulk of the offset. However, there may be additional fluctuations in the DC bias due to temperature varaiations as well as noise in the microphone biasing voltage. Thus, we also add a feedback current generated by the μC and passed through a DAC to eliminate any other DC component. The μC will run some kind of successive approximation algorithm which will track the signal extrema and continuously update the average signal value, in order to push the average towards the desired value.

2.2 Automatic Gain Control

The DC compensated current signal is then fed through the feedback resistor of our low noise op-amp amplifier. We use a digital potentio-meter as our feedback resistor in order to implement automatic gain control. The regulated signal at the output of the op-amp is then fed into an ADC going into the μC. This signal is used by the μC to **generate the feedback** for **automatic gain control** as well as **DC bias compensation**.

2.3 Signal Output

The ADC output is passed into the μC. The initial design will simply route this signal to a Bluetooth module so that it can be transmitted to an external device. However, it will be routed via the micro-controller. This will allow us to add more digital audio processing functionality to the design by simply reprogramming the μC. This also highlights the need to provide an interface to conveniently reprogram the μC over USB.

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 makes our project different

4.1 Ripple Free Power Supply Implementation

Two key voltages in our design need to be made as noise free as possible. These are the **constant offset current** 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 utilise zener diodes to stabilise the voltage and eliminate the digital noise in the power supply. The other team plans to use an alternative design using diodes.

4.2 Signal Output via Bluetooth

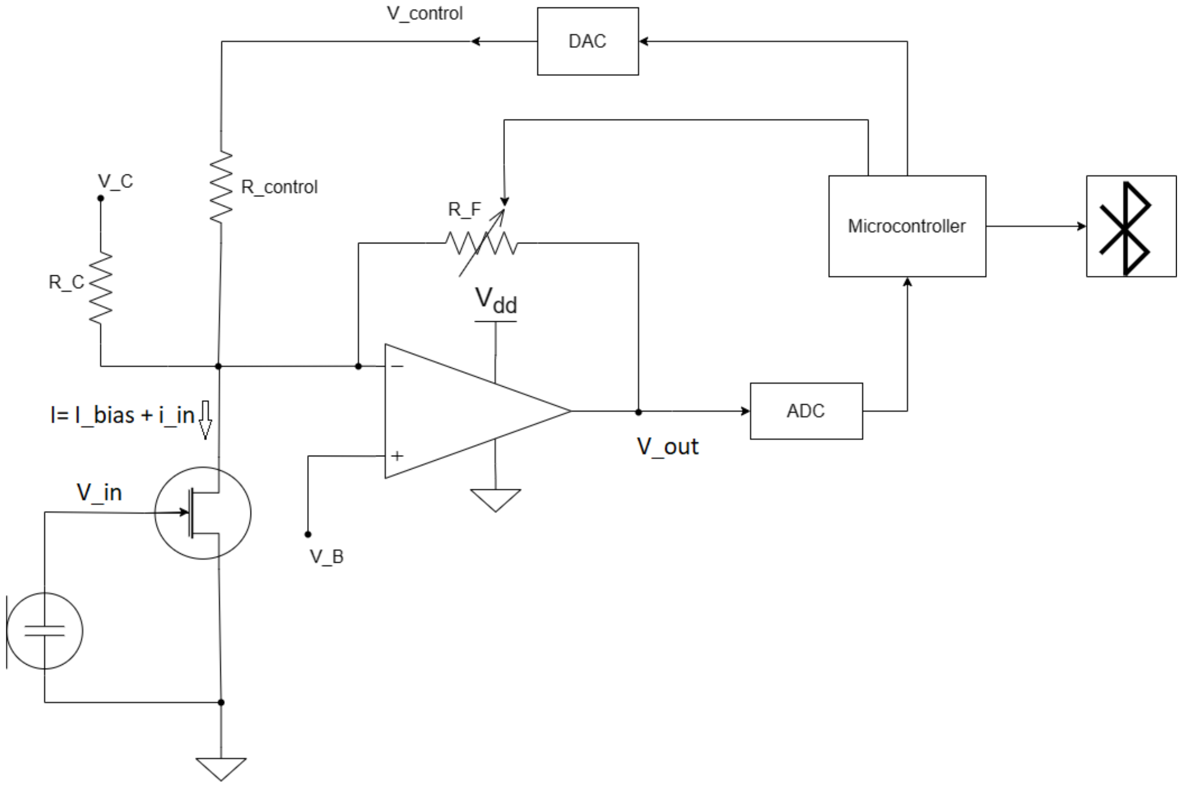
Our team will transmit the output signal using bluetooth while the other team is planning to WiFi. We have not yet been able to find a suitable bluetooth μC interface which takes digital input. Most bluetooth interfaces are designed to directly wok with microphone/other analog input and have their own DC removal circuitry which will eliminate the wideband nature of audio captured by our device.

4.3 Control Algorithm

While we have not finalised the exact control algorithms that will be used for **DC bias removal** and **AGC**, we will try to implement different algorithms across teams and compare their performance.

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. 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.
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
- TI TM4C123GH6PM: An appropriate programmable micro-controller with in-built ADC and sufficient I/O bandwidth and computation power to process input signals.
- TI 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.
- MCP4921: A DAC with SPI Interface to efficiently convert Digital input to Analog output for DC bias compensation.
- TI TLV2472: Reliable Operational Amplifiers which support rail-to-rail operation for precise acquisition of signals.