Study of ADC-DAC Circuits

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This experiment aims to construct and study 4 bit R-2R ladder DAC circuit and 2 bit ADC circuit.. 4 bit R-2R ladder DAC circuit is constructed using 741 Op-Amp. ADC circuit is constructed using LM 339 comparator and 74147 priority encoder.After conversion of analog voltage to binary, it was further converted to binary coded decimal using 7447 BCD decoder, with the output displayed on 7 segment BCD display as decimal digit. The DAC circuit gave the average relative error as 0.6%. Also, the ADC circuit gave the desired output hence proving the conversion of digital to analog conversion or vice versa by the usage of these circuit components.

Keywords: Comparator, Ladder, Op-Amp

I. THEORY

ADC and DAC expands to Analog to Digital converter and Digital to Analog converter. Some of the micro-controllers work only in the digital environment, hence they cannot read analog signals but digital signals in form of 0s and 1s. DACs are used in speakers, televisions to convert digital audio / video signals to analog signals. Hence, this conversion is necessary and can be done with the ICs and resistors as follows.

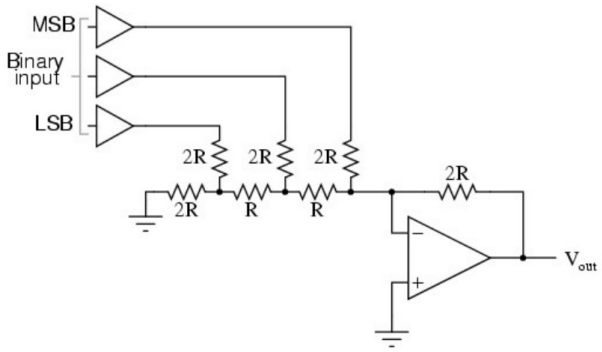

Figure 1: The circuit diagram of 4 bit binary digital to analog conversion using IC 741 and R-2R ladder network.

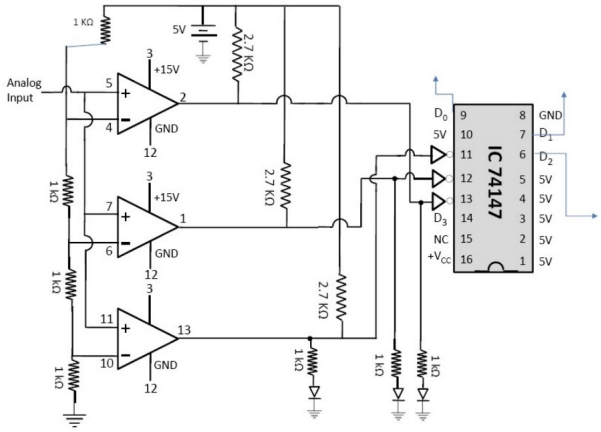

Figure 2: The circuit diagram of 2 bit binary analog to digital conversion using LM 339, IC 7404 and IC 74147

From the voltage analysis of Figure (1), the output from the Op-Amp is given by :

$$V_{out} = \frac{-R_f}{R}\left(\frac{a_1}{2} + \frac{a_2}{4} + \frac{a_3}{8}\right) \tag{1}$$

where R_f is the feedback resistor, $R_f = 2R$ in this case, a_1 is the most significant bit, a_2 is the middle bit, a_3 is the least significant bit.

LM 339 and 74147 is used as the priority encoder for ADC circuit as shown in figure (2) The general formula for resolution of n-bit ADC can be expressed by:

$$Resolution = 2^n \tag{2}$$

The pin diagram of LM 339 and 74147 are shown in figure(3) and figure(4).

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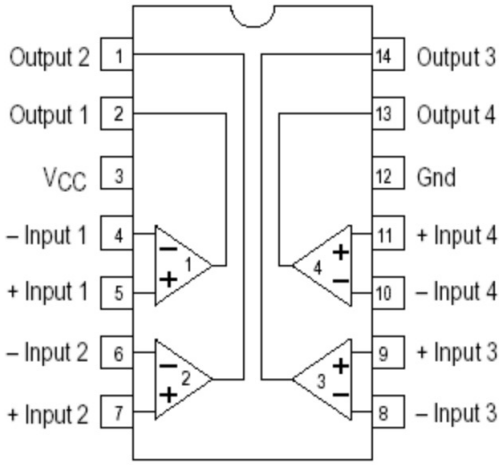

Figure 3: PIN diagram of IC LM339

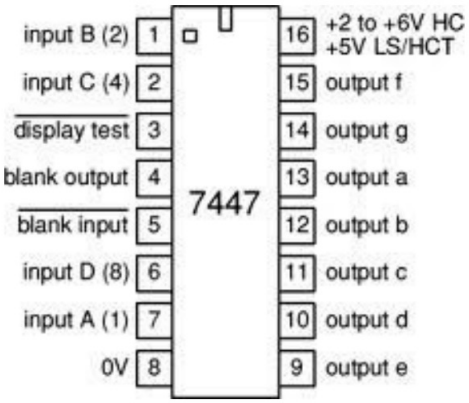

Figure 5: PIN diagram of IC 7447

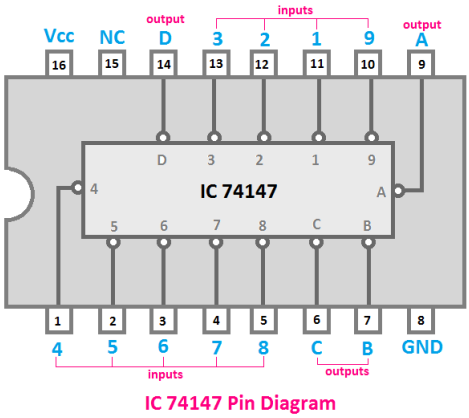

Figure 4: PIN diagram of IC 74147

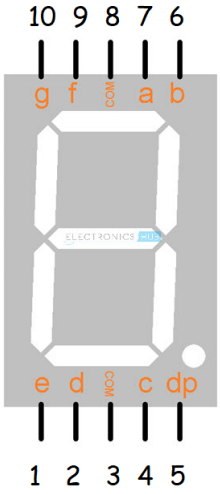

Figure 6: PIN diagram of common cathode 7 segment Binary coded decimal display

The conversion of analog voltage to binary can be displayed on BCD displayed by using binary to BCD decoder, where IC 7447 can be used to display on common cathode 7 segment cathode BCD display. The PIN diagram of IC 7447 and 7 segment BCD display is as shown in figure (5) and (6).

II. EXPERIMENT

There are three steps in this experiment, the first one being designing and testing of 4 bit R-2R ladder DAC circuit, second step is the construction of ADC circuit, and finally converting binary to decimal display.

Step 1: The circuit was constructed using IC 741 with the resistors R and 2R making a ladder creating voltage dividers. The R-2R ladder network is used to eliminate the need of large number of accurate resistors and the feedback resistor was taken to be 2R. Advantage of ladder network is that the output impedance is always R for any no. of bits.

Step 2: The circuit was constructed using an LM 339

comparator and 74147 priority encoder. Analog input from a DC power supply was compared with a reference voltage using the LM339 comparator. The output was then given to the 74147 priority encoder chip. Three out of the four comparators available in the LM339 were used. Unused input pins of IC 74147 were connected to 5 V input supply. Digital binary output was obtained from D_o, D_1 and D_2 from the pin nos. 9, 7 and 6 of the IC 74147. The operation of the LM339 was understood by connecting one comparator and checking the output. The supply voltage for LM339 should be kept at 15 V and 74147 at 5V.

Step 3: After conversion of analog voltage to digital, the binary output can be converted to decimal using 7447 BCD decoder. The output was displayed on the common cathode 7-segment BCD display, which is active low as decimal digit. The 330 Ω resistor was used to connect with the output of of 7447.

III. OBSERVATION AND ANALYSIS

Table I: Digital to Analog Conversion

Binary Input			Experimental Output V_{out} (V)	Theoretical Output V_{out} (V)
MSB		LSB		
0	0	0	0	0
0	0	1	-1.279	-1.261
0	1	0	-2.539	-2.521
0	1	1	-3.814	-3.782
1	0	0	-5.060	-5.043
1	0	1	-6.340	-6.304
1	1	0	-7.600	-7.564
1	1	1	-8.870	-8.825

The analog output is obtained theoretically from the equation (1). We can see that experimental and theoretical values are approximately close to each other with average relative error as 0.6%.

The output from the ADC circuit is as shown in figures (7), (8), (9) and (10). The output is obtained as the input voltage goes beyond certain voltage, we get the output as a discrete decimal as it is due to the comparator circuit.

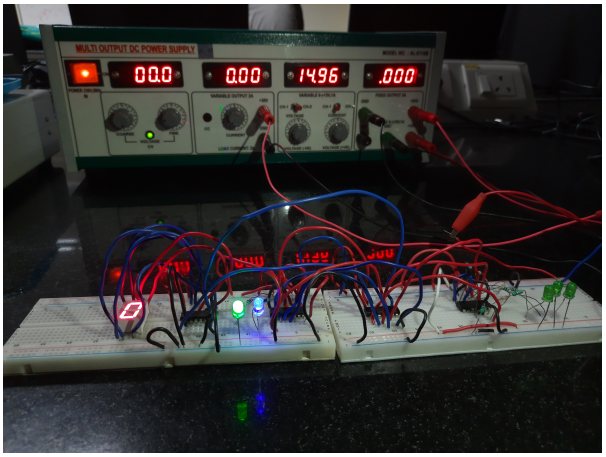

Figure 7: BCD display converted digital output as 0

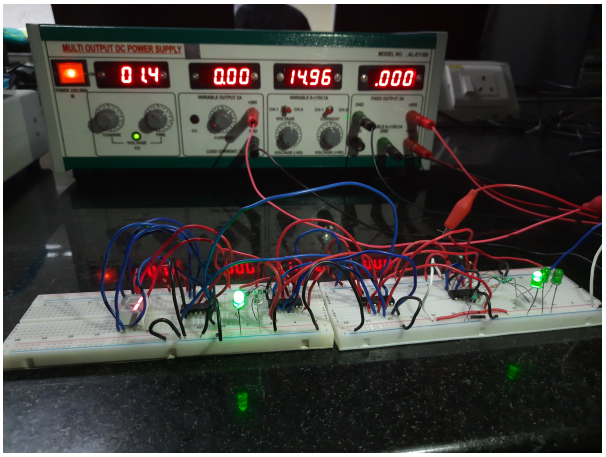

Figure 8: BCD display converted digital output as 1

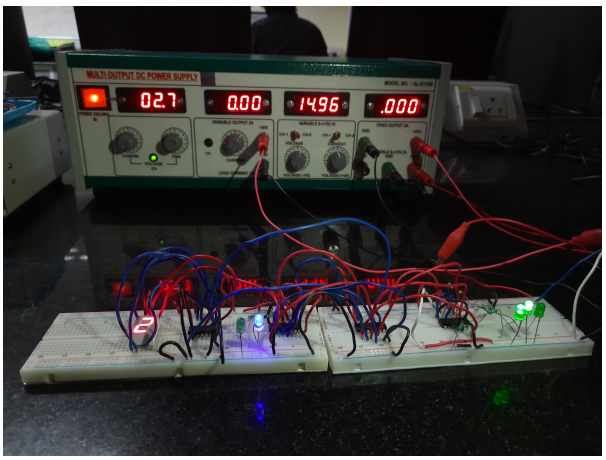

Figure 9: BCD display converted digital output as 2

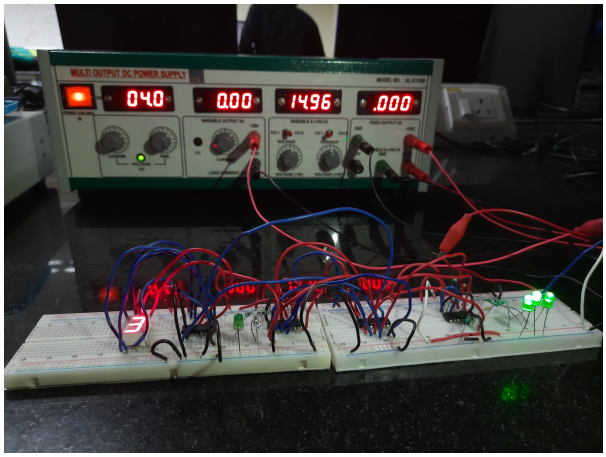

Figure 10: BCD display converted digital output as 3

IV. CONCLUSION

The digital to analog signal was converted through IC 741 OP-Amp and using R-2R ladder network as it eliminates requirement of large number of accurate resistors. The average relative error in the experimental voltage output was 0.6%. Similarly analog to digital signal was converted by using LM 339 as comparator and IC 74147 as priority encoder. This output was further converted to BCD format using 7447, which can be displayed on 7 segment BCD display which was successful. Further experiments can be done to test the circuit's performance and accuracy with different input values and circuit variations. The circuit can be modified to increase the number of bits for both DAC and ADC for higher precision. Such conversions play wide role in the applications of digital devices.

V. REFERENCES

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