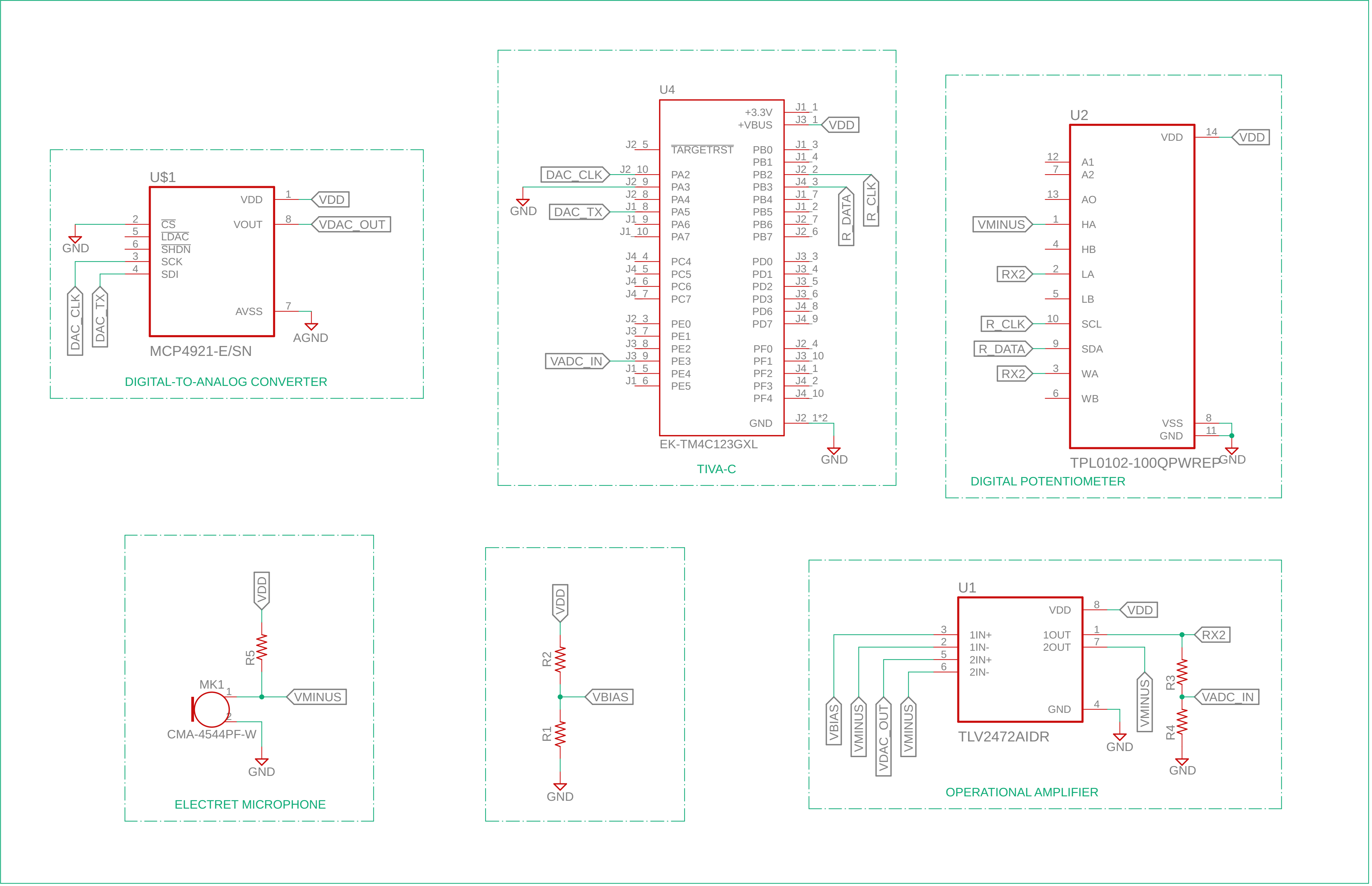
EE 344 Design Review Report
Wideband Audio Acquisition Using an Electret Microphone

Pranava Singhal, Waqar Mirza, Keshav Singhal
200070057, 200070090, 20d070047

Guides : Prof. P.C. Pandey, Prof. V.M. Gadre
TAs : Prashant Shettigar, Paturu Rajesh

Contents



17-02-2023 12:47 AM f=0.95 C:\Users\Pranava\AppData\Local\Temp\Neutron\ElectronFileOutput\22436\sch-d16a5a60-eee6-44a4-b656-7040b9c8a152\Untitled.sch (Sheet: 1/1)

1 Component Selection

1.1 Electret Microphone

The CMA-4544PF-W electret microphone is a suitable choice for this experiment for several reasons.

- It has a small form factor of 9.7 x 4.5 mm^2, which is important for compact circuit designs.
- It has a high signal-to-noise ratio, which is crucial for capturing clean audio signals.
- It has a wide frequency response range that covers frequencies from 50Hz to 20KHz, making it suitable for capturing a broad range of sounds.
- It has low power consumption, which is advantageous for battery-powered applications.
- Finally, it is affordable, making it a cost-effective option for experimental setups.

The CMA-4544PF-W offers a good balance of performance and practicality, making it an excellent choice for this experiment.

1.2 Microcontroller

The TIVA C TM4C123GH6PM microcontroller has the following properties which make it a suitable choice for this experiment.

- It has a 32-bit ARM Cortex-M4F core, which provides high-performance computing and DSP capabilities, making it well-suited for audio signal processing.
- It has a high clock speed of up to 80 MHz, which allows for fast data processing and high sampling rates.
- It has a built-in ADC, which are essential for capturing analog signals.
- It has 4 SPI communication interfaces, which allows for easy data transmission to other devices using Bluetooth.
- It has a low-power mode, which is important for energy-efficient applications, especially in battery-powered systems.
- It has a robust software development kit (SDK), which makes it easy to develop and test applications using a range of programming languages and development tools.
- Finally, it has a rich set of peripherals and I/O ports, which makes it highly configurable and customizable for various experimental setups.

Overall, the TIVA C TM4C123GH6PM offers a good balance of performance, power efficiency, and flexibility, making it an excellent choice for this experiment.

1.3 Bluetooth Microcontroller Interface

The following reasons make LAUNCHXL CC2640R2F a suitable choice for this experiment.

- It is a low-power, high-performance microcontroller, which is essential for energy-efficient applications, particularly in battery-powered systems.
- Second, it has a built-in Bluetooth 5.1 Low Energy (BLE) module, which allows for wireless data transmission to other devices, making it easy to integrate into a wider range of systems.
- It has a variety of interfaces, including 1 UART, 2 SPI, 1 I2C, and 1 I2S which make it easy to communicate with other devices or sensors.

- It has 28 KB of RAM, which is sufficient for data processing and storage for the proposed experiment along with a 12 bit ADC.
- It has a compact form factor, which is important for space-constrained applications.
- Finally, it has a low cost, making it an affordable option for experimental setups.

In summary, the LAUNCHXL CC2640R2F is a cost-effective and versatile option that strikes a good balance between performance, power efficiency, and flexibility, making it a highly suitable choice for our experiment.

1.4 Digital Potentiometer

The following reasons make TPL0102-EP a suitable choice for this experiment.

- It provides a high-resolution 256-tap adjustment for fine-grained gain control in the audio acquisition circuit.
- It has an I2C interface, which enables easy digital communication with the microcontroller, simplifying the integration of the digital potentiometer into the circuit.
- It has a low-power consumption, making it an energy-efficient option for battery-powered applications.
- The evaluation module provides a convenient way to test and evaluate the performance of the TPL0102 digital potentiometer, which helps streamline the design process.

Overall, the TPL0102 digital potentiometer with I2C interface evaluation module offers a high level of functionality, accuracy, and convenience.

1.5 Digital to Analog Converter (DAC)

The MCP4921 DAC with SPI interface is a suitable choice for this experiment for several reasons.

- It has a high resolution of 12 bits, which ensures accurate digital-to-analog conversion.
- It has a fast settling time, which is important for applications where rapid changes in the output voltage are required.
- It has a compact form factor, which is important for space-constrained applications
- It has a wide input voltage range, which makes it suitable for a variety of input signal levels.
- It has an SPI interface, which enables easy digital communication with the microcontroller, simplifying its integration into the circuit.

The MCP4921 DAC with SPI interface offers reliable and efficient operation, making it an excellent choice.

1.6 Operational Amplifier

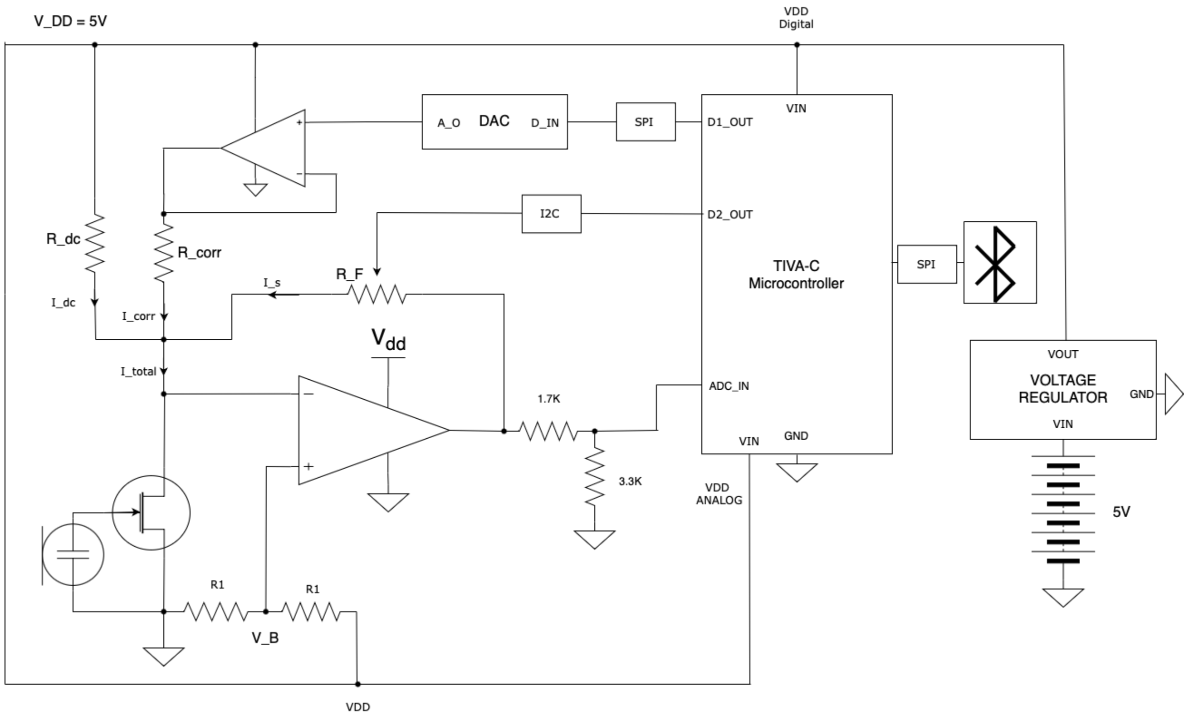
The selection of TI TLV2472 operational amplifiers for this project is based on several factors.

- The Op-amp provides reliable and accurate signal acquisition, which is essential for high-quality audio recording as the amplifier supports rail-to-rail operation, which enables precise acquisition of signals across the full input range.
- This feature is particularly important in low-voltage applications, where the voltage range can be limited.
- Furthermore, the Op-amp has low input noise and low offset voltage, which ensures that the acquired signal is free from unwanted noise and distortion.

- The amplifiers also has a high gain bandwidth product, which allows for fast signal processing and ensures that the acquired signal is faithfully represented in the output.

Overall, the TI TLV2472 operational amplifiers provide a robust and reliable solution for signal acquisition in this project, which is crucial for obtaining high-quality audio recordings.

2 Principle of Operation



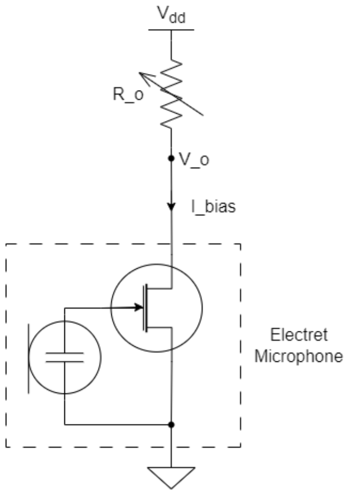
2.1 Bias Current Compensation

The principle of operation of the experiment involves the conversion of incoming sound signals into voltage signals using an electret microphone. This voltage signal is then fed into the gate of the FET, and a negative feedback opamp configuration sets the voltage at the drain to V_B. A current $I = I_{bias} + i_{in}$ flows into the drain of the FET, where i_{in} is the small signal component carrying the sound signal information, and I_{bias} needs to be compensated.
To compensate for the bias current, compensating currents from the sources $I_D C$ and $I_{correction}$ are brought in. The current I_C cancels most of the bias current and is fixed, while $I_{correction}$ is a variable output of the microcontroller, which handles small variations in the bias current. The TIVA C muC and the MCP4921 DAC with an SPI interface are used to efficiently convert the digital input to analog output for DC bias compensation.
The microcontroller 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 digitized signal is also transmitted to an external device through a Bluetooth module, where further operations may be performed on the signal. The TPL0102 256-tap dual-channel digital potentiometer with an I2C interface evaluation module is used to set the voltage $V_{control}$, which controls the gain of the opamp. The LAUNCHXL CC2640R2F Bluetooth microcontroller interface is used to transmit the digitized signal to external devices.
Finally, the TI TLV2472 operational amplifiers are used in the circuit to support rail-to-rail operation, ensuring precise acquisition of signals. Overall, the principle of operation of the experiment

involves integrating various components and techniques to ensure the accurate acquisition and transmission of sound signals while compensating for DC bias.

3 Preliminary Analysis

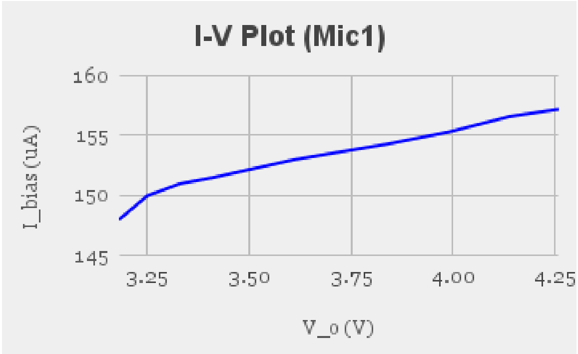
It is important that our circuit should be able to compensate the bias current for any electret microphone that the user decides to use, that is, we should be able to handle the process variation in the bias current. For this reason, we experimented with multiple electret microphones to get an idea of this process variation. The experimental setup is shown in the below circuit diagram.

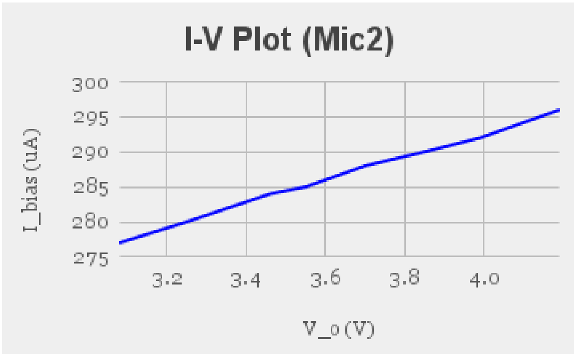


We used 3 different microphones for the experiment. For every microphone, the supply V_{dd} was fixed and potentiometer value R_o was varied. The drain voltage V_o and the bias current I_{bias} were measured and recorded. Since the internal gate voltage of the electret is fixed, this gives us the I_D vs V_{DS} characteristic of the FET at fixed V_{GS}. The readings and plots for the 3 microphones are as shown.

MIC 1		**MIC 2**		**MIC 3**	
V_o (V)	**I_bias (uA)**	**V_o (V)**	**I_bias (uA)**	**V_o (V)**	**I_bias (uA)**
3.18	148	4.19	296	4.3	167
3.25	150	3.99	292	4.11	166
3.33	151	3.85	290	3.95	165
3.41	151.5	3.7	288	3.83	164
3.61	153	3.55	285	3.7	163
3.84	154.3	3.46	284	3.59	163
3.99	155.3	3.25	280	3.42	162
4.14	156.6	3.08	277	3.3	161
4.26	157.2	-	-	3.19	161

From these readings, we see a significant process variation in the bias current and we can use this data to select a suitable range of bias currents that our circuit will be designed to compensate.





4 Risk Mitigation

Currently we are not anticipating any major problems, but some possible issues we may have to deal with are:

- The Opamp used in the current to voltage conversion would in practice have non idealities and we have to carefully consider the effect of these on the performace. For instance, the inverting and non inverting terminal may end up having a significant difference in voltage which will affect the biasing of the microphone. Another issue may be non linearity of output if the voltage swings close to saturation, which we can tackle by keeping the voltage in a desired range by adjusting the variable gain suitably.

- We need to ensure sufficient resolution of the control voltage from the DAC so that we can almost completely cancel the bias current. If there is significant uncompensated current, it will be amplified when the variable gain is later increased and can lead to saturation of output.

- We can encounter large amplification of noise if the automatic gain control is not done carefully. So we will have to choose the noise threshold carefully, and we amplify only when the signal is sufficiently above this threshold.

5 References

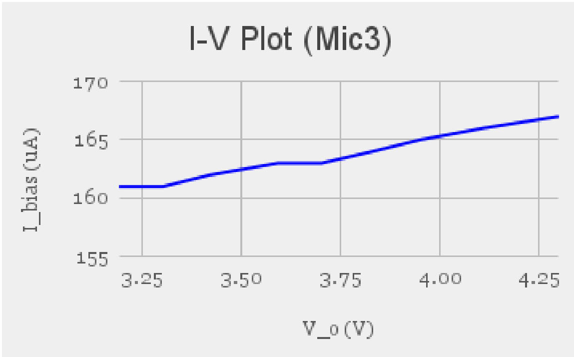
1. Open Music Labs: http://www.openmusiclabs.com/learning/sensors/electret-microphones/index.html

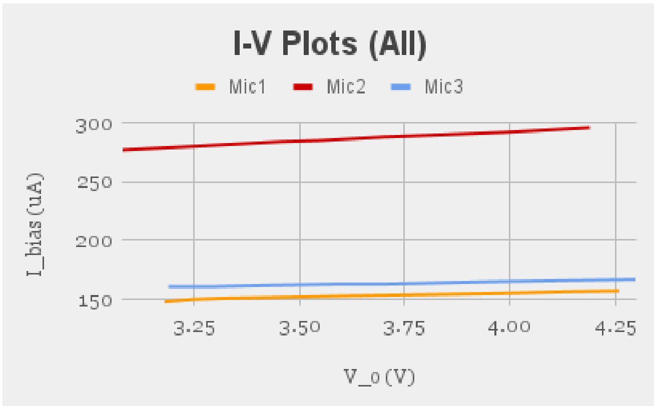
2. Best Sound Electronics https://www.endrich.com/fm/2/SOB-413S42-EM.pdf

3. HOSIDEN Guide for Electret Condenser Microphones: http://www.es.co.th/Schemetic/PDF/KUC.PDF

4. CUI Devices: https://cdn-shop.adafruit.com/datasheets/CMA-4544PF-W.pdf

5. Texas Instruments: https://www.ti.com/product/TM4C123GH6PM





6. Texas Instruments: https://www.ti.com/product/CC2640R2F
7. Texas Instruments: https://www.ti.com/product/TPL0102-EP
8. Microchip: http://ww1.microchip.com/downloads/en/devicedoc/21897b.pdf
9. Texas Instruments: https://www.ti.com/product/TLV2472