UNIT VI

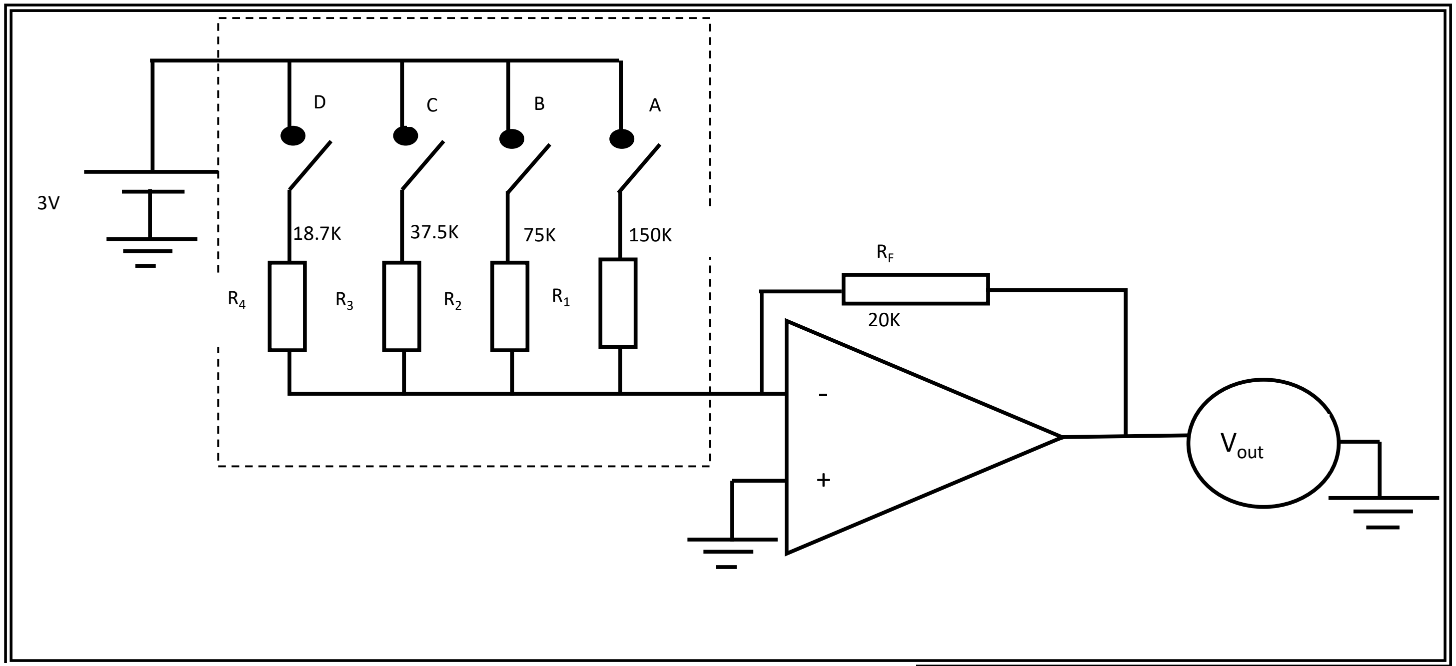
Analog to digital converter

And

Digital to analog converter

Weighted Binary Resistance Network

Weighted Binary Resistance Network Circuit



Voltage Gain (A_V) = $\frac{R_F}{R_1}$

$R_{IN} = \frac{1}{R_4} + \frac{1}{R_3} + \frac{1}{R_2} + \frac{1}{R_1}$

Voltage Output (Vout) = Vref X Av or Vref X R_F X Rin

Continue

- For example
- Referring to the circuit as shown, the highest value resistor (150KΩ) is a digital input resistor. The smallest bit (least significant bit), and the values of other resistor is

$$R_1 = 150K$$

$$R_2 = \frac{R_1}{2^1} = \frac{150K}{2^1} = 75k\Omega, \Rightarrow \text{Bit ke } 2^1$$

$$R_3 = \frac{R_1}{2^2} = \frac{150K}{2^2} = \frac{150K}{4} = 37.5k\Omega, \quad \Rightarrow \text{Bit ke } 2^2$$

$$R_4 = \frac{R_1}{2^3} = \frac{150K}{8} = 18.75k\Omega \quad \Rightarrow \text{Bit ke } 2^3$$

Circuit analysis to find V_{out}

If binary input is 0001

$R1 = 150K\Omega$, $R_F = 20K\Omega$, $Vref = 3V$

$$\text{Voltage Gain } (A_V) = \frac{R_F}{R1} = \frac{20K\Omega}{150K\Omega} = 0.133$$

$$\begin{aligned} Vout &= Vref \times A_V \\ &= 3V \times 0.1333 \\ &= \underline{0.4V} \end{aligned}$$

Continue

- If binary input is 0110

$R2 = 75K\Omega$, $R3 = 37.5K\Omega$, $R_F = 20K\Omega$, $Vref = 3V$

$R_T = R2//R3 = 25K\Omega$

$$\text{Voltage Gain } (A_V) = \frac{R_F}{R_T} = \frac{20K\Omega}{25K\Omega} = 0.8$$

$$\begin{aligned} Vout &= Vref \times A_V \\ &= 3V \times 0.8 \\ &= \underline{2.4V} \end{aligned}$$

Calculate

❖ If binary input is 1100

R3 = 37.5KΩ, R4=18.75 R_F = 20KΩ, Vref = 3V

R_T = R3//R4 = 12.5KΩ

Voltage Gain (A_V) = $\frac{R_F}{R_T}$ = $\frac{20K\Omega}{12.5K\Omega}$ = 1.6

Vout = Vref X A_V
= 3V X 1.6
= <u>4.8</u>

Simply that we can see the resulting output is shown in the table below

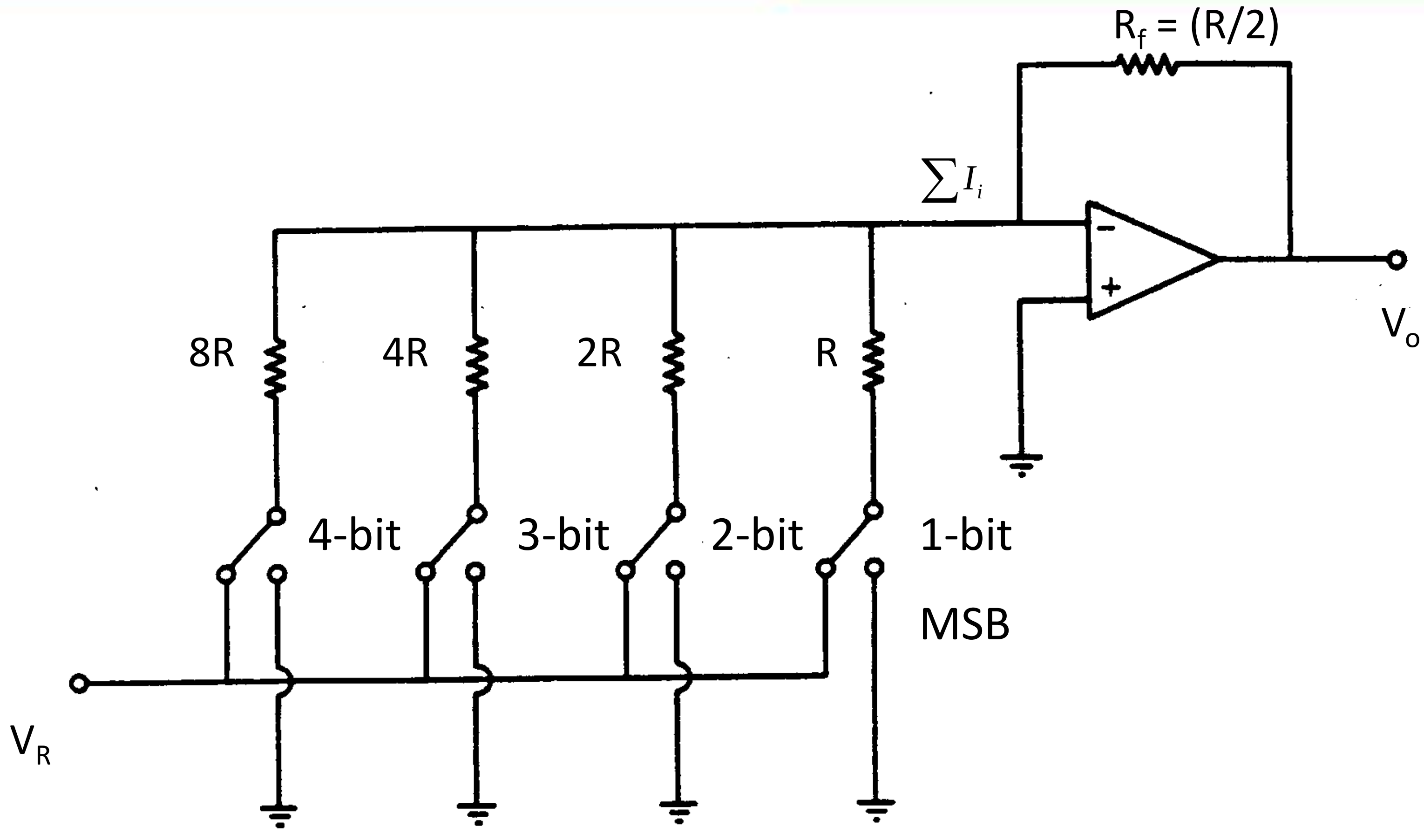
Decimal	Digital input				V_{out} (V)
	D	C	B	A	
0	0	0	0	0	0
1	0	0	0	1	0.4
2	0	0	1	0	0.8
3	0	0	1	1	1.2
4	0	1	0	0	1.6
5	0	1	0	1	2.0
6	0	1	1	0	2.4
7	0	1	1	1	2.8
8	1	0	0	0	3.2
9	1	0	0	1	3.6
10	1	0	1	0	4.0
11	1	0	1	1	4.4
12	1	1	0	0	4.8
13	1	1	0	1	5.2
14	1	1	1	0	5.6
15	1	1	1	1	6.0

Example

Find output voltage and current for a binary weighted resistor DAC of 4 bits where :

R = 10 k Ohms, R_f = 5 k Ohms and V_R = 10 Volts. Applied binary word is 1001.

Solution



Solution Cont'd

$$I_o = -\frac{10\,\text{V}}{\Omega}\left[\frac{1}{2^0 * 10^4} + \frac{0}{2^1 * 10^4} + \frac{0}{2^2 * 10^4} + \frac{1}{2^3 * 10^4}\right]$$

$$I_0 = \text{-}\,0.001125\,\text{A}$$

$$\text{V}_0 = \text{-}\,\text{R}_\text{f}\,\text{I}_0$$

$$V_0 = -(5 * 10^3\,\Omega)(-0.001125\,\text{A}) = 5.625\,\text{V}$$

Solution Cont'd

Binary input = 1001 = 9

From example, $V_0 = 5.625V$

$V_0/V_R = 5.625V/10V = 9/16$

Binary Weighted Resistor

- Advantages
  - Simple Construction/Analysis
  - Fast Conversion
- Disadvantages
  - Requires large range of resistors (2000:1 for 12-bit DAC) with necessary high precision for low resistors
  - Requires low switch resistances in transistors
  - Can be expensive. Therefore, usually limited to 8-bit resolution.

Limitations of binary weighted

Has problems if bit length is longer than 8 bits

For example, if R = 10 k Ohms

$R_8 = 2^{8-1}(10 \text{ k Ohms}) = 1280 \text{ k Ohms}$

If $V_R = 10$ Volts,

$I_8 = 10V/1280 \text{ k Ohms} = 7.8\ \mu A$

Op-amps to handle those currents are expensive because this is usually below the current noise threshold.

Limitations Cont'd

If R = 10 Ohms and V_{ref} = 10 V

I = V_R/R = 10V/10 Ohms = 1 A

This current is more than a typical op-amp can handle.

Large resistors more error

Questions

Quick Quiz

Why the switches used in weighted resistor DAC are of single pole double throw (SPDT) type?

a) To connect the resistance to reference voltage
b) To connect the resistance to ground
c) To connect the resistance to either reference voltage or ground
d) To connect the resistance to output

Quick Quiz

What is the disadvantage of binary weighted type DAC?

a) Require wide range of resistors
b) High operating frequency
c) High power consumption
d) Slow switching

Quick Quiz

- The smallest resistor in a 12 bit weighted resistor DAC is 2.5kΩ, what will be the largest resistor value?
  a) 40.96MΩ
  b) 10.24MΩ
  c) 61.44 MΩ
  d) 18.43MΩ