INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

LAB-MANUAL

Experiment No:-7

Study of DAC using R-2R Ladder Network

TRANSDUCERS AND INSTRUMENTATION

VIRTUAL LAB

Experiment No:-7

Aim:- Study of DAC, using R-2R Ladder Network.

Apparatus Requirement:-

- Personal computer
- Lab view 2009 Runtime engine
- Internet facility (for online experiment and for offline experiment just download the executable file from the experiment download link given in website)

Theory:-

Now a day's signal processing typical requirements are increased, resulting to employment of digital rather than analog processing, since digital processing has better potentials. Consequently, signal conversion is mandatory, since more often the output signals are analog. Signal conversion requirements continuously increase, in terms of conversion-speed, resolution, accuracy and power dissipation.

Digital to Analog Convertor:-

A Digital to analog converter converts an abstract finite-precision number (usually a fixed-point binary number) into a concrete physical quantity (e.g., a voltage or a pressure). A device for converting information in the form of combinations of discrete (usually binary) states or a signal to information in the form of the value or magnitude of some characteristics of a signal, in relation to a standard or reference. Most often, it is a device which has electrical inputs representing a parallel binary number, and an output in the form of voltage or current. The output of the D/A converter is proportional to the product of the digital input value and the reference. In many applications, the reference is fixed, and the output bears a fixed proportion to the digital input. In other applications, the reference, as well as the digital input, can vary; a D/A converter that is used in these applications are thus called a multiplying D/A converter. It is principally used for imparting a digitally controlled scale factor, or "gain," to an analog input signal applied at the reference terminal.
The fundamental circuit of most D/A converters involves a voltage or current reference; a resistive "ladder network" that derives weighted currents or voltages, usually as discrete fractions of the reference; and a set of switches, operated by the digital input, that determines which currents or voltages will be summed to constitute the output.

R-2R Digital to Analog Convertor:-

R-2R resistor ladder network is a binary linear circuit which has following remarkable features:

1. Only two resistance values are used anywhere in the entire circuit. This means that only two values of precision resistance are needed, in a ratio of 2:1. This requirement is easy to meet, and not especially expensive.

2. The input resistance seen by each digital input is the same as for every other input. The actual impedance seen by each digital source gate is 3R.
3. The circuit is indefinitely extensible for binary numbers. Thus, if we use binary inputs we can simply double the length of the ladder network for an 8-bit number (0 to 255) or double it again for a 16-bit number (0 to 65535). We only need to add two resistors for each additional binary.

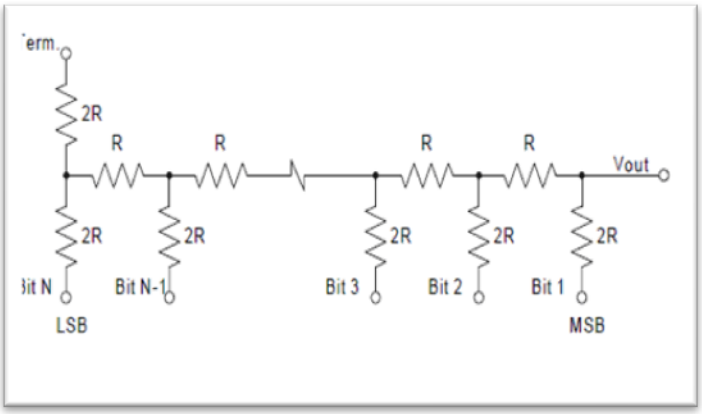

Fig1: N-bit R-2R resistor ladder

DAC using R-2R is actually just a variant of a simple op amp summer circuit, i.e., an operational amplifier configured to output a voltage that is proportional to the sum of the input voltages.

- In this circuit, the inputs are binary weighted with respect to each other, with the binary weighting of the inputs achieved by the R-2R ladder resistor network at the non-inverting input of the op-amp.

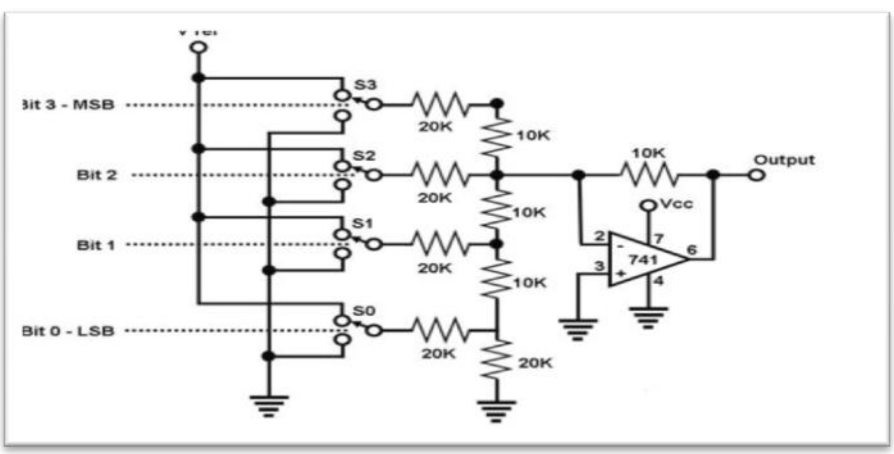

Fig2: Circuit Diagram for 4 bit R-2R Ladder Network DAC

- As its name implies, the R-2R network consists of resistors with only two values, R and 2R (10K and 20K, respectively, in the circuit shown). The input S_N to bit N is '1' if it is connected to a voltage V_R and '0' if it is grounded.

Formula Used:-

- The output V_o of an R-2R ladder DAC with N bits is:

$$\mathbf{V_o = V_{Ref}/2^N (S_{N-1}2^{N-1} + S_{N-2}2^{N-2}+...+S_0 2^0)}$$

Thus, the output V_0 of the 4-bit R-2R ladder DAC in Fig 2 is:

$$\mathbf{V_o = V_{Ref} (S_3/2 + S_2/4 + S_1/8 + S_0/16)}$$

Where S_3 (MSB), S_2, S_1, and S_0 (LSB) are the logic inputs ('1' or '0' for bits 3, 2, 1, and 0, respectively).

Resolution:-

- The number of bits of this DAC may be increased by connecting more switches with corresponding R/2R resistors. Since there are two possible states at each input, ground or Vr, (also designated as "0" or "1" in digital lingo for positive logic) there are 2^N combinations of Vr and ground to the inputs of an R/2R ladder.
- The resolution of the ladder is the smallest possible output change for any input change to the ladder.

Resolution=$1/2^N$
where N is the number of bits.

This is the output change that would occur for a change in the least significant bit.

- For a 10bit R/2R there are 2^N or 1024 possible binary combinations at the inputs. The resolution of the network is 1/1024 or .0009766. A change in state at the LSB input should change the output of the ladder by .09766% of the full scale output voltage.

Accuracy:-

The output accuracy of the R/2R ladder is typically specified in terms of full-scale output ± some number of least significant bits. R/2R ladders are usually specified with output accuracies of ±1 LSB or ±1/2 LSB. For example, a ±1/2 LSB specification on a 10 bit ladder is exactly the same as ±0.04883% full-scale accuracy.

Percentage Error:-

$$\textit{Percentage Error} = \frac{\textit{Observed Value} - \textit{Actual Value}}{\textit{Actual Value}} \times 100\%$$

Procedure:-

1) Select the experiment, (Study of DAC, Using R-2R Ladder)

2) On Front panel of the VI, select the type of waveform we want to take through the tab that is either the computer generated waveform or the waveform simulated through DAQ.

a) If we are using DAQ for signal generation then input the sampling rate and no. of samples required per channel, here the temperature is varied from outside to get the waveform.
b) In case of computer generated signal temperature can be varied using the knob from inside the set up, from which we can select the desired temperature and get the waveform

3) Select the desired digital input and reference voltage using the knobs which are provided on the front panel.
4) The analog output voltage for corresponding digital input is generated and displayed on the front panel.
5) To continue simulating the same experiment with different digital inputs follow above 4, 5, 6 steps.
6) To stop the simulation click on the stop button.

Observational table:-

(Input Reference Voltage in Volts) V_{ref} =…………..V

Sr. No.	**Digital input**	**Analog output (v)**
1.	0000	
2.	0001	
3.	0010	
4.	0011	
5.	0100	
6.	0101	
7.	0110	
8.	0111	
9.	1000	
10.	1001	
11.	1010	
12.	1011	
13.	1100	
14.	1101	
15.	1110	
16.	1111	

Result:- The analog outputs are given in the observation table according to digital inputs shown in observation table. And the percentage error has been calculated using given formula.

Precaution:-

- Follow instructions carefully.
- For fetching correct value, wait until the process gets complete.
- Runtime engine should be properly installed.
- Switch OFF the supply after you completed the experiment.