Weighted Resistor Type DAC

The DAC converts digital or binary data into its equivalent analog value. The input digital data for a DAC is an n-bit binary word(D). The bit b_1 is called the most significant bit (MSB) and bit b_n the least significant bit (LSB). The binary number D can be represented as

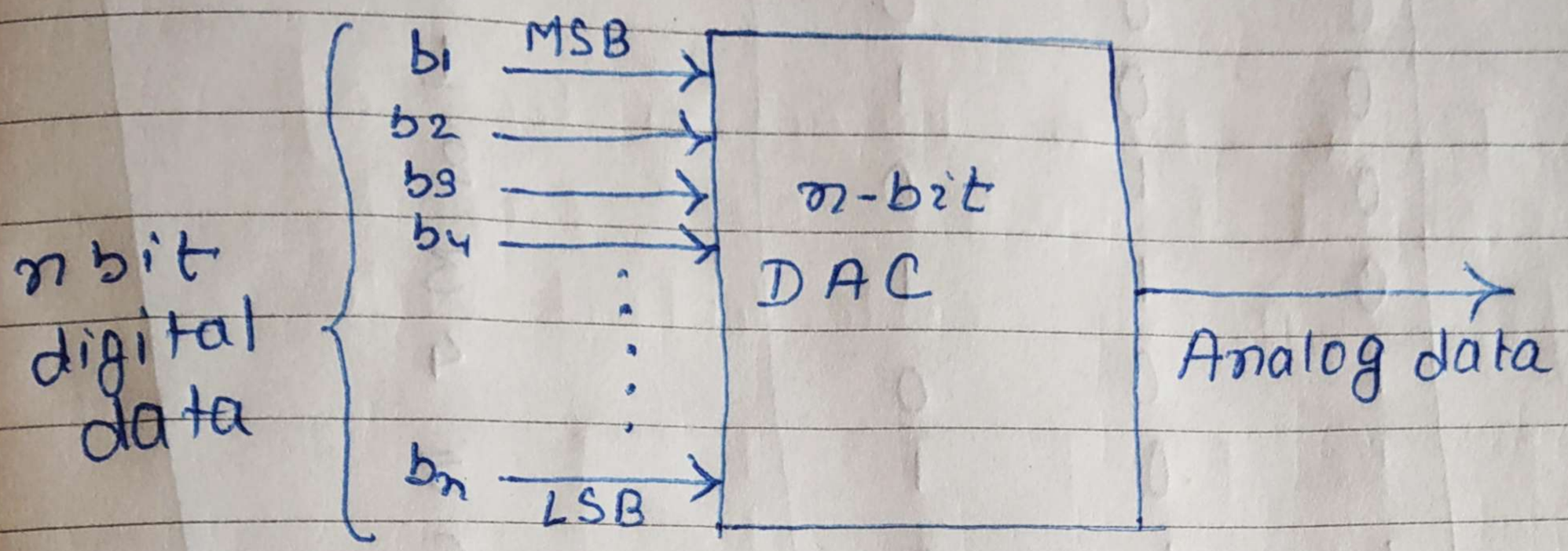
$$D = \frac{b_1}{2} + \frac{b_2}{2^2} + \frac{b_3}{2^3} + \cdots + \frac{b_n}{2^n}$$

The DAC accepts the binary input D and produces an analog output, which is proportional to D using a reference voltage V_R.

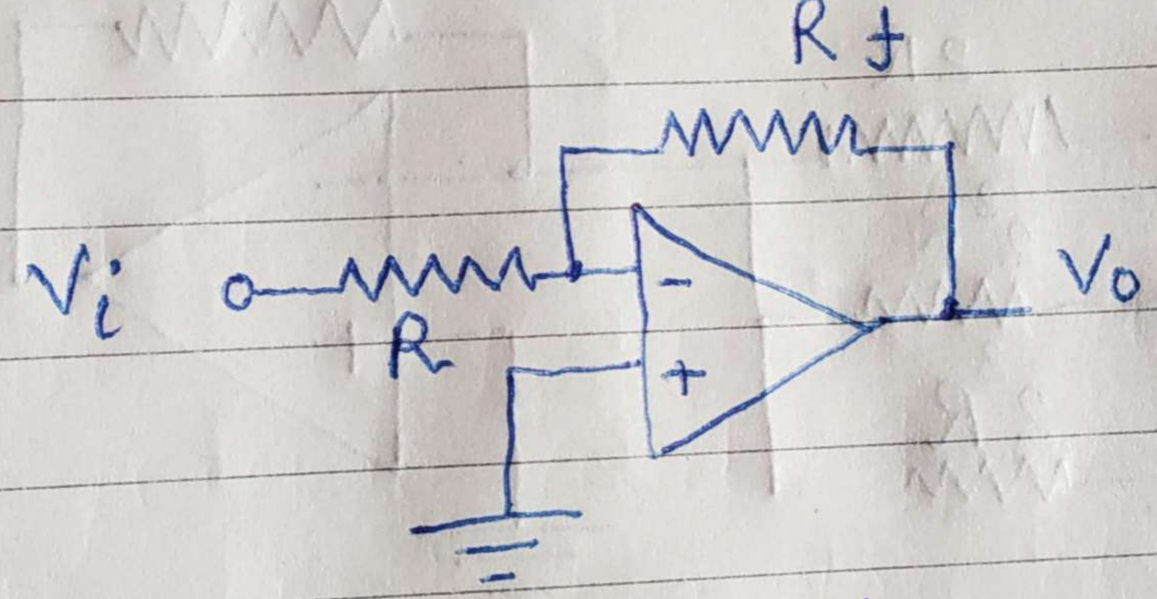
The conversion characteristic of DAC may be expressed as

$$V_0 = K V_R \left(b_1/2 + b_2/2^2 + b_3/2^3 + \cdots + b_n/2 \right.$$

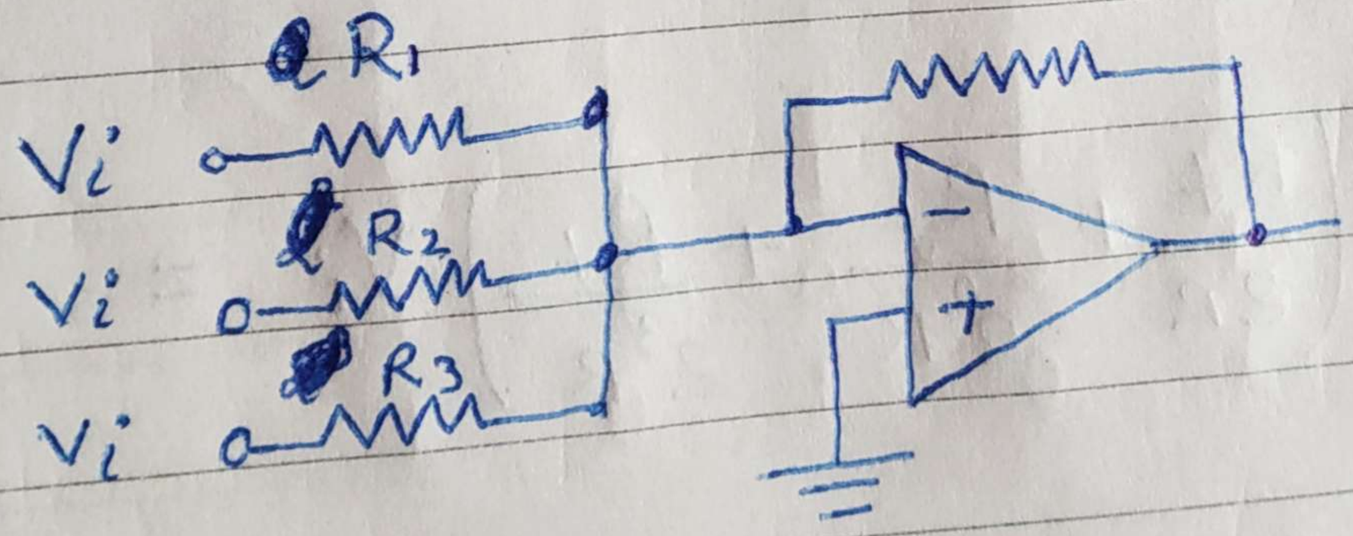
The Symbolic representation of an n-bit DAC is



Before Studying about Weighted Resistor Type DAC, we need to know about Op-amp circuit



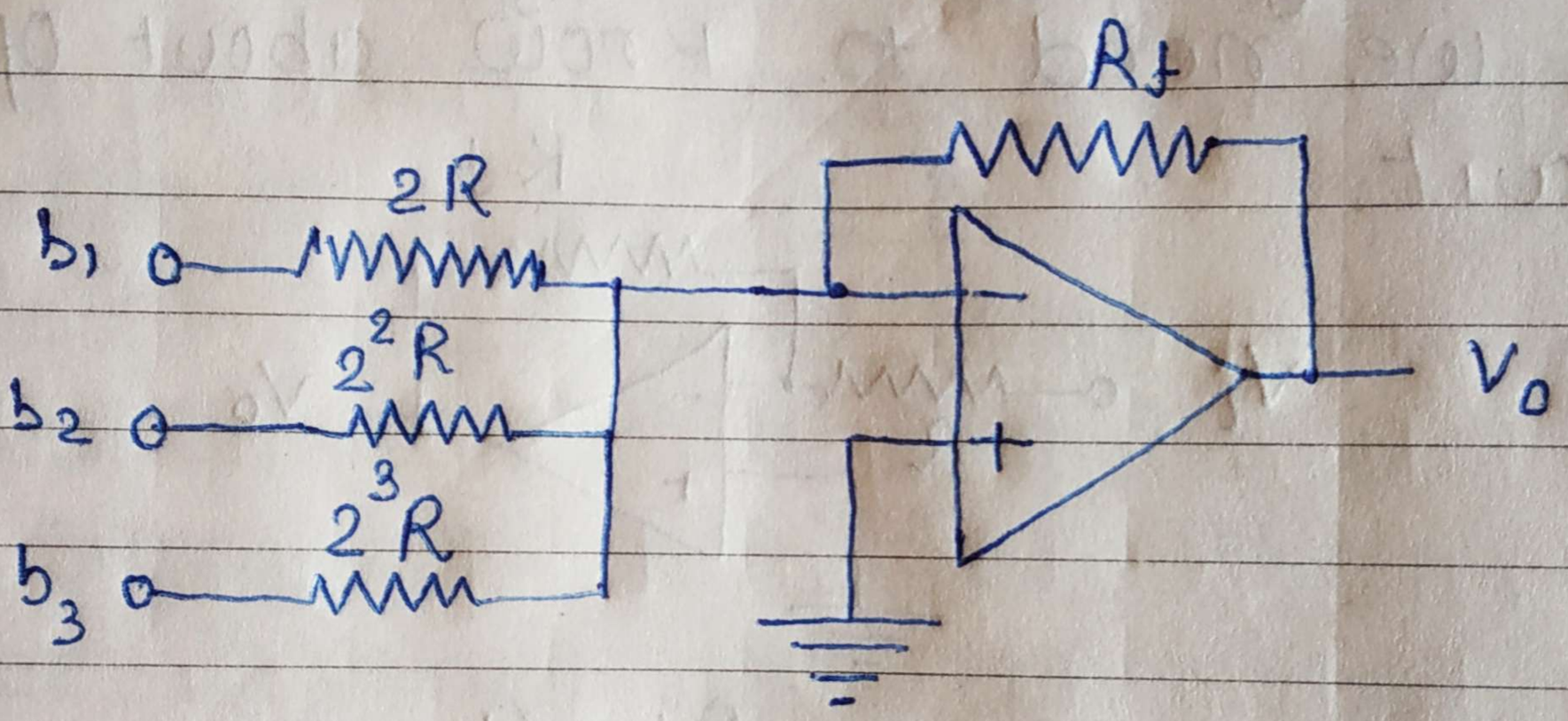
$$V_0 = -\frac{R_f}{R} V_i$$



$$V_0 = -\left(\frac{R_f}{R_1} + \frac{R_f}{R_2} + \frac{R_f}{R_3}\right) V_i$$

Let us consider 3-bit DAC

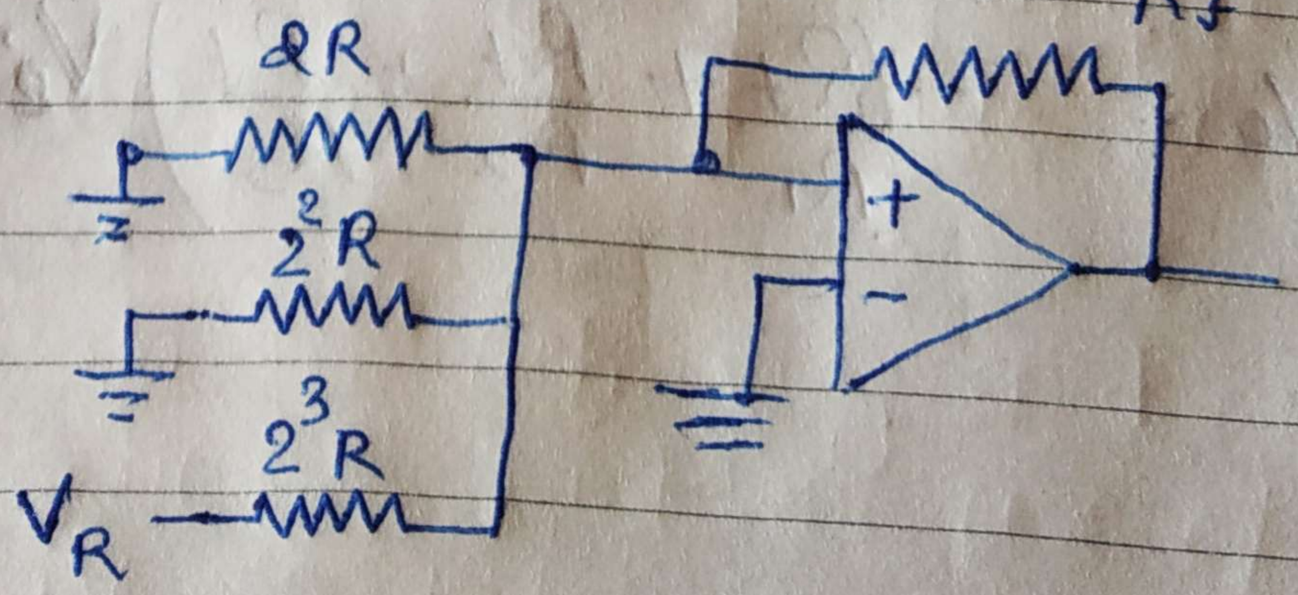
I/P b_1	b_2	b_3	Equivalent Analog O/P
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	7



For $b_1 = b_2 = b_3 = 0$

$$V_o = -\left(\frac{R_f}{2R} + \frac{R_f}{2^2R} + \frac{R_f}{2^3R}\right) V_i = 0$$

AY For $b_1 = b_2 = 0$, $b_3 = 1 (V_R)$

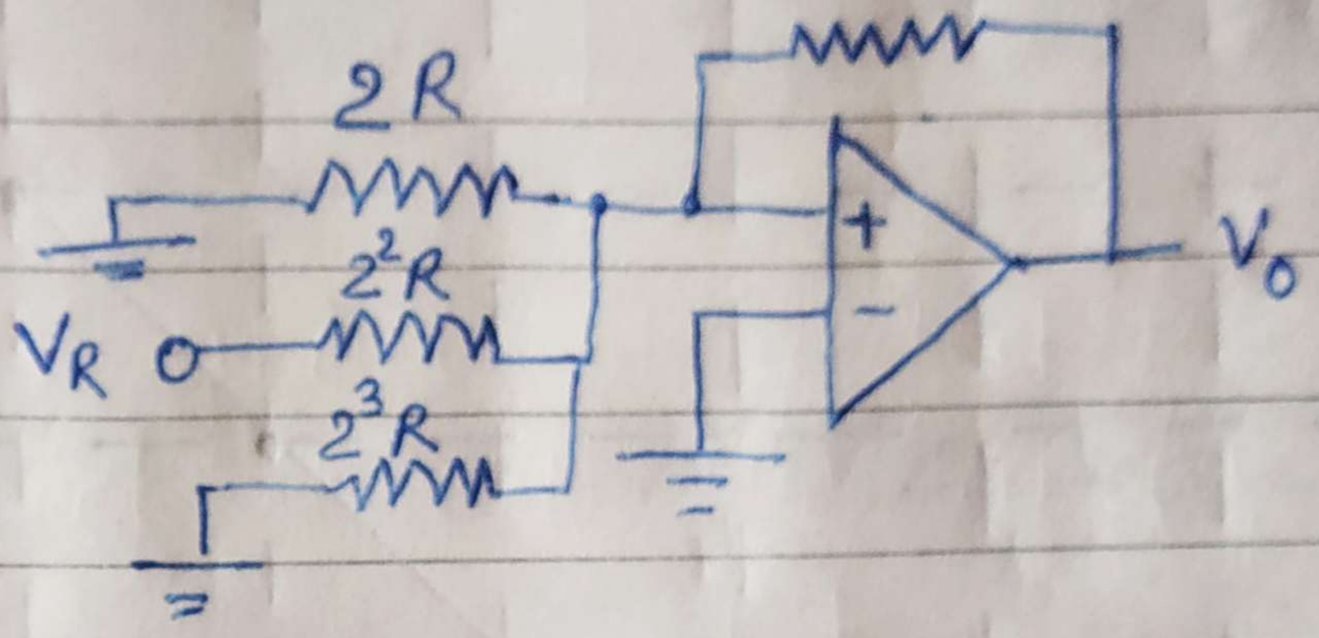


$$V_0 = -\frac{R_f}{2^3 R} V_R$$

If $V_R = -8V$ & $R = R_f$, then

$$V_0 = 1\,V$$

For $b_1 = b_3 = 0$, $b_2 = 1(V_R)$

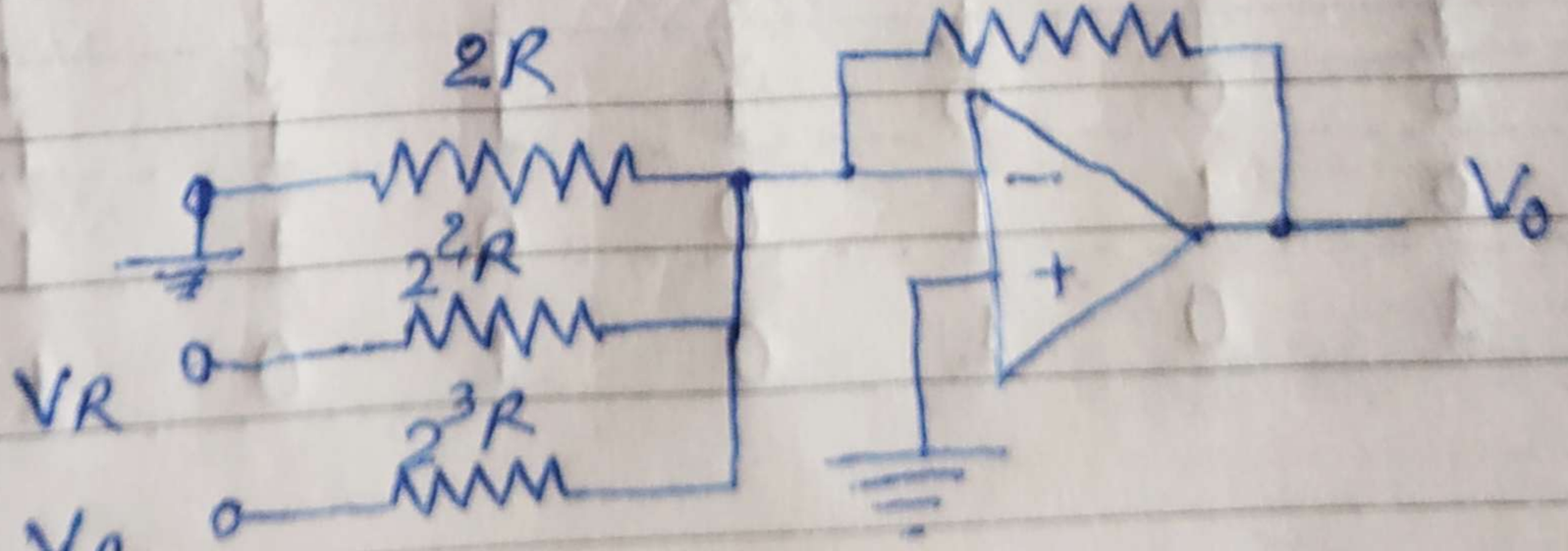


$$V_0 = -\frac{R_f}{2^2 R} V_R$$

If $V_R = -8V$ & $R = R_f$, then

$$V_0 = 2\,V$$

For $b_1 = 0$, $b_2 = b_3 = 1(V_R)$



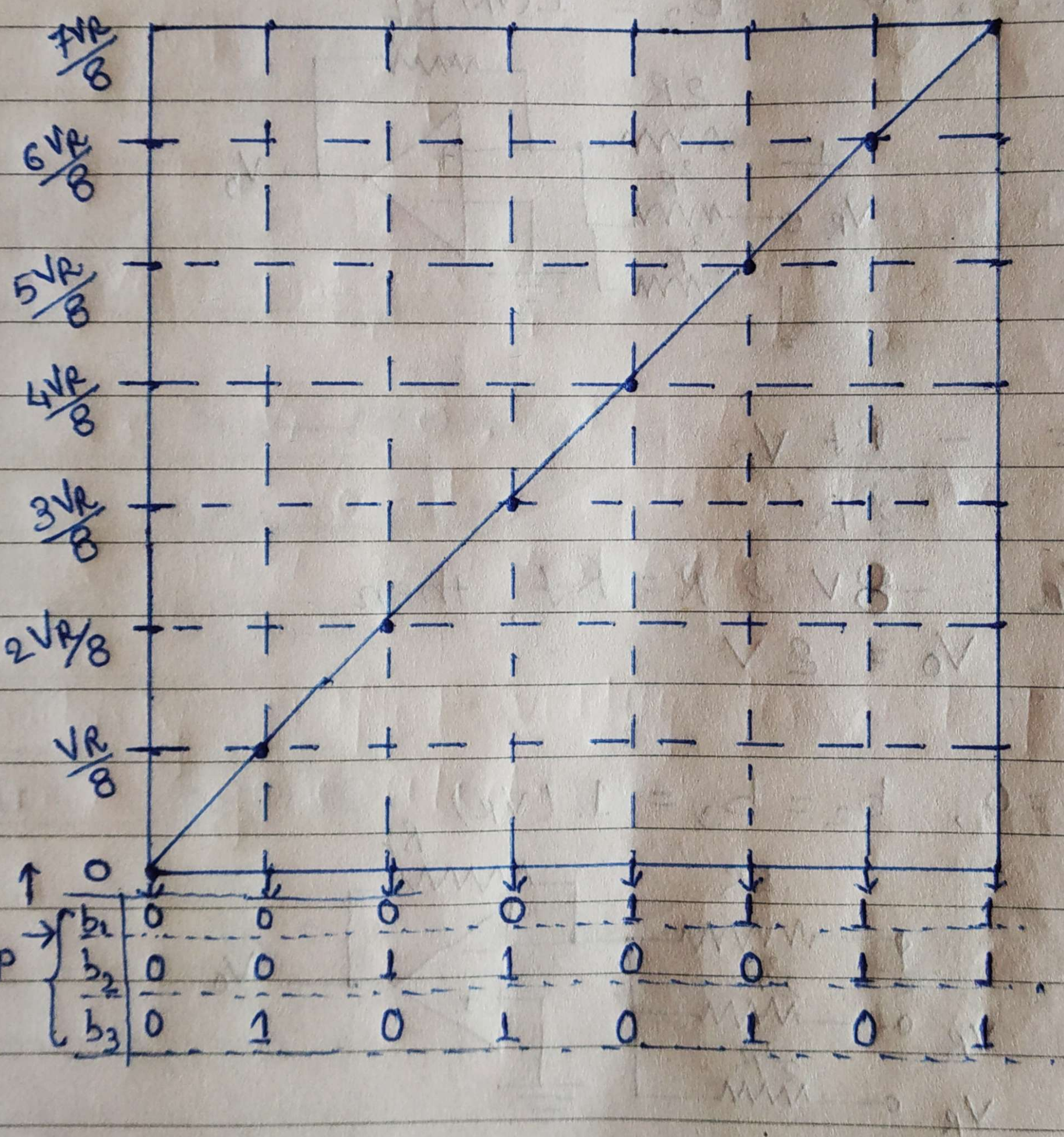
$$V_0 = -\left(\frac{R_f}{2^2 R} + \frac{R_f}{2^3 R}\right) V_R$$

for $V_R = -8V$, $R_f = R$,

$$V_0 = 3\,V$$

Similarly results for rest of the case can be calculated.

The transfer ~~function~~ characteristics of 3-bit weighted Resistor DAC can be drawn from above calculated value as



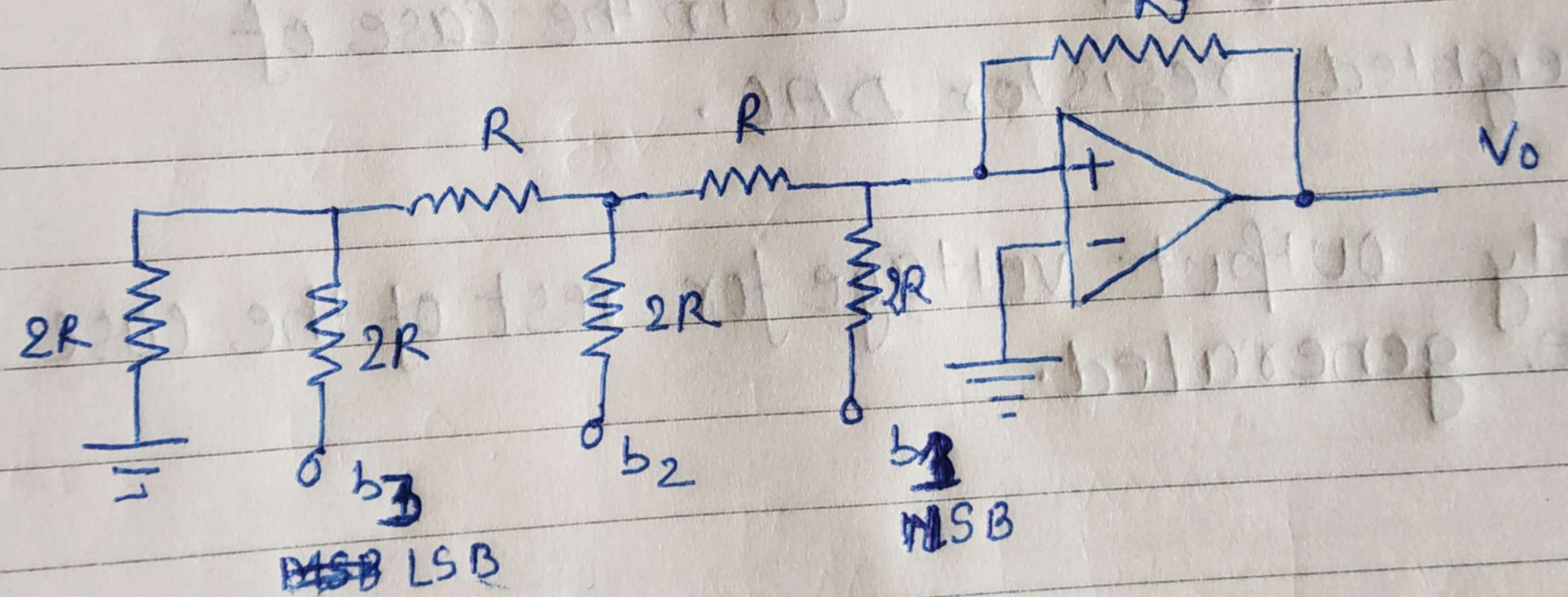
The main disadvantage of binary weighted DAC is the requirement of wide range of resistor values.

The limitation in achieving and maintaining resistor ratios restrict the use of weighted resistor DAC to below 8-bit of word length.

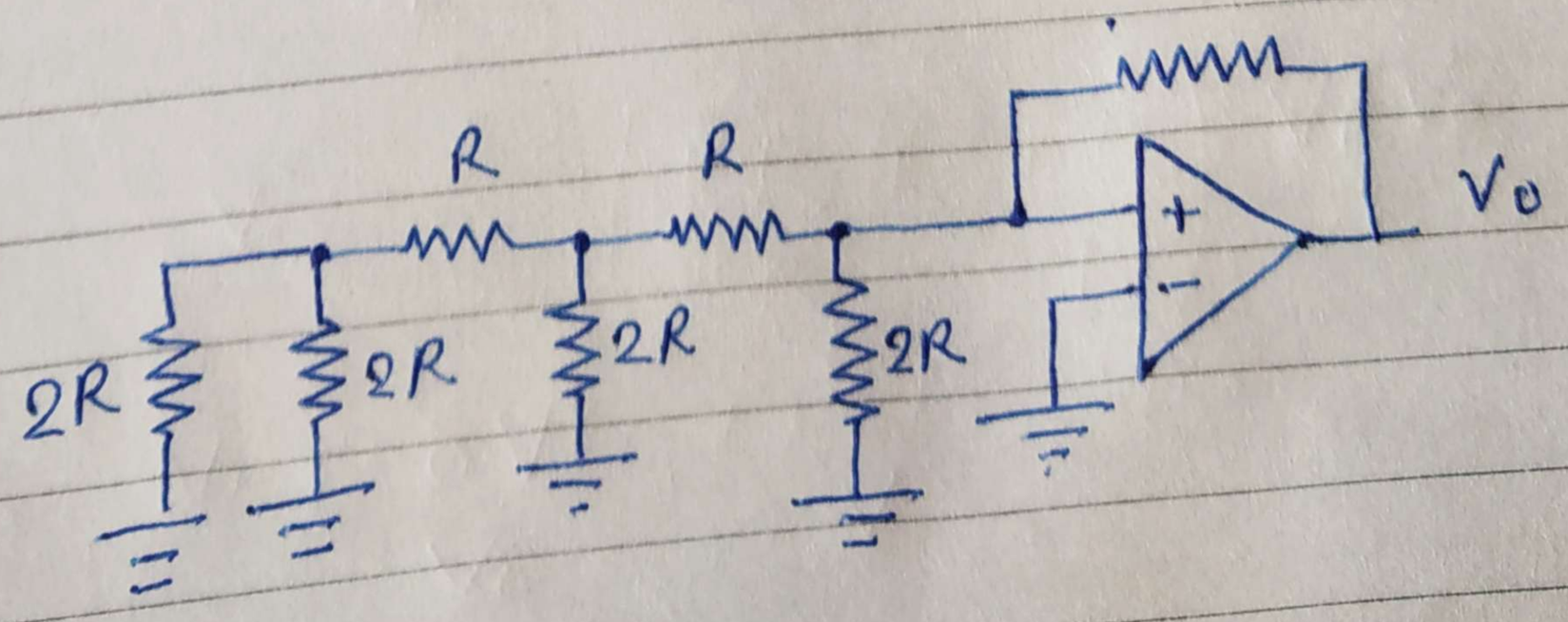
R-2R Ladder DAC

A wide range of resistor values is required in the design of binary weighted resistor DAC. In R-2R ladder DAC, resistors of only two values i.e R and 2R are used. Hence, it is suited well for integrated circuit fabrication.

Let us consider a 3-bit R-2R ladder DAC, with binary input b_1 b_2 b_3 with b_1 as MSB & V_0 as analog output

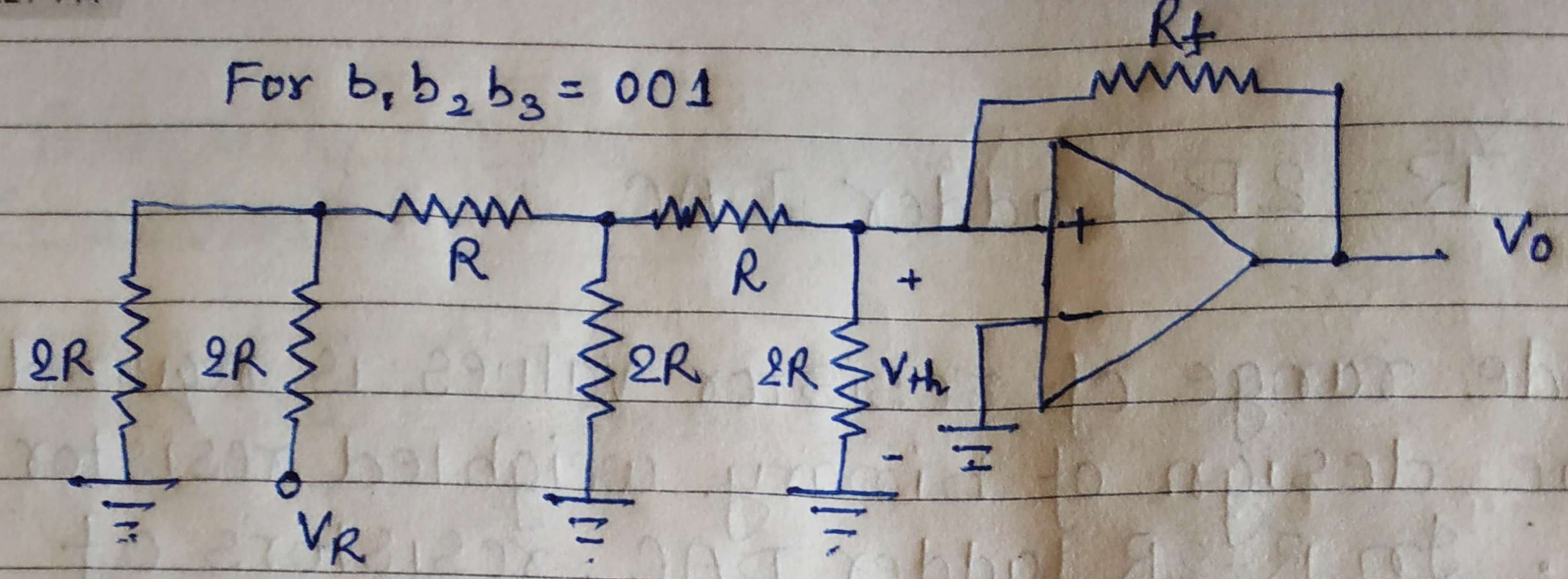


For $b_1 b_2 b_3 = 0\,0\,0$, Circuit would be



$V_0 = 0$

For $b_1 b_2 b_3 = 001$



$$V_{Th} = \frac{V_R}{4}$$

$$R_{Th} = 2R$$

$$V_o = -\frac{R_f}{2R} \times \frac{V_R}{4} = -\frac{R_f}{R}\frac{V_R}{8}$$

for $V_R = -8$, $R_f = R$

$V_o = 1$ as in the case of weighted resistor DAC.

Similarly output voltage for rest of the case can be generated.