Design of a 4-bit Digital to Analog Converter

Danny Moreno
Computer Engineering
California Polytechnic State University
San Luis Obispo, CA USA
dmoren32@calpoly.edu

Austin Dailey
Computer Engineering
California Polytechnic State University
San Luis Obispo, CA USA
adailey@calpoly.edu

***Abstract*— The DAC is a digital-to-analog converter. In our case, the converter was used with a level shifter and an Arduino to take in signals from an audio jack, pass it through the Arduino (digital signal) then output through the DAC back to 4-bit analog.**

Keywords—DAC

I. Introduction

A DAC is a Digital to Analog Converter. DACS translate digitally stored information from a device into the analog sound that we hear[1]. Computers, tablets, and smartphones have built-in DACs.[2] We use DACs every day without realizing it.

A major difference between our DAC design and other DAC design is the output audio. Out DAC has a 4-bit output whereas most DACs have at least 16-bits. [2]

Our 4-bit DAC was an excellent source of learning as it allowed us to get experience with EAGLE modeling software and LTSpice circuit simulating software, which allowed us to test our design.

We will talk about how we designed and virtually simulated our DAC, how we integrated our design onto a 1” x 1” PCB, how we assembled and tested our completed DAC, and finally, how we used our DAC in a real-world application.

II. 4-BIT DAC DESIGN AND SIMULATION

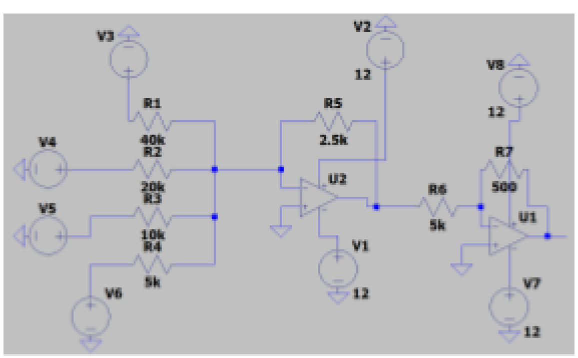

Figure 1: 4-bit DAC Schematic

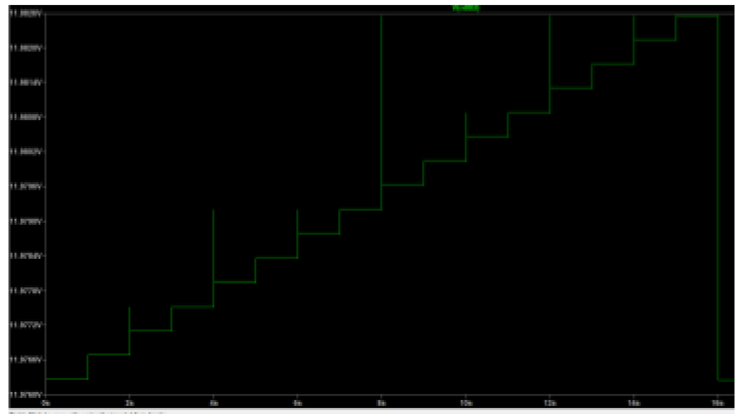

Figure 2:DAC Simulation Output

Figure 1 shows our original DAC concept created in LT SPICE. We tested our DAC design using the SPICE simulation feature. The simulation shows the 16-level stair step which proves that our DAC operates correctly because when a binary counter is connected to a DAC for testing, the counter increments in the form of a step. This stairstep is shown in Figure 2.

Because our design is a summing amplifier, the resistor values for resistors R1, R2, R3, and R4, must correspond with each other. Each resistor has half the value of the previous resistor. These resistor values determine the multiplier for each bit.

III. PCB Design

We used AutoDesk Eagle 9.6.2[3] to design the PCB for our 4-bit DAC. The Eagle schematic is shown in Figure 3. We were able to fit all of our components onto a 1” x 1” board by using surface-mount resistors of size 1206, and a surface-mount IC.

We powered the circuit using a three-pin header with a positive and negative 12V input and ground. A four-pin header was used for the four DAC inputs. A third pin header was used for the two output stages.

From the schematic, we generated a single-layer PCB board layout as shown in Figure 4. We manually placed the components onto the board but used EAGLE's auto-router to route our design. Our design was successfully routed and met the requirement of having 4 or fewer vias.

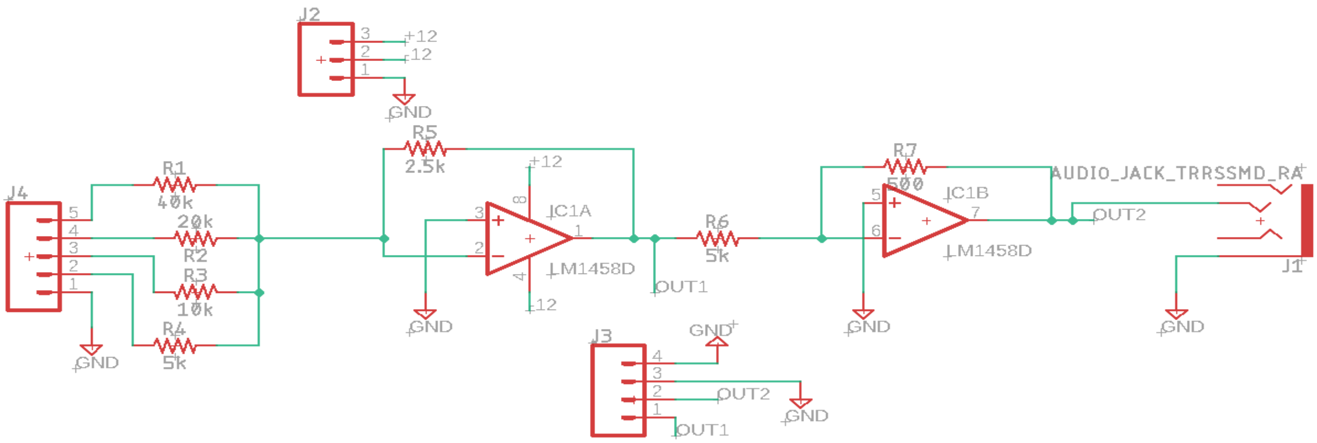

Figure 3: Eagle DAC Schematic

We added drill holes at each corner of the board so that it could be mounted to our 3D-printed chassis mount. The board is 1" x 1" in size which fits within the 1" x 1" size limitation.

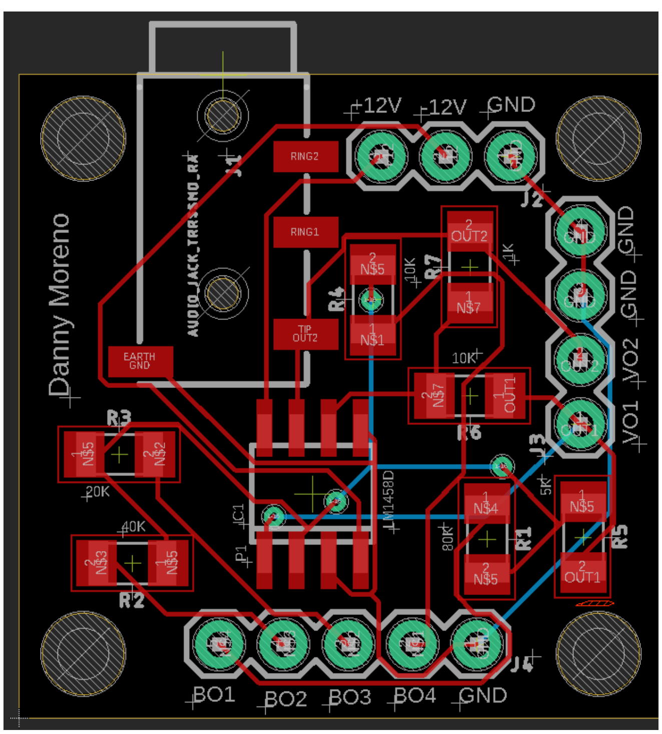

Figure 4: PCB Board Layout of DAC

IV. PCB Assembly and TESTING

All of the surface mount components for the PCB were provided in the classroom. We did order the PCB from Oshpark[4], a PCB manufacturer. OshPark charges $5 per square inch for a board and sends 3 boards in each order. After shipping and taxes, the total price was about $10.

To assemble the PCBs, we used solder paste and a reflow oven to adhere the surface mount components and a soldering iron for the through-hole components. Figure 5 shows the assembled PCB.

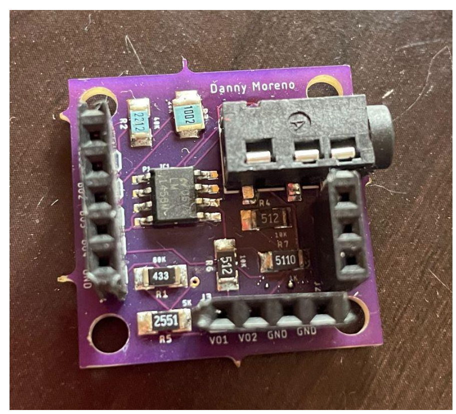

Figure 5: Assembled PCB

We powered the board with a +/-12V supply and checked for proper operation by connecting the 4 inputs to a binary counter and connecting the DAC outputs to an oscilloscope. We observed the output and the result was a stairstep.

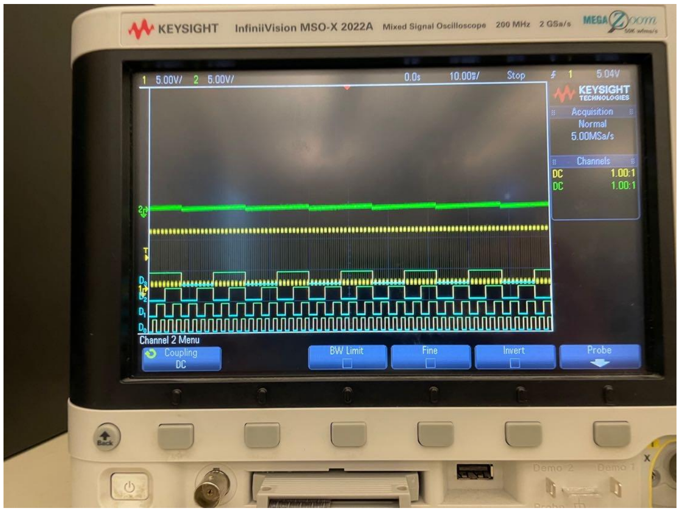

Figure 6: Output 1 of DAC test

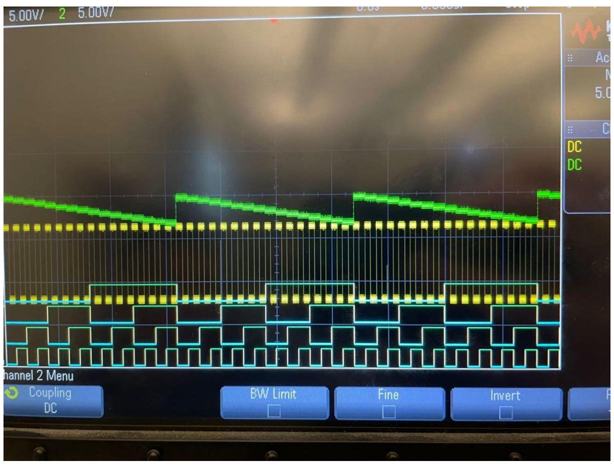

Figure 7: Output 2 of DAC test

The green waveform in Figure 6 and Figure 7 shows the output of the DAC. The wave appears to be a stairstep, just like the waveform from the SPICE simulation. It is difficult to see the stairstep pattern in Figure 6 but you can see that the wave increases then drops down as it reaches the top step. In Figure 7, the stairstep is more visible but it is backward compared to our SPICE simulation. We were not able to obtain the exact values of the output because we ran out of time during the lab.

V. 4-bit DAC Application

During the lab, we tested the functionality of our DAC by using our phones and a speaker to play music. We connected our phone to the level shifter that connected to an Arduino mega which then connected to our DAC. A speaker was connected to the output of the DAC which then played the music from the phone. In the end, the circuit did function properly but the speaker output was very muffled and static. This may have been caused by an issue with our level shifter.

Figure 8 shows an output waveform from the DAC. The yellow wave is an input wave from a function generator and the green wave is the output of our DAC. Figure 9 shows the completed circuit of the level shifter, Arduino, and DAC.

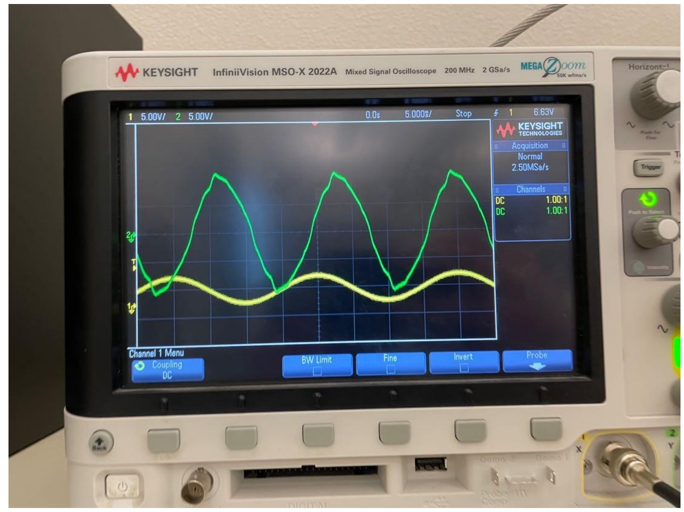

Figure 8: Function generator input with DAC output

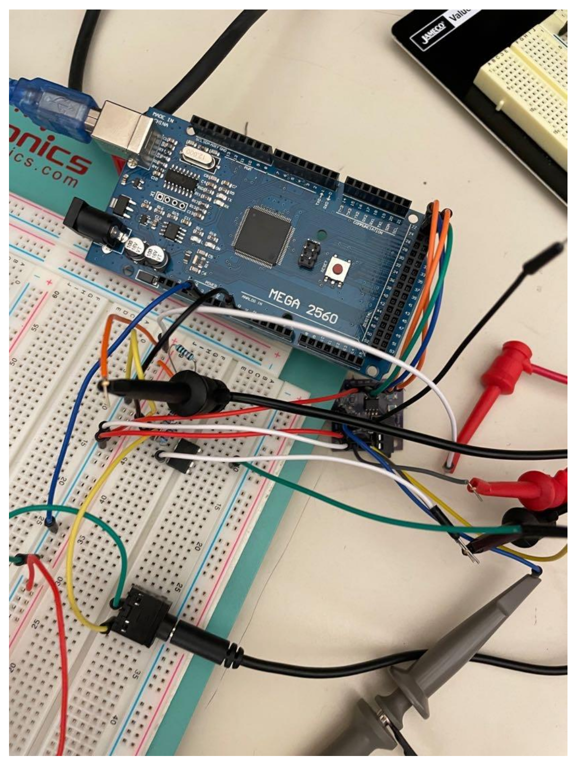

Figure 9: DAC circuit

VI. CONCLUSION

Overall, our 4-bit DAC project was fun but challenging. Although the outcome wasn't what we completely desired, we were still satisfied that our DAC functioned properly.

ACKNOWLEDGMENT

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