EXPERIMENT #7 **DIGITAL TO ANALOG CONVERSION**

I OBJECTIVES

To understand the concepts in Digital to Analog conversion and be able to design build and test a simple Digital to Analog Converter circuit to meet given specifications.

II INTRODUCTION

In this experiment, you will use your knowledge of Superposition and Thevenin's theorems to analyze a popular digital to analog conversion circuit. This circuit is similar to those found in CD and DVD players and in computer sound cards. It has the ability to convert a set of bits (which each occupy one of two states) into a continuous analog signal (which may occupy many intermediate states) representing sound. The bits are stored as logic levels on data buses inside a computer, as pits on the surface of a CD, or as the state of switches in this lab.

III COMPONENTS AND INSTRUMENTATION

Digital to uni-polar analog conversion will be the focus of the experiment. For this purpose, DAC0808 and a general purpose op-amp µA-741 will be utilised. Apart from these, resistors, potentiometer (for nulling offset in op-amp) will be needed. For measurement, use a two channel oscilloscope and/ or a digital multimeter.

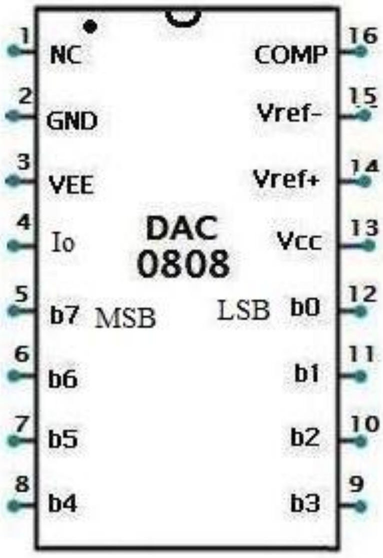

Fig. 7.1 Pin diagram of DAC0808

IV Theory of Digital to analog conversion

The CD player must accomplish the inverse action and produce an analog voltage level given the binary number. The equation it implements is

$$V_{analog} = \frac{B}{2^N} V_{ref}$$

As an example, a 3-bit CD player using a V_{ref} of 8.0V and reading binary values 111, 100, 001, 101 would output analog voltages of

$$\frac{7}{2^3} \times 8\,, \quad \frac{4}{2^3} \times 8\,, \quad \frac{1}{2^3} \times 8\,, \quad \frac{5}{2^3} \times 8 = (7,4,1,5)V$$

(Do you see that B is the decimal equivalent of the 3-bit binary input and V_{ref} is simply a scaling factor with units of Volts?)

A circuit that can accomplish this conversion is shown in Fig.6.1, where binary digits are represented by switches. By hand, analyze the circuit but alter the switches so that the circuit input is a binary 111 (i.e. all switches are set to 8.0V) and find V_{out}. Use superposition to solve. This will require drawing three separate circuits. For each of these three circuits, solve using Norton/ Thevenin source transforms and resistor simplification. (show your work, on additional sheets).

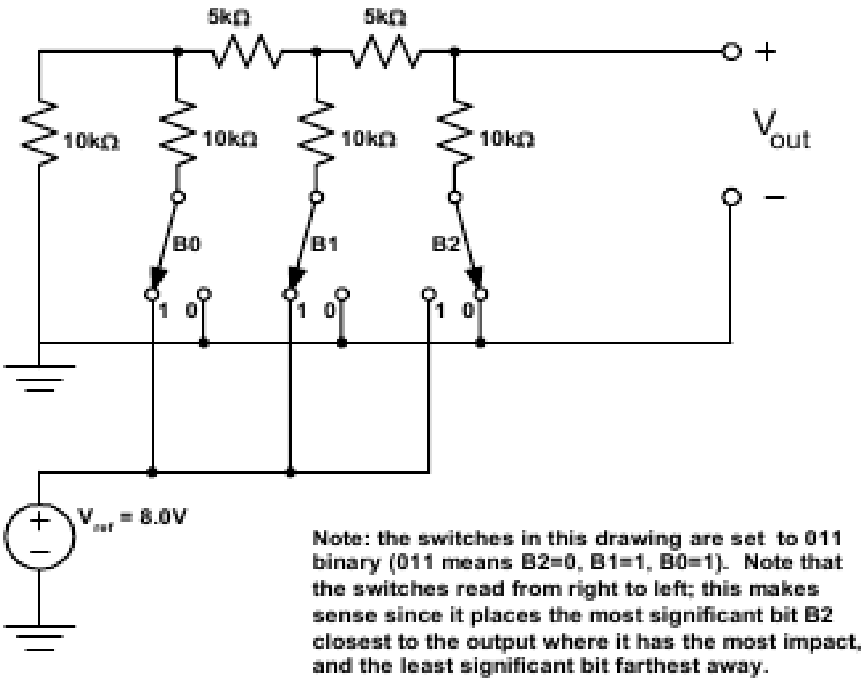

Fig. 7.2 A R-2R ladder circuit demonstrating digital to analog conversion

III PREPARATION

Q1. What is V_{out} for a input of binary 101?

Ans.

Q2. By superposition, you now know the contribution of each bit makes to V_{out} !

Ans. Contribution of MSB (B_2) is ………

Contribution of next MSB (B_1) is ……..

Contribution of LSB (B_0) is ………….

Q3. For instance, the output for an input of 011 by superposition is your output for 001 plus your output for 010 (i.e. 001 + 010 = 011). For your pre-work finish filling out the following table.

Ans.

(rough work/ calculations may be done on additional sheet)

Table 6.1 V_{out} for different input settings in Fig.6.2

B_2	B_1	B_0	Binary input	Decimal equivalent	V_{out} predicted (V)
Gnd	Gnd	Gnd	000	0	0.0
Gnd	Gnd	8 V	001	1	
Gnd	8 V	Gnd			
Gnd	8 V	8 V			
8 V	Gnd	Gnd			
8 V	Gnd	8 V			
8 V	8 V	Gnd			
8 V	8 V	8 V			V_{fs}=

Note: **DAC Resolution**

For an N-bit digital to analog converter (DAC) whose voltage range is ***b*** (volts) to ***a*** (volts), the RESOLUTION of the converter is given by the following expression:

Resolution = $|b-a|/2^N$

{This is the same as $V_{fs}/(2^N-1)$ where V_{fs} is the analog voltage when all the input bits are at logical '1'. This is also called as the **step size.**}

For example: A 2-bit converter, with a range of 0 to 10 volts, has a resolution:
Resolution = $|0-10|/2^2$ = 2.5 V.

Q4. Consider a 8-bit D/A converter shown in Fig.6.3. Consider V_{ref}=5V and R_1=R_2= R_3=R= 10kΩ. The output voltage of DAC is given by $V_0 = -B\times\left(\frac{R3}{R}\right)\times\frac{Vref}{2^8}$. How many discrete output voltages can this circuit render?

Ans.

Q5. What is the smallest increment by which you can change the output voltage (as a p.u. of V_{ref})?

Ans.

Q6. What is the full scale voltage V_{fs} for this DAC?
Ans.

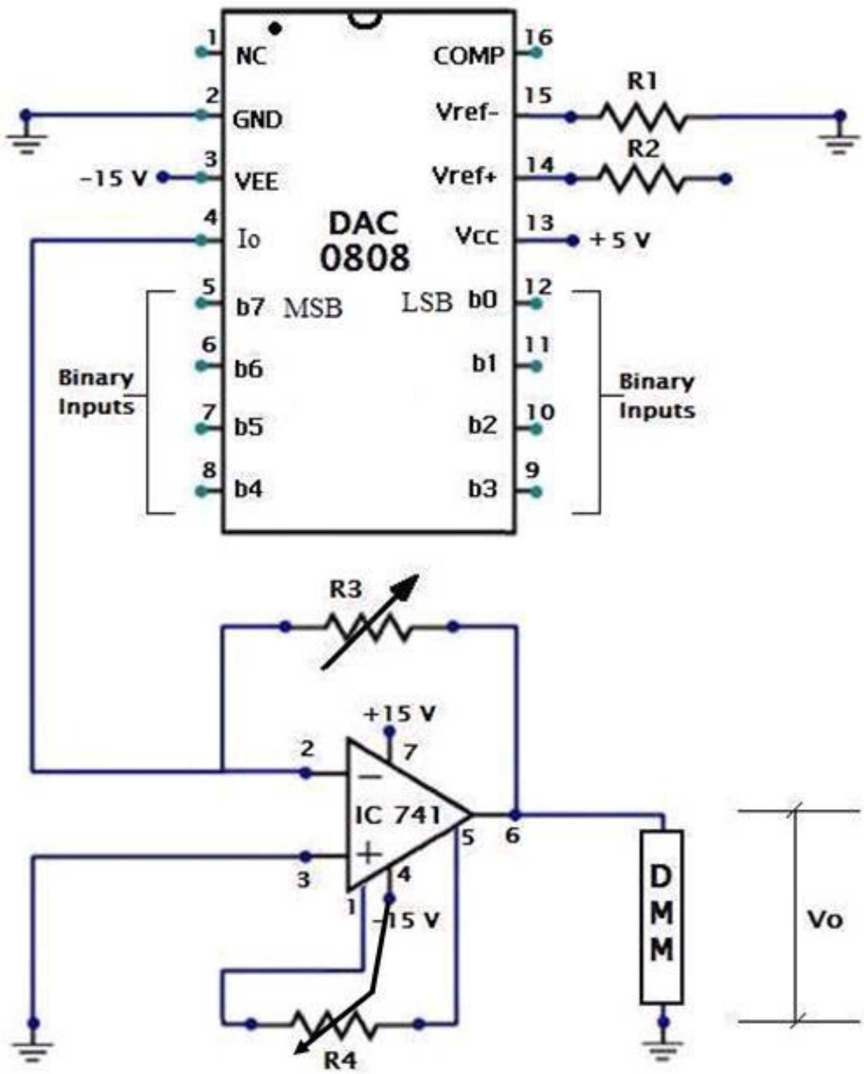

Fig. 7.3 Uni-polar 8-bit digital to analog conversion using DAC0808

Q7. Calculate the analog output for the eleven input words below at one second intervals, with V_{ref} = +5.0 V:

0000 0000; 0011 0011; 0110 0110; 1001 1010; 1100 1101; 1111 1111; 1100 1101; 1001 1010; 0110 0110;

0000 0000; 0011 0011 and 0110 0110. Write the values as a sequence.

Plot this analog data (on y-axis) with time in seconds on x-axis.

IV EXPLORATIONS

4.1 From the reference information (given in section III) for DAC0808, **draw a neat circuit diagram** for converting a 8-bit digital signal to a uni-polar analog signal, showing all the pin connections. (Pay attention to the power supply levels and LSB and MSB positions.) The circuit should also contain the offset nulling feature in the op-amp part.

4.2 Design calculations: Given the reference voltage (V_{ref+}) and the full-scale voltage (V_{fs}), compute the other data needed to build the circuit. (V_{fs} is the output voltage when all the input bits are at logical '1').

Design data: V_{fs} = V ; V_{ref+} = V and R_1=R_2= R= kΩ.

Compute R_3

Build the above circuit. Connect the necessary supplies and the reference voltage.

Firstly set all the input bits to zero. After switching on the power supply, check the output voltage of the op-amp. Adjust the knob of 10kΩ potentiometer (between pins 1 and 5 of op-amp 741) to give the minimum magnitude of output offset voltage. Note the output offset voltage, if it is not zero. This is the zero error that you need to take into account in your analog measurements. Keep the offset adjustment potentiometer in this position **undisturbed** through the entire experiment.

Measurements: Set the input bits (to zero or V_{ref}) and measure the output voltage for each setting. Record it in Table 6.2 after correcting for zero error. Also compute the error (%) which is given by

$$\%error = \frac{V_{out}(\,predicted\,) - V_{out}(\,measured\,)}{V_{out}(\,predicted\,)} \times 100$$

.

Table 6.2 Digital to analog conversion – set of measurements

Binary input (logical ‘0’ or ‘1’)								V_{out} (predicted) V	V_{out} (measured) V	% error
b7	**b6**	**b5**	**b4**	**b3**	**b2**	**b1**	**b0**			
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**			
1	**1**	**1**	**1**	**1**	**1**	**1**	**1**	$\mathbf{V_{fs}=}$	$\mathbf{V_{fs}=}$	

Plot the predicted transfer characteristics i.e., V_o (analog) vs. V_{in} (decimal equivalent of digital input) on a normal graph sheet. Add the measured results to the graph. (For clarity, use a continuous line **without marker** for predicted plot and only a * marker with **no line** for the measured points).

Comment on the error. Suggest the possible sources of error in your report.

V. INFERENCE / CONCLUSIONS