CSE 350
Digital Electronics and Pulse Techniques

Analog to Digital Converter (ADC)

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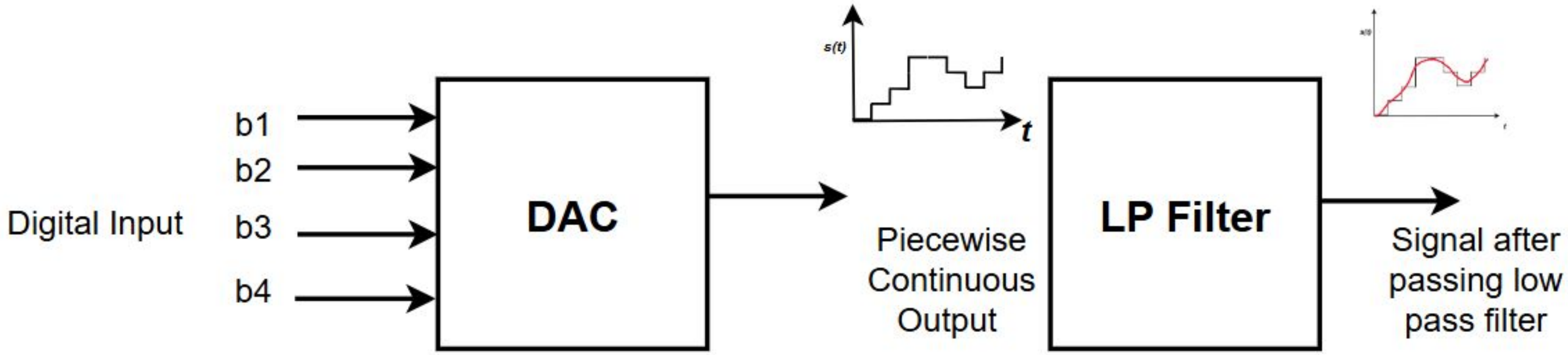
Digital to Analog Converter (DAC)



Binary to Decimal Conversion

Binary Number: $B_3 B_2 B_1 B_0$

Equivalent Decimal Number: $B_3 * 8 + B_2 * 4 + B_1 * 2 + B_0 * 1$

Example : Convert 1101_2 value into a decimal value.

Solve: $1001_2 = 1 * 8 + 0 * 4 + 0 * 2 + 1 * 1 = 9_{10}$

Binary Weighted DAC

Key features of this circuit,

- LSB branch will contain biggest resistor
- MSB branch will contain Smallest resistors
- Output will be positive if the input voltage is negative
- Resistor of adjacent branch will be either double or half
- There are 2^n output level for n bit input.

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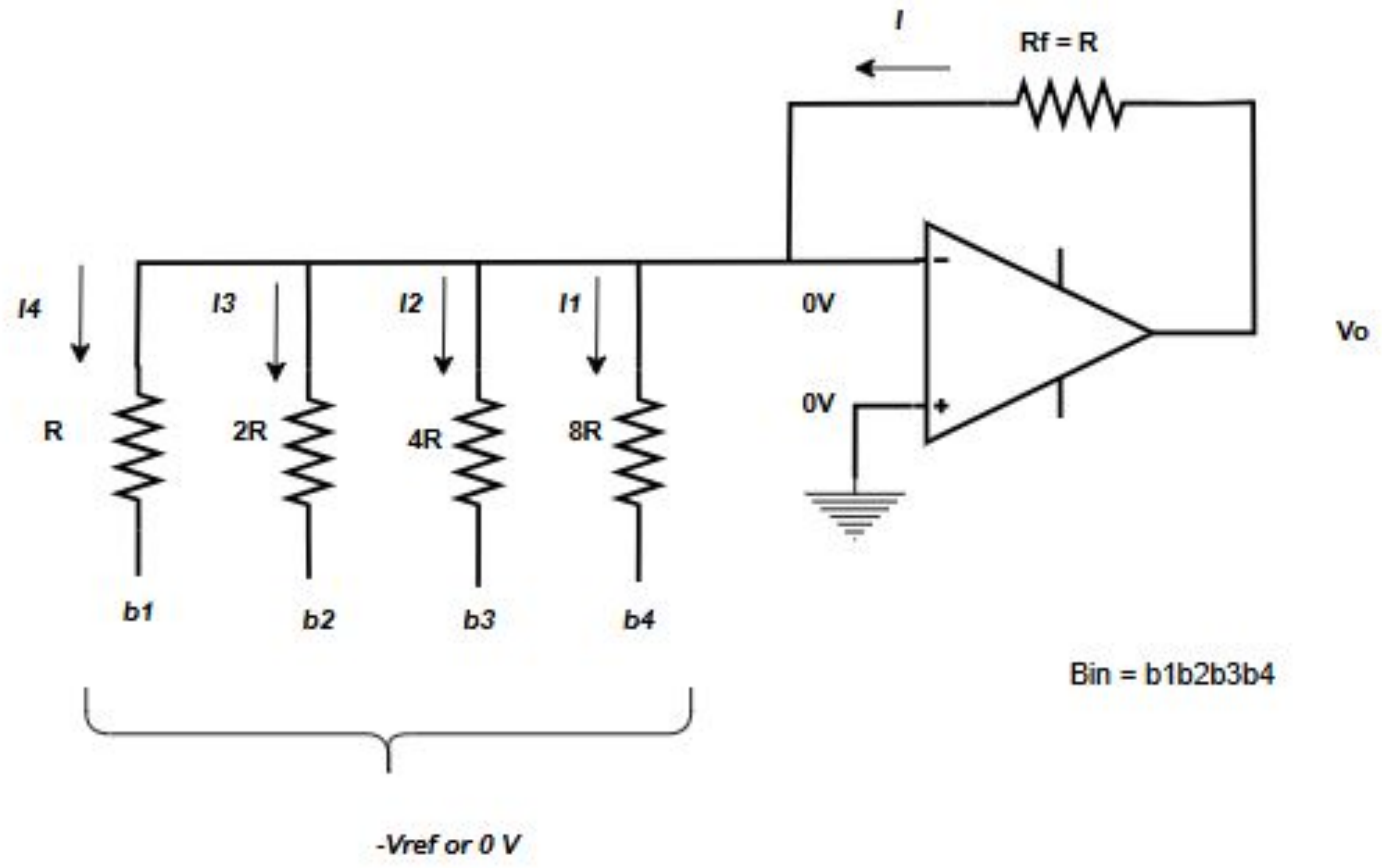
Output of the DAC circuit



Digital to Analog Converter (DAC)

If $b_1 = 1$, input of first branch is connected to the $-V_{REF}$ and

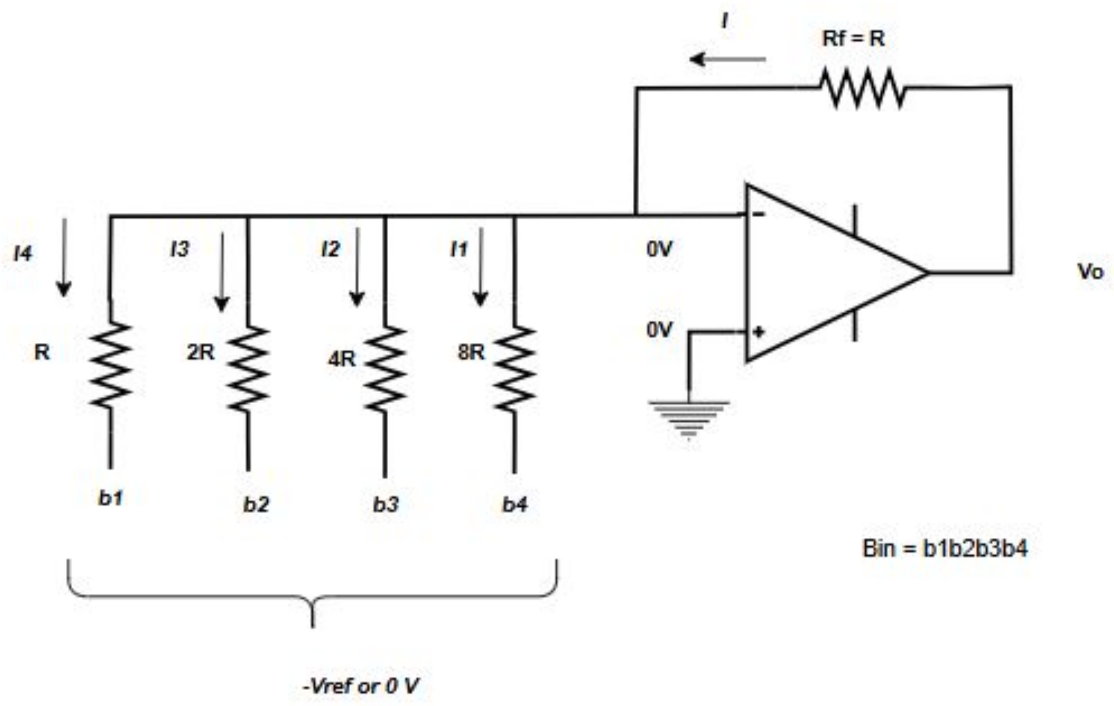
If $b_1 = 0$, input of the first branch is connected to the $0V$ (GND).

Same goes for the b_2, b_3 , b_4

Voltage of the first branch can be modeled as,

$$V_1 = -b_1 V_{REF}$$

Same for other brach.



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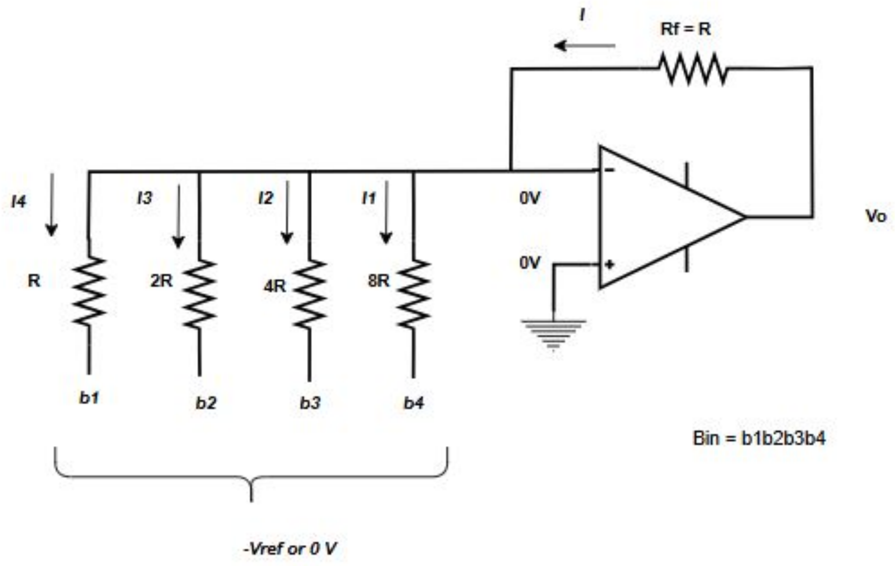
Digital to Analog Converter (DAC)

Node equation at $V\_$ terminal,

$$I = I_1 + I_2 + I_3 + I_4$$

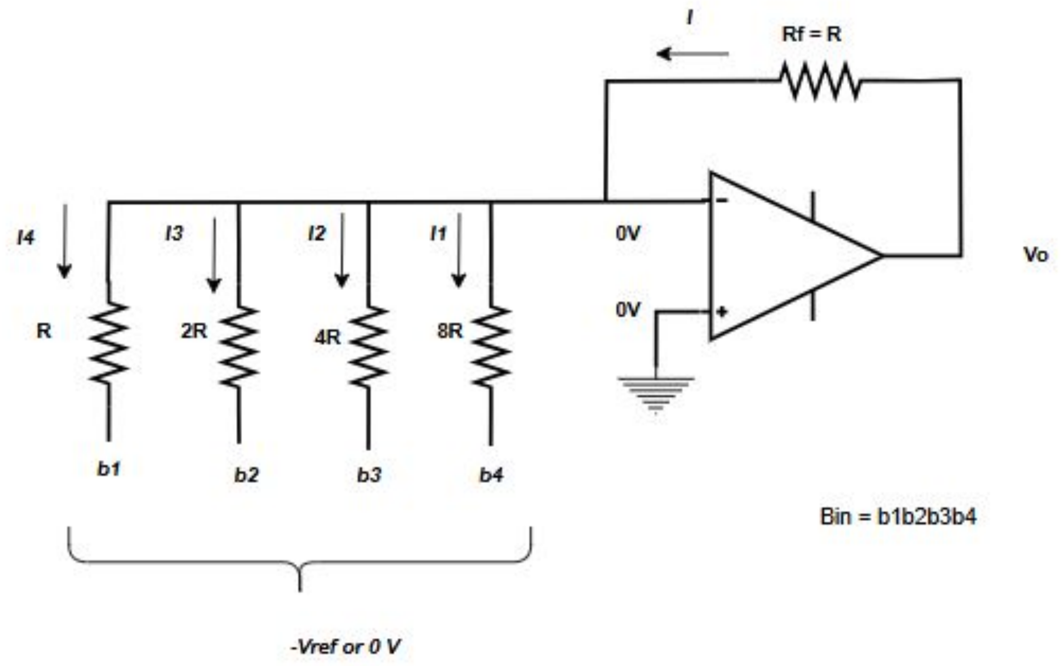
$$\Rightarrow \frac{V_o - 0}{R} = \frac{0-(-b_1 V_{REF})}{R} + \frac{0-(-b_2 V_{REF})}{2R} + \frac{0-(-b_3 V_{REF})}{4R} + \frac{0-(-b_4 V_{REF})}{8R}$$

$$V_o = V_{RE}(b_1 + \frac{b_2}{2} + \frac{b_3}{4} + \frac{b_4}{8})$$



Digital to Analog Converter (DAC)

Table: For different input combination.
Combination $= 2^4 = 16\,, V_{REF} = 8\,V$



b1	B2	b3	b4	Vo
0	0	0	0	0V
0	0	0	1	1V
0	0	1	0	2V
0	0	1	1	3V
0	1	0	0	4V
0	1	0	1	5V
0	1	1	0	6V
0	1	1	1	7V
1	0	0	0	8V
1	0	0	1	9V
1	0	1	0	10V
1	0	1	1	11V
1	1	0	0	12V
1	1	0	1	13V
1	1	1	0	14V
1	1	1	1	15V

Step Size

If $V_{REF} = 8\,V$, what will be the

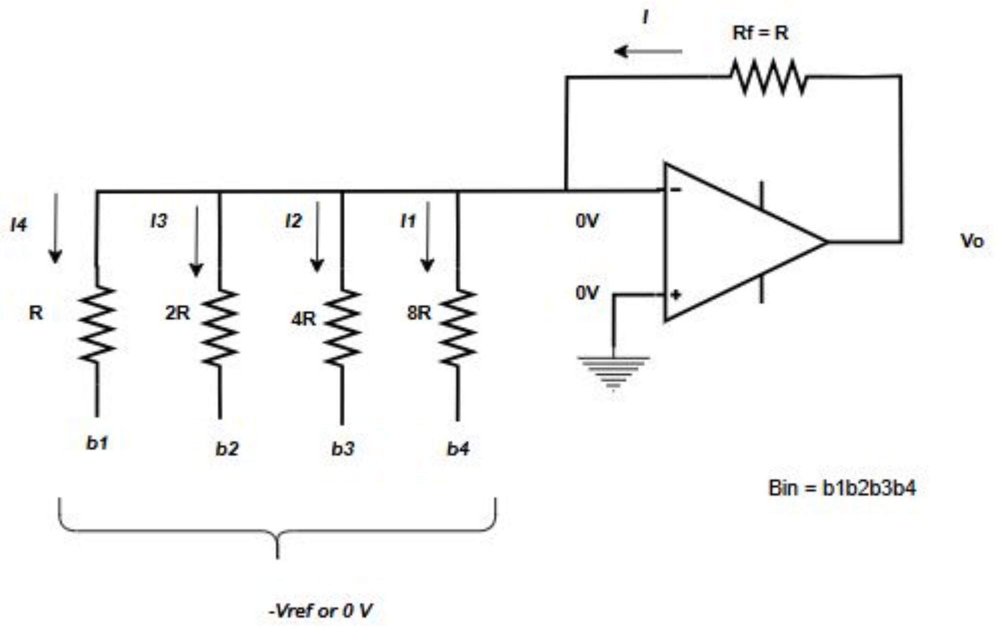
step size ?

Step size is the difference between two adjacent output values or the output value for the LSB bits contribution only.

For 0001 input, output will be the step size.

$$\Delta = V_{REF}\left(b1 + \frac{b2}{2} + \frac{b3}{4} + \frac{b4}{8}\right)$$

$$= 8\left(0 + \frac{0}{2} + \frac{0}{4} + \frac{1}{8}\right) = 1\text{ V}$$



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Maximum Output

If $V_{REF} = 8\,V$, what will be the

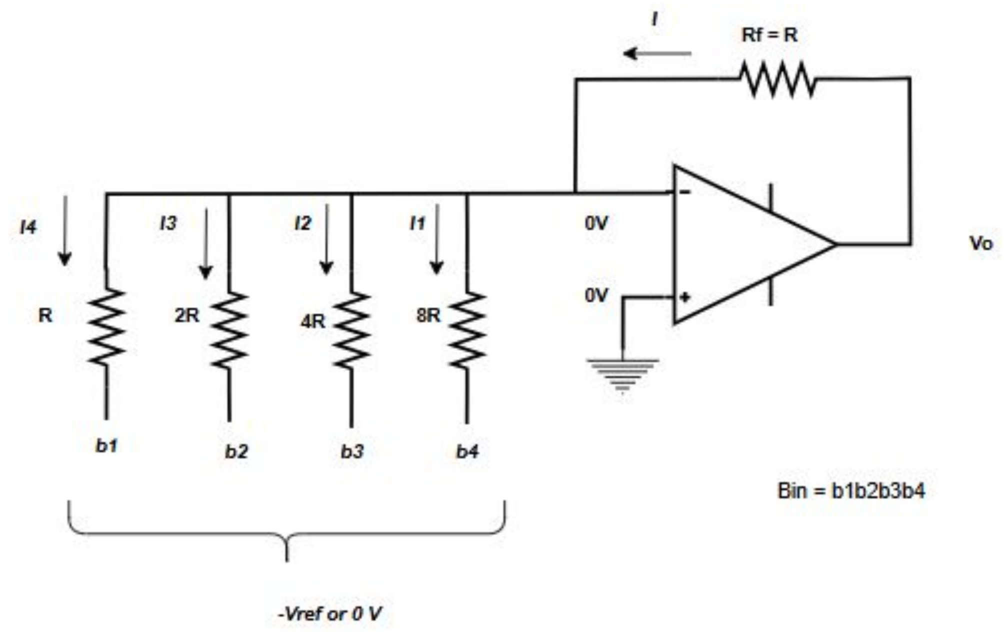
Max output ?

Max output level can be found for high input at every input.

For 1111 input, output will be max.

$$\Delta = V_{REF}\left(b1 + \frac{b2}{2} + \frac{b3}{4} + \frac{b4}{8}\right)$$

$$= 8\left(1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8}\right) = 15\text{ V}$$



General Formula for DAC

Binary: DCBA

$$V_o = -R_f\left(\frac{V_D}{R_D} + \frac{V_C}{R_C} + \frac{V_B}{R_B} + \frac{V_A}{R_A}\right)$$

$$R_A > R_B > R_C > R_D \text{ and factor of } 2$$

If we assign,

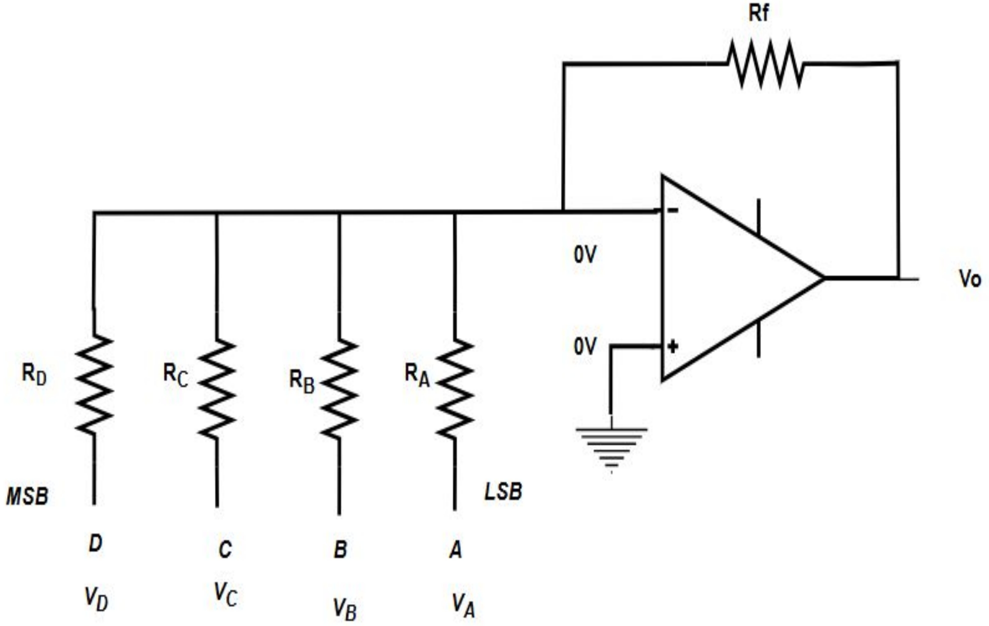
$$R_D = R, then, R_C = 2R, R_B = 4R, R_A = 8R$$

If we assign,

$$R_A = R, then, R_B = R/2, R_C = R/4, R_D = R/8$$

If we want, positive output, V_{REF} need to be negative.

If we want, negative output, V_{REF} need to be positive.



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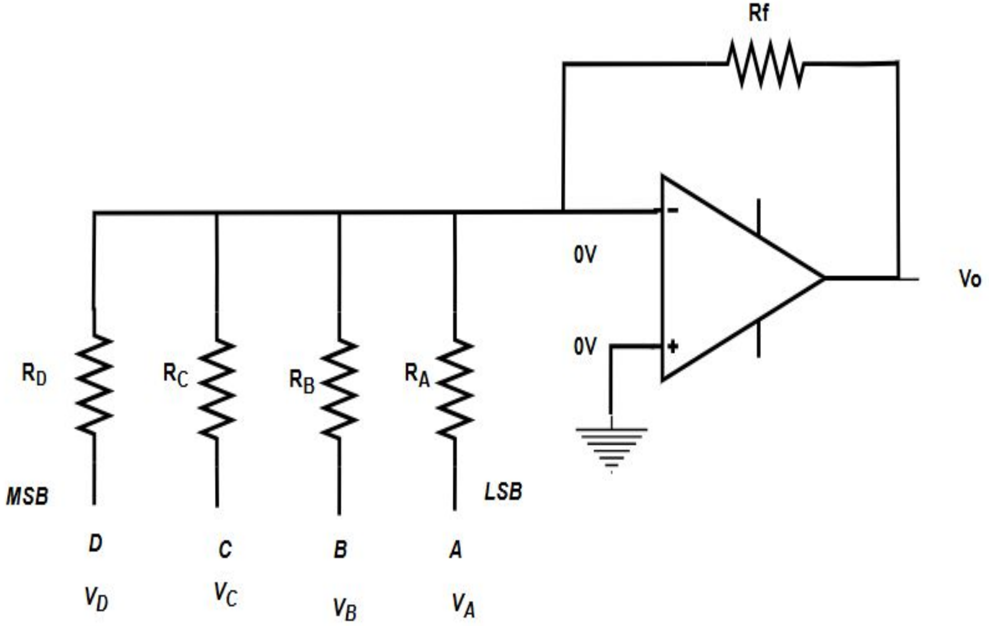
DAC (MSB R)

Binary: DCBA

If $V_A = A * V_{REF}, V_B = B * V_{REF}$,
$V_C = C * V_{REF}$, $V_D = D * V_{REF}$

$R_D = R, then, R_C = 2R, R_B = 4R, R_A = 8R$



$$V_o = -\frac{R_f}{R}\left(V_D + \frac{V_C}{2} + \frac{V_B}{4} + \frac{V_A}{8}\right)$$

$$V_o = -\frac{R_f * V_{REF}}{R}\left(D + \frac{C}{2} + \frac{B}{4} + \frac{A}{8}\right)$$

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DAC (LSB R)

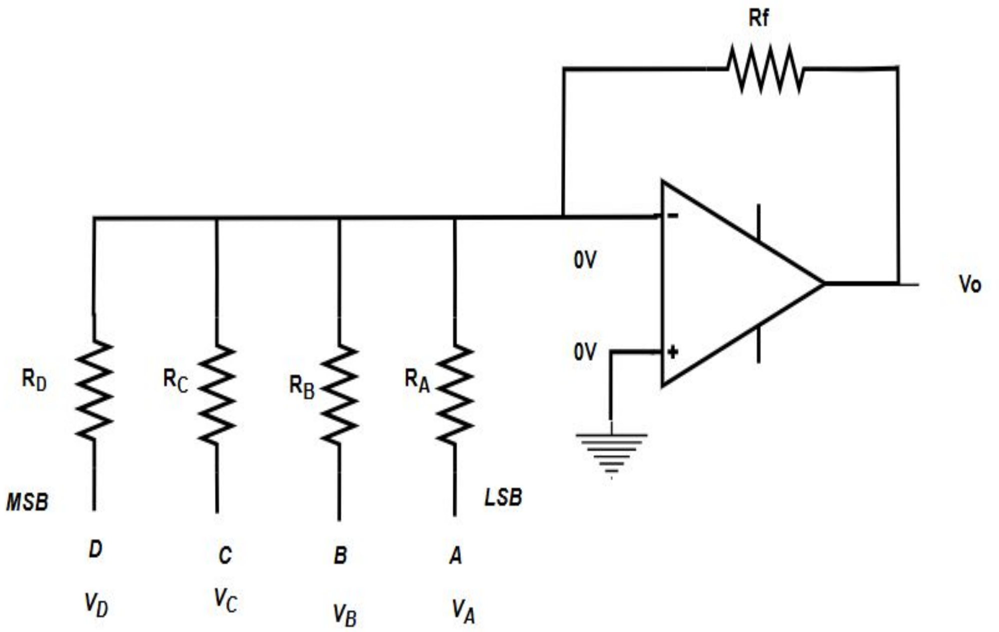
Binary: DCBA

If $V_A = A * V_{REF}, V_B = B * V_{REF}$,
$V_C = C * V_{REF}$, $V_D = D * V_{REF}$

$$R_A = R, R_B = \frac{R}{2}, R_C = \frac{R}{4}, R_D = \frac{R}{8}$$

$$V_o = -\frac{R_f}{R}(8 * V_D + 4 * V_C + 2 * V_B + 1 * V_A)$$

$$V_o = -\frac{R_f * V_{REF}}{R}(8 * D + 4 * C + 2 * B + 1 * A)$$



Exercise:

Binary: DCBA

If $R_A = R_F = 10k\Omega$, Find the following parameter for this DAC circuit. Given, $V_{REF} = 0.5\ V, V_H = 30\ V\ and\ V_L = -30\ V$

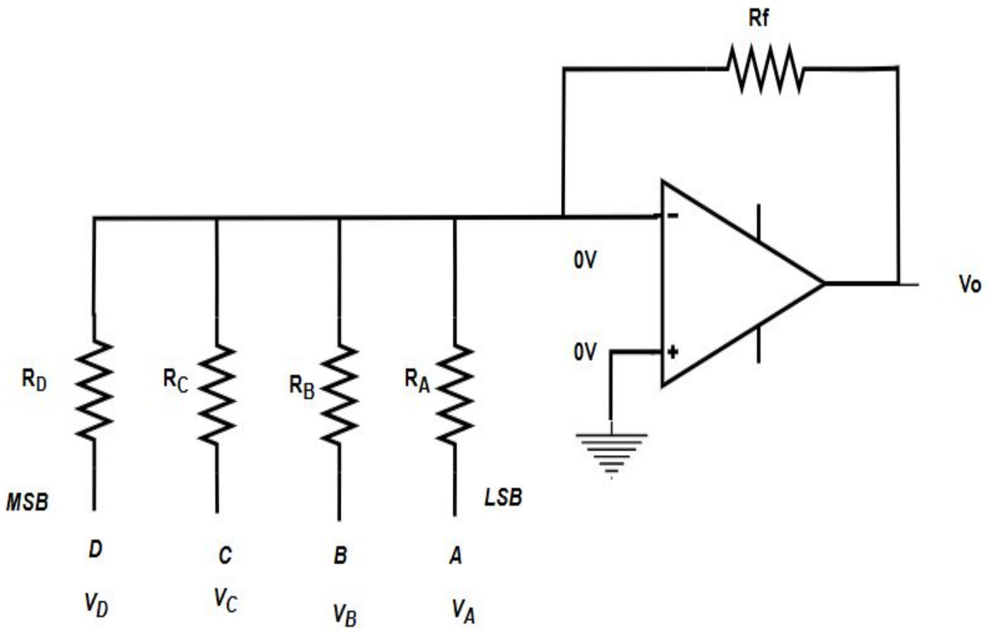
a. Find the value of maximum output.

b. Find the value of the step size.

c. Find the value of the 1LSB voltage.

d. Find the value of the 1MSB value.

e. Plot the Output voltage vs input binary.



Exercise:

The figure below shows the input-output characteristic of a converter. The output of the converter is denoted as V0 and the input as Vin. Identify the converter type and the number of bits used by the converter. Further, calculate Vref when RF = 2R.