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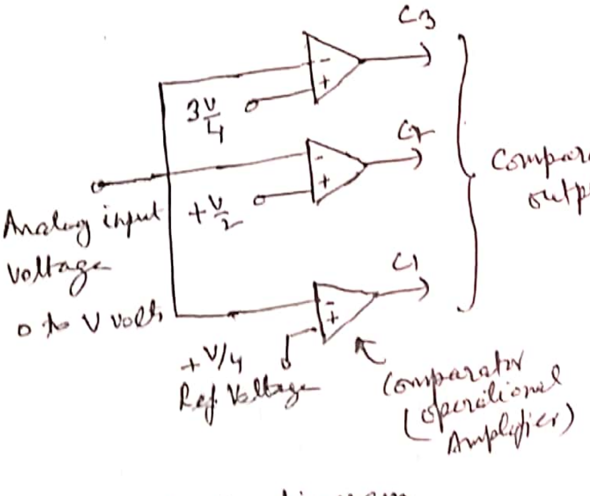
A/D and D/A Conversion.

Analog-to-Digital Conversion:- The process of changing an analog signal to an equivalent digital signal is accomplished by the use of an A/D converter. For example, an A/D converter is used to change the analog output signals from transducers into equivalent digital signals. These signals would then be in a form suitable for entry into a digital system. An A/D converter (ADC) is often referred to as an encoding device since it is used to encode signals for entry into a digital system.

A number of different methods have been developed.
(1) Counter method (2) Simultaneous method (3) Continuous A/D conversion
(4) Dual-slope A/D conversion

A/D Converter - ~~counter~~ simultaneous method:- The simultaneous method of A/D conversion is based on the use of a number of comparator circuits. The analog signal to be digitized serves as one of the inputs to each comparator. The second input is a standard voltage.

If the analog input signal exceeds the reference voltage to any comparator that comparator turns on. Now, if all the comparators are off, the analog input signal must be between 0 and $+V/4$. If C_1 is high (comparator C_1 is on) and C_2 and C_3 are low, the input must be between $+V/4$ and $V/2$. If C_1 and C_2 are high while C_3 are low, the input must be between $+\frac{V}{2}$ and $\frac{3V}{4}$. Finally, if all comparator outputs are high, the input signal must be between $+\frac{3V}{4}$ and $+V$. The comparator output levels for the various ranges of input voltages are summarized.



Logic diagram

Input Voltage	Comparator output C_1	C_2	C_3	Binary output 2^1	2^0
0 to $+\frac{V}{4}$	L	L	L	0	0
$+\frac{V}{4}$ to $\frac{V}{2}$	H	L	L	0	1
$+\frac{V}{2}$ to $3V/4$	H	H	L	1	0
$+\frac{3V}{4}$ to $+V$	H	H	H	1	1

Comparator outputs for input voltage ranges.

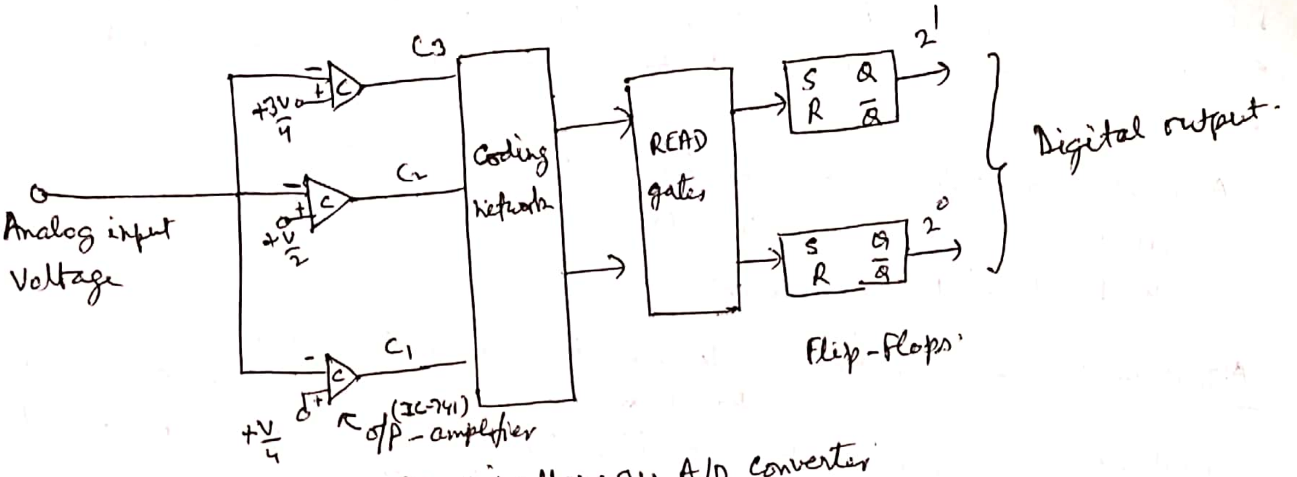
The reference voltages used are $+\frac{V}{4}$, $+\frac{V}{2}$ and $+\frac{3V}{4}$. The system is then capable of accepting an analog input voltage between 0 and $+V$.

For the 2-bit converter, there are three comparators were necessary for defining four ranges ($2^2=4$).

In general, it can be said that 2^n-1 comparators are required to convert to a digital signal that has n bits.

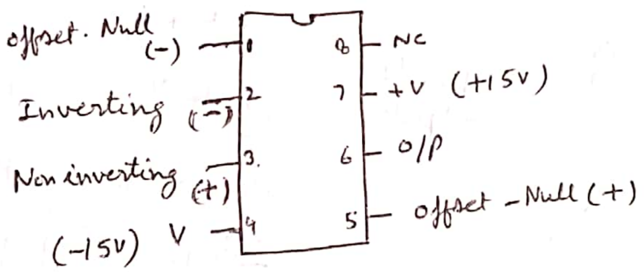
* There are four voltage ranges that can be detected by this converter. Four ranges can be effectively discerned by two binary digits. The three comparator outputs can then be fed into a coding

network to provide 2 bits which are equivalent to the input analog voltage. The bits of the coding network can then be entered into a flip-flop register for storage. The complete block diagram for such an A/D converter is shown in below fig.



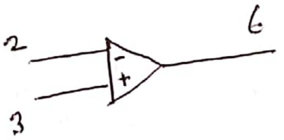
2 - bit simultaneous A/D converter

Digital Principles and Applications
Albert Paul Malvino & Donald P. Leach
Tata Mc Graw-Hill Publishing Company Limited



V ref.

IC-741
op-amplifier → Difference amplifier
two input < inverting, non-inverting

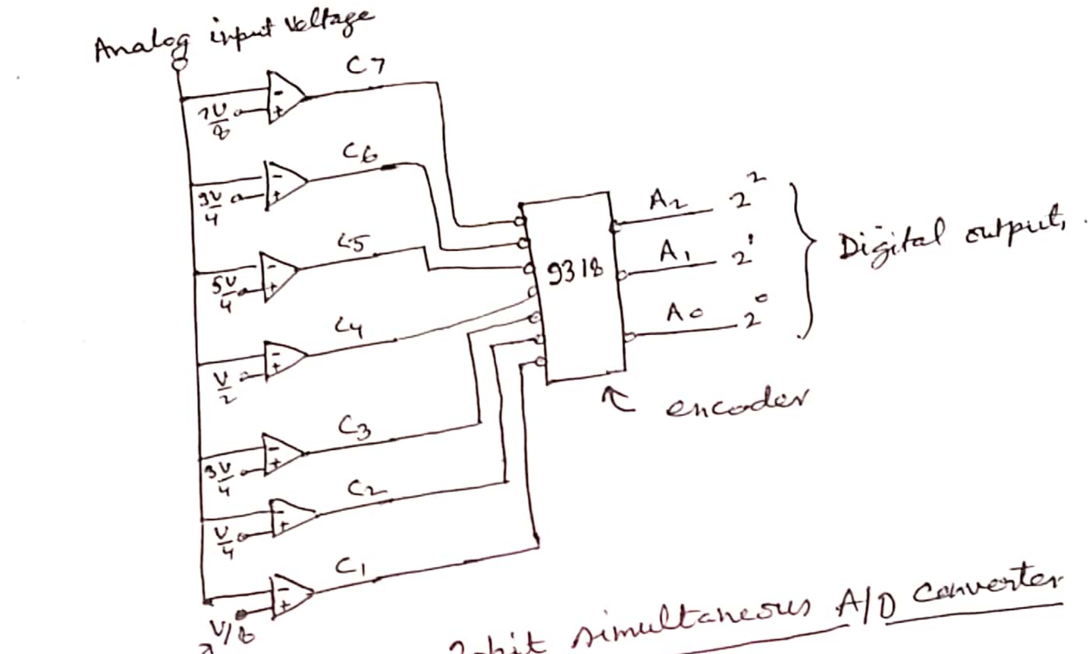


~~A (inverting) - A(non~~
A (noninverting) - B(inverting)

= output (A-B)

To gain a clear understanding of the operation of the simultaneous A/D converter, let us investigate the 3-bit converter shown in below figure. In order to convert the input signal to a digital signal having 3 bits, it is necessary to have seven comparators (this allows a division of the input into eight ranges). (2^n level)

The encoding matrix must accept seven input levels and encode them into a 3-bit binary number (having eight possible states). Operation of the encoding matrix can be most easily understood by examination of the table of outputs in figure.



3-bit simultaneous A/D converter

Input Voltage	Comparator for level							Binary output		
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	2^2	2^1	2^0
0 to V/8	L	L	L	L	L	L	L	0	0	0
V/8 to V/4	H							0	0	1
V/4 to 3V/8	H	H						0	1	0
3V/8 to V/2	H	H	H					0	1	1
V/2 to 5V/8	H	H	H	H				1	0	0
5V/8 to 3V/4	H	H	H	H	H			1	0	1
3V/4 to 7V/8	H	H	H	H	H	H		1	1	0
7V/8 to V	H	H	H	H	H	H	H	1	1	1

Logic table for the converter

Scanned with CamScanner

Digital-to-Analog Converters :- Digital-to-analog (D/A) and analog-to-digital (A/D) conversion form two very important aspects of digital data processing. Digital-to-analog conversion involves translation of digital information into equivalent analog information. As an example, the output of a digital system might be changed to analog form for the purpose of driving a pen recorder.

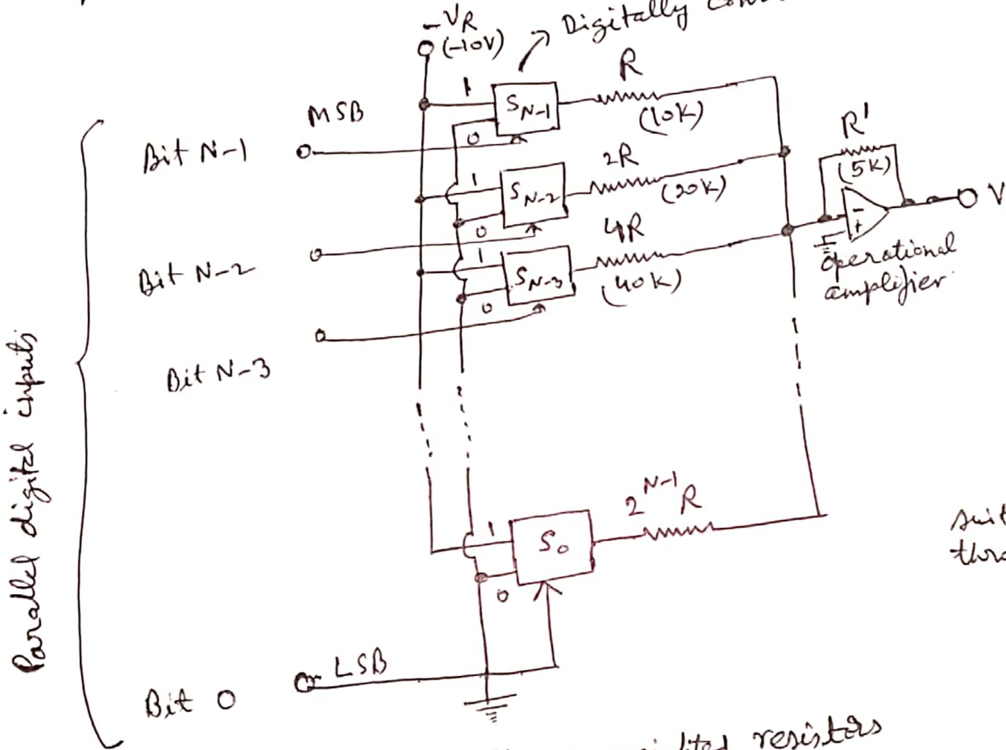
Digital-to-analog conversion is a straight forwarded process and is considerably easier than A/D conversion. In fact, a D/A converter is usually an integral part of any A/D converter.

The digital word is presented in a variety of codes, the most common being pure binary or binary-coded-decimal (BCD).

The output V_o of an N-bit D/A converter is given by the following equation:

$$V_o = (a_{N-1}2^{-1} + a_{N-2}2^{-2} + a_{N-3}2^{-3} + \cdots + a_0 2^{-N})V_R \qquad (1)$$

where the coefficients a_n represent the binary word and $a_n = 1(0)$ if the nth bit is $1(0)$. The voltage V_R is a stable reference voltage used in the circuit. The most significant bit (MSB) is that corresponding to a_{N-1} and its weight is $V_R/2$, while the least significant bit (LSB) corresponds to a_0 and its weight is $V_R/2^N$.



The blocks $S_0, S_1, S_2 \ldots S_{N-1}$ are electronic switches which are digitally controlled. For example, when a 1 is present on the MSB line, switch S_{N-1} connects the 10-K resistor to the reference voltage $-V_R$ (−10V); conversely, when a 0 is present on the MSB line, the switch connects the resistor to the ground line. Thus switch is a single-pole double-throw (SPDT) electronic switch.

1010
MSB ↙ ↘ LSB

D/A Converter with binary weighted resistors

Consider, for example, a 5-bit word $(N=5)$, so that Eqn (1) becomes.

$$V_o = \left(\frac{a_4}{2} + \frac{a_3}{4} + \frac{a_2}{8} + \frac{a_1}{16} + \frac{a_0}{32}\right)V_R \qquad (2a)$$

$$= (16a_4 + 8a_3 + 4a_2 + 2a_1 + a_0)\frac{V_R}{32} \qquad (2)$$

For simplicity, assume $V_R = 32V$. Then, if $a_0 = 1$ and all other a's are zero, i.e. $a_1 = a_2 = a_3 = a_4 = 0$, then eqn (2) becomes

$$V_o = 1.$$

$R = V/I$
$I = V/R$
$= \frac{10V}{10 \times 10^3}$
$= 1mA$

- If $a_1 = 1$ and all other a's are zero, we obtain, $V_0 = 2$.

If $a_0 = a_1 = 1$ and all other a's are zero, $V_0 = 2 + 1 = 3V$ etc.

Clearly, V_0 is an analog voltage proportional to the digital input.

Using the numerical values shown in above figure, we see that if the MSB is 1 and all other bits are 0, then the current through the 10-K resistor will be 1mA and the output voltage will be $V_0 = \cancel{5} = 16 \times \left(\frac{5}{16}\right) V$. $=5V$ We see that the weight of the LSB (if N=5) becomes $V_0 = \frac{1}{16} \times 5 = 1 \times \frac{5}{16}$ V. — $\frac{10}{32}$ from Eq ②

$\Rightarrow$ If all five bits are 1, the output become $= (1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16}) \frac{10}{2}$ where $V_R = 10$ Volt

from Eq. (2A) $V_0 = (\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32}) V_R$

$V_0 = (1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16}) \times 5 = \frac{31}{16} \times \frac{5}{\cancel{1}} = 9.68V$ — (A)

~~Let $a_0 = 1, a_1 = a_2 = a_3 = a_4 = 1, V_R = 10V$~~

from Eq ②, ~~$V_0 = (16 + 8 + 4 + 2 + 1) \frac{10}{32} = 31 \times \frac{10}{32} = 9.68V$~~.

From circuit,

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{2R} + \frac{1}{4R} + \frac{1}{8R} + \frac{1}{16R}$$

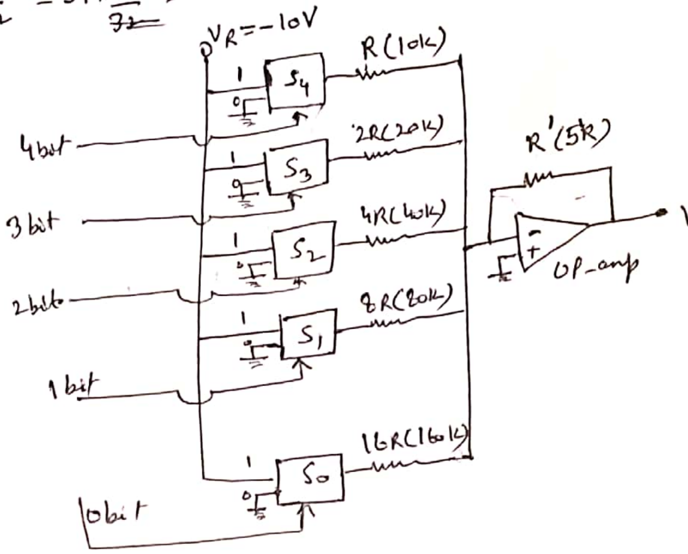
$$= \left(1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16}\right) \frac{1}{R}$$

$$= \frac{(16 + 8 + 4 + 2 + 1)}{16} \frac{1}{R}$$

$$= \frac{31}{16} \times \frac{1}{10} (K\Omega)^{-1}$$

$$= \frac{31}{160} (K\Omega)^{-1}$$

for inverting O/P amp.



$$\frac{V_0}{V_{in} \to V_R} = -\frac{R_f}{R_{in}}$$

$$V_0 = -V_{in} \frac{R'}{R_{in} \to R_{eq}}$$

$$= 10 \times \frac{5 \times 10^3}{160 \times 10^3} \times 31 = \frac{5 \times 31}{16} = \frac{10 \times 31}{32} = 9.68 V. \quad \text{Ans}$$ — (B)

We see the value of V_0 is same for using Eq ② as well as using circuit

The accuracy and stability of they D/A converter depend primarily on the absolute accuracy of the resistors and the tracking of each other with temperature.

Integrated Electronics → Jacob Millman + Christos C. Halkias
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