2 bits Arduino Analog to Digital Converter

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Abstract

The goal for this project is to examine the relationship between analog signals and digital signals by making a 2 bits analog to digital converter with Arduino and other basic electronic parts. We collect the analog signals from the 4 resistor in series. Process the signals with comparator, and digital logic gates chips to convert the analog signals to digital signals.

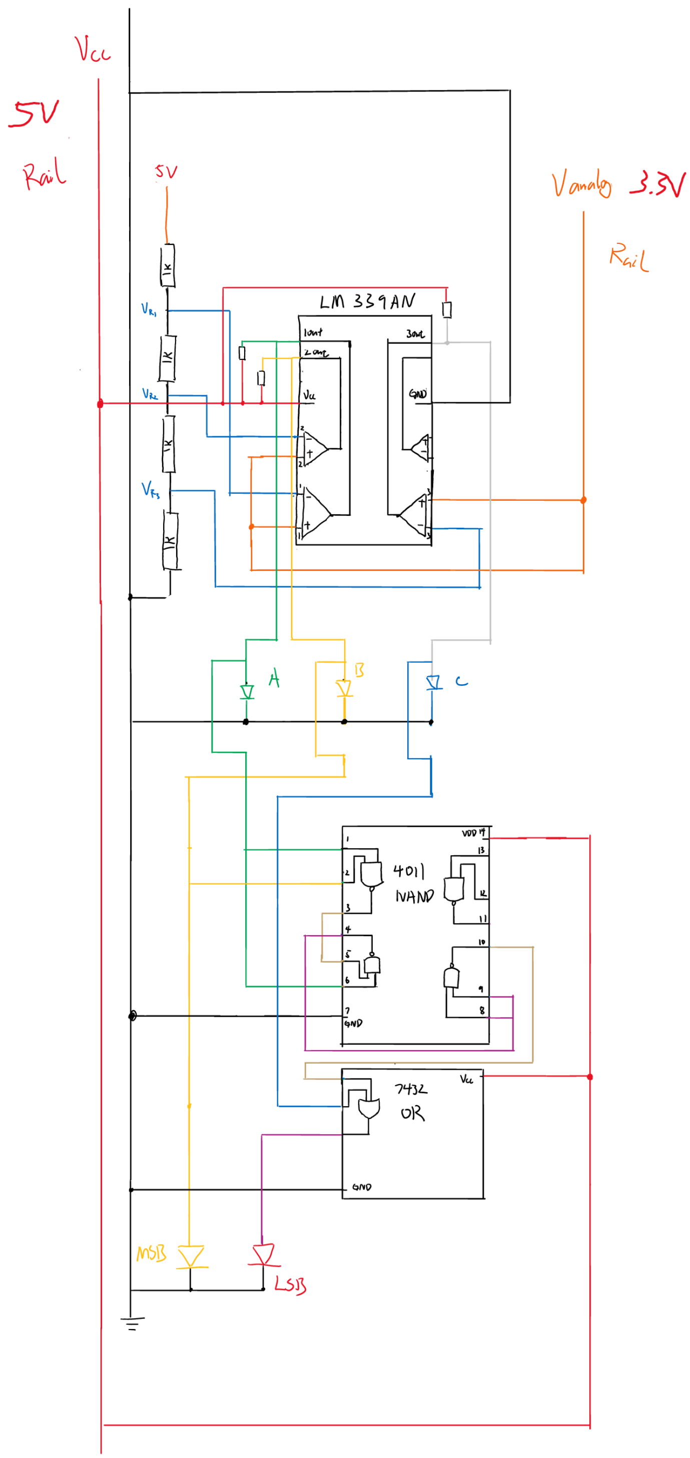
Introduction

The purpose of this project is to build an analog to digital converter (ADC), taking analog signals and convert to digital signals. To have a better understanding the differences between analog signals and digital signals. Develop skills in designing circuits and troubleshooting complex circuits.

Equipment

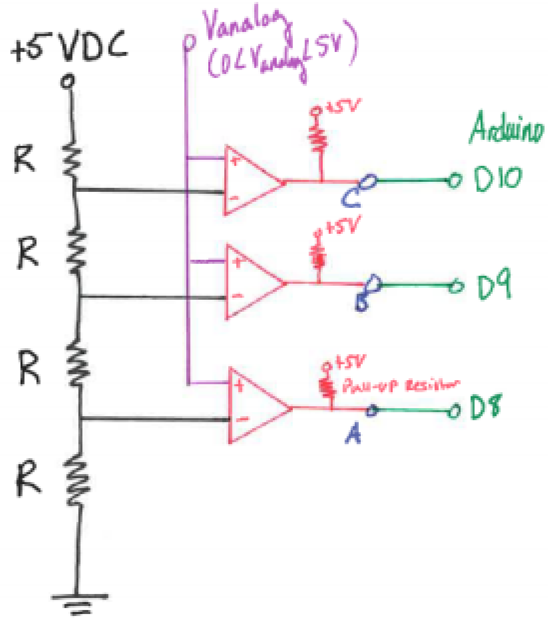
- LM339AN Quad analog comparator
- CD4011 Quad AND chip
- SN7432 Quad OR chip
- Four 1k Ω Resistors
- Three 220 Ω Resistors
- Five LEDs
- Breadboard
- Arduino
- Wires

Circuit Diagram



Due to the power limitation from the Arduino, we were not able to power the decoder chip, therefore we simplified the decoder, we feed in the analog signals(A, B, C) from the comparator into the Arduino and decoder the signals digitally by programming the decoder on Arduino.

Circuit diagram without decoder:



Theory and Procedure

The comparator is where we generate analog signals. Inside of a LM339AN consists 4 op-amp comparators. The comparator havs 2 inputs: V_{-}, V_{+}. The ideal output of the comparator is the following:

$$V_{out} = \begin{cases} V_{cc} & V_{+} > V_{-} \\ 0 & V_{+} < V_{-} \end{cases} \tag{1}$$

Where $V_{cc} = 5V$ from the Arduino.
Each of our three comparators' V_{-} are plugged into 3 different locations of our 1k Ω resistor ladder. V_{+} from all comparators are bridged together so we can vary the voltage input for all three comparators simultaneously and do the comparison to generate different values for our output: A, B, C. Where we used 3 different colors of LEDs to indicates the status for our outputs.

After we generate 3 analog outputs, we feed these signals into our decoder chip. We have to use CD4011 AND and SN7432 OR chips to produce the following truth table:

A	B	C	MSB	LSB
1	1	1	1	1
1	1	0	1	0
1	0	0	0	1
0	0	0	0	0

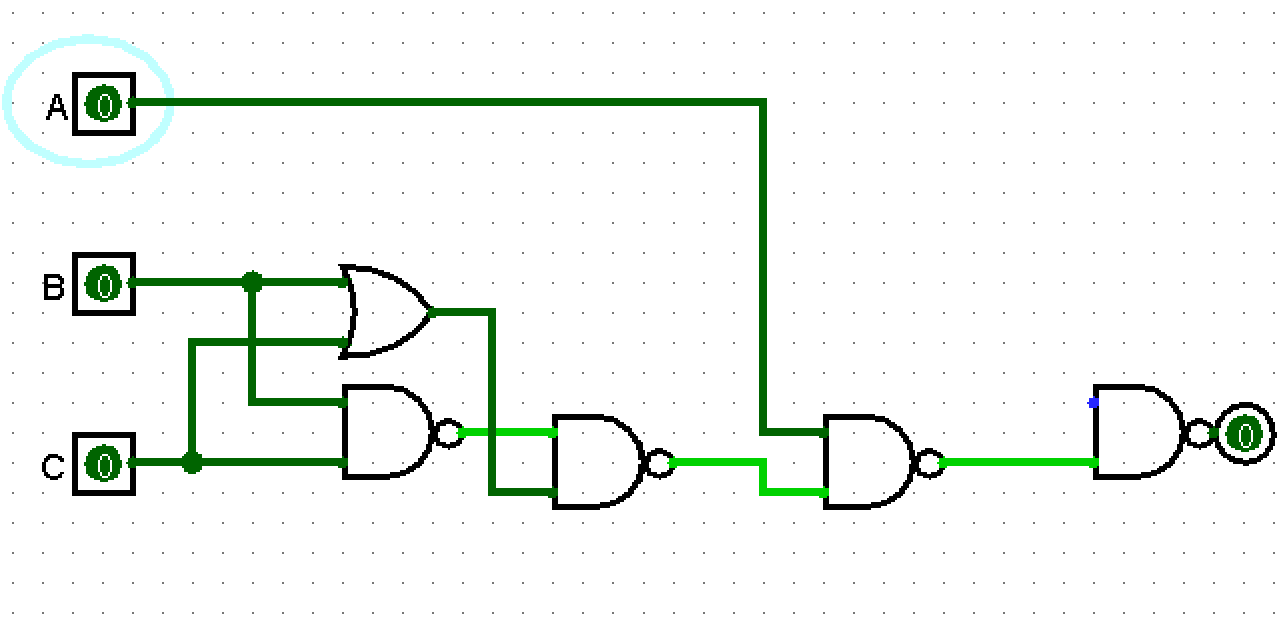
Where MSB stands for most significant bit and LSB stands for least significant bit.

From the truth table, we can see that the output of B is exactly the same as the output for MSB. MSB = B

For LSB. We constructed a Boolean expression that fits our output values for LSB, and we have the following:

$$LSB = (A \wedge B \wedge C) \vee (A \wedge \sim B \wedge \sim C) \tag{2}$$

We have the following logic gates combination:



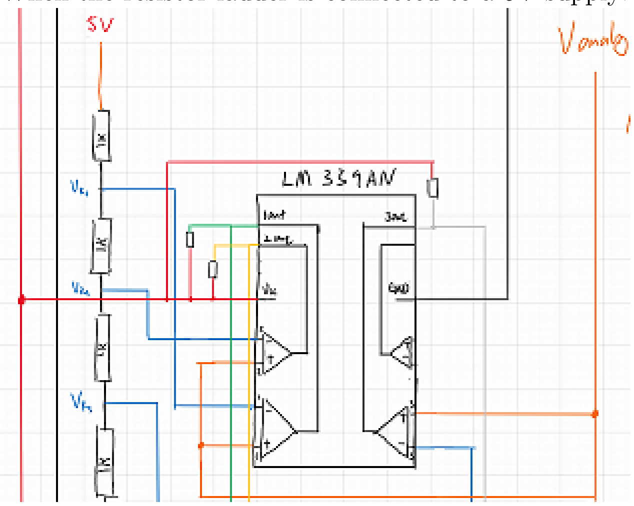
After we calculated the MSB and LSB, we used two LEDs to indicate the output values.

With the default power supply as our Arduino, with insufficient power for the whole circuit. Therefore we took A, B, C outputs and send them into the Arduino. Here is a segment of code where we calculate our LSB:

```
int dStateA = digitalRead(DinA);
int dStateB = digitalRead(DinB);
int dStateC = digitalRead(DinC);
boolean LSB = ((dStateA & dStateB & dStateC) | (dStateA & !dStateB & !dStateC));
```

Data and Analysis

When the resistor ladder is connected to a 5V supply:



The voltages across the resistor ladder are the following:

V_{R1}	3.77V
V_{R2}	2.51V
V_{R3}	1.25V

For comparator which output is A:

V_{R2}	V_{analog}	V_{1out}
3.77V	0V	1.24V
3.77V	3.3V	1.27V
3.77V	5V	5.04V

For comparator which output is B:

V_{R1}	V_{analog}	V_{2out}
2.51V	0V	1.23V
2.51V	3.3V	5V
2.51V	5V	5V

For comparator which output is C:

V_{R3}	V_{analog}	V_{3out}
1.25V	0V	1.19V
1.25V	3.3V	5V
1.25V	5V	5V

When we finished constructing the circuit and check the results on our serial monitor for our Audrino, we have the following:

When $V_{analog} = 5V$

$$A = 1, B = 1, C = 1, MSB = 1, LSB = 1$$

When $V_{analog} = 3.71V$

$$A = 1, B = 1, C = 0, MSB = 1, LSB = 0$$

When $V_{analog} = 3.33V$

$$A = 1, B = 1, C = 0, MSB = 1, LSB = 0$$

When $V_{analog} = 2.51V$

$$A = 1, B = 1, C = 0, MSB = 1, LSB = 0$$

When $V_{analog} = 1.25V$

$$A = 1, B = 0, C = 0, MSB = 0, LSB = 1$$

When $V_{analog} = 0V$

$$A = 0, B = 0, C = 0, MSB = 0, LSB = 0$$

The results above matches with the truth table before.

Troubleshooting

We encountered couple errors in our circuit. First of all, part of our circuit had no power. The reason for that is a faulty breadboard. The positive and ground rail on the right has a upper part and a lower part. With the help of a multimeter, we found that the upper rail is not connected with the lower rail. The solution was to bridge the upper rail and the lower rail to provide power for all the circuit.

Secondly, our decoder chips did not function properly. We examine the decoder circuit independently, and the decoder circuit was able to produce the correct truth table. So we concluded that our Arduino cannot provide sufficient power to drive the complete circuit. Therefore, instead of feeding in our analog signals to the decoder chips, we feed it into our Arduino and program a function to decode the signal digitally.

Conclusion

Our circuit with Arduino decoder was able to produce the correct truth table. We validated the theory of conversion from analog signals to digital signals. The reason that our original circuit did not work is due to a systematic error: the insufficient power supply from the Arduino which is not enough to power the entire circuit.