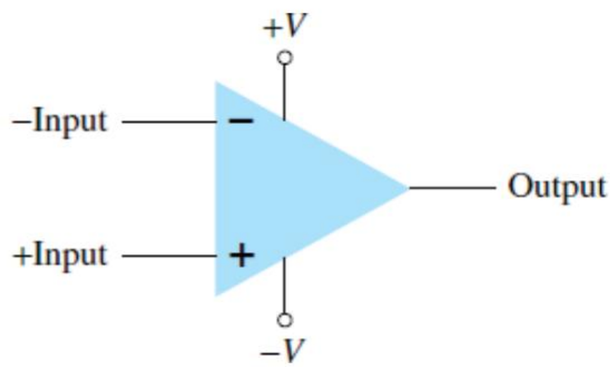
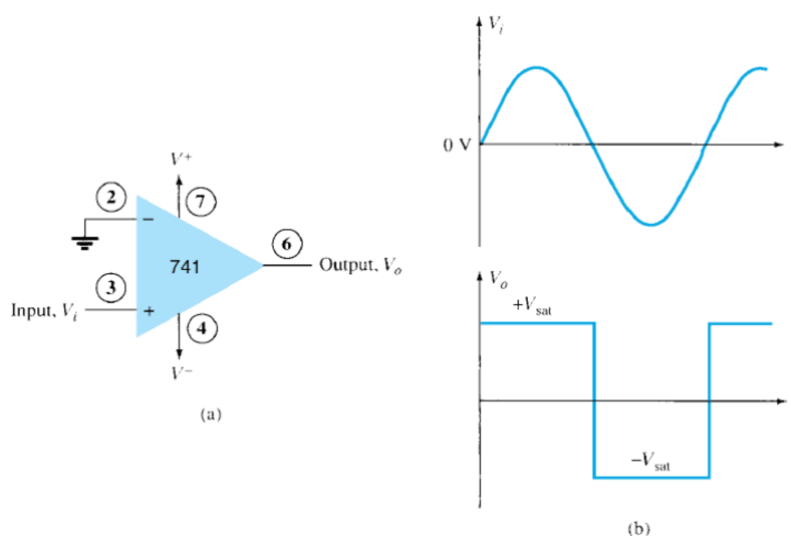
Al-Mustaqbal University College
Department of Medical Instrumentation Techniques Engineering
Class: Three / second semester
Subject: Medical electronic system
Lecturer: Dr. zahraa hashim kareem
Lecture-1: comparator and digital to analog conversion

1. Comparator unit operation

A comparator circuit accepts input of linear voltages and provides a digital output that indicates when one input is less than or greater than the second. A basic comparator circuit can be represented as in Fig. The output is a digital signal that stays at a high voltage level when the noninverting (+) input is greater than the voltage at the inverting (-) input and switches to a lower voltage level when the noninverting input voltage goes below the inverting input voltage.



In general use, the reference voltage need not be 0 V but can be any desired positive or negative voltage. Also, the reference voltage may be connected to either plus or minus input and the input signal then applied to the other input.



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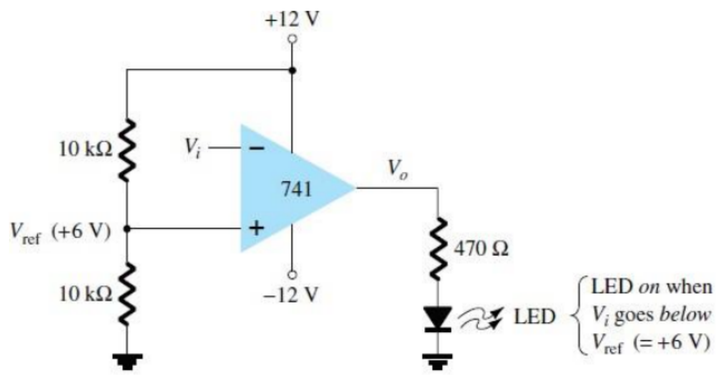
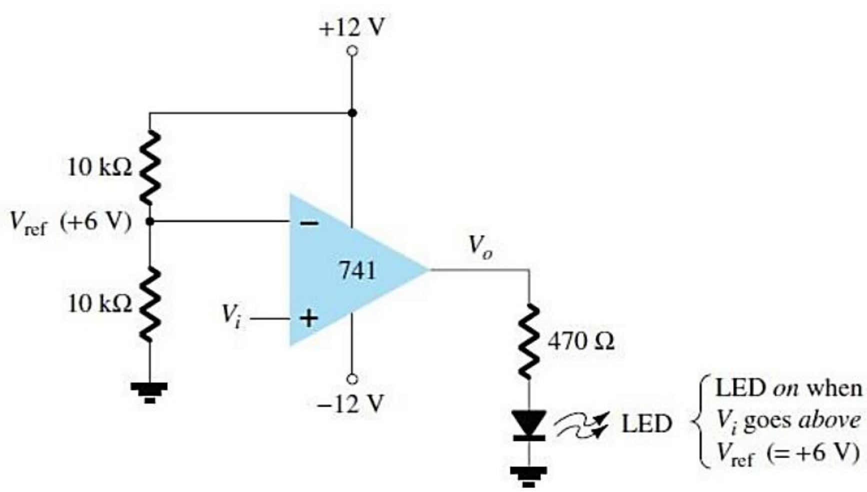
As an alternative connection, the reference voltage could be connected to the noninverting input as shown in Fig. With this connection, the input signal going below the reference level would cause the output to drive the LED on. The LED can thus be made to go on when the input signal goes above or below the reference level, depending on which input is connected as signal input and which as reference input.



Use of Op-Amp as Comparator

Figure a shows a circuit operating with a positive reference voltage connected to the inverting input and the output connected to an indicator LED. The reference voltage level is set at

$$V_{ref} = \frac{10\,k\Omega}{10\,k\Omega + 10\,k\Omega}(+12\,V) = +6\,V$$



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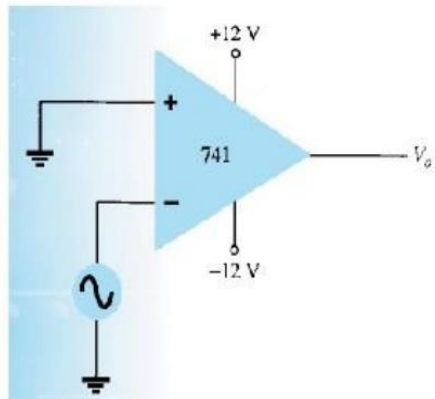
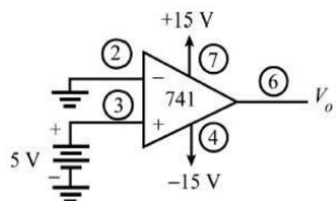
Comparator Unit Operation

1. Draw the diagram of a 741 op-amp operated from ±15-V supplies with $V_i(-) = 0$ V and $V_i(+) = +5$ V. Include terminal pin connections.
2. Sketch the output waveform for the circuit of Fig.



1.



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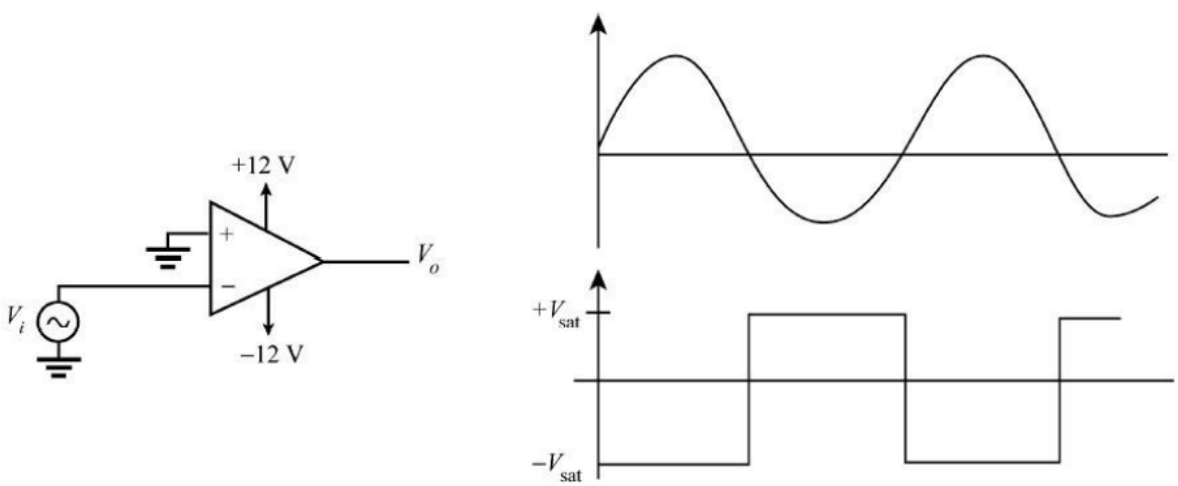

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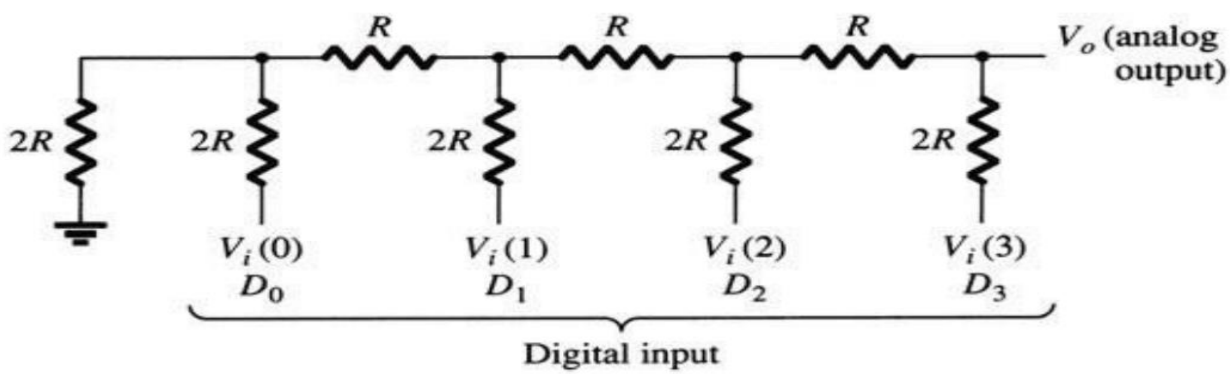
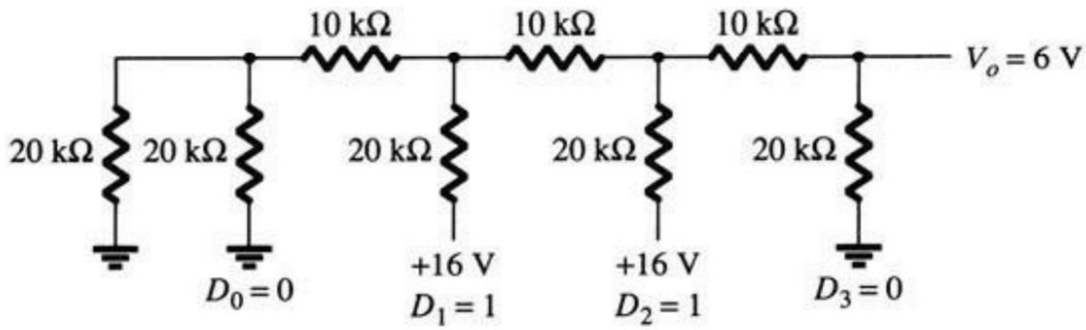
2. Digital-to-Analog Conversion

Digital-to-analog conversion can be achieved using a number of different methods. One popular scheme uses a network of resistors called a ladder network. A ladder network accepts inputs of binary values at, typically, 0 V or V ref and provides an output voltage proportional to the binary input value. Figure (a) shows a ladder network with four input voltages, representing 4 bits of digital data and a dc voltage output. The output voltage is proportional to the digital input value as given by the relation.

$$V_0=(D_0 \times 2^0+D_1 \times 2^1+D_2 \times 2^2+D_3 \times 2^3)V_{ref}/2^4$$



(a)



(b)

Four-stage ladder network used as a DAC: (a) basic circuit; (b) circuit example with 0110 input.

In the example shown in Fig. b, the resulting output voltage is

$$V_o = \frac{0 \times 1 + 1 \times 2 + 1 \times 4 + 0 \times 8}{16}(16\text{ V}) = 6\text{ V}$$

Therefore, 0110_2 digital converts to 6 V analog.

The function of the ladder network is to convert the 16 possible binary values from 0000 to 1111 into one of 16 voltage levels in steps of $V_{ref}/16$. Using more sections of the ladder allows us to have more binary inputs and a greater quantization for each step. For example, a 10-stage ladder network could extend the number of voltage steps or the voltage resolution to $V_{ref}/2^{10}$, or $V_{ref}/1024$. A reference voltage of $V_{ref} = 10$ V would then provide output voltage steps of 10 V/1024, or approximately 10 mV. More ladder stages provide greater voltage resolution. In general, the voltage resolution for n ladder stages is

$$\frac{V_{ref}}{2^n}$$

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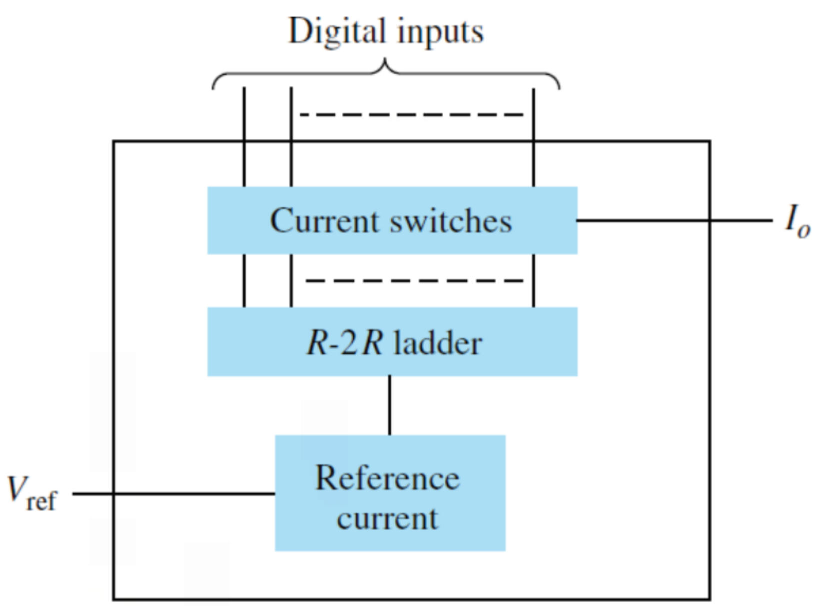
Figure shows a block diagram of a typical DAC using a ladder network. The ladder network, referred to in the diagram as an *R-2R ladder*, is sandwiched between the reference current supply and current switches connected to each binary input, the resulting output current being proportional to the input binary value. The binary input turns on selected legs of the ladder, the output current being a weighted summing of the reference current. Connecting the output current through a resistor will produce an analog voltage if desired.



DAC IC using R-2R ladder network.

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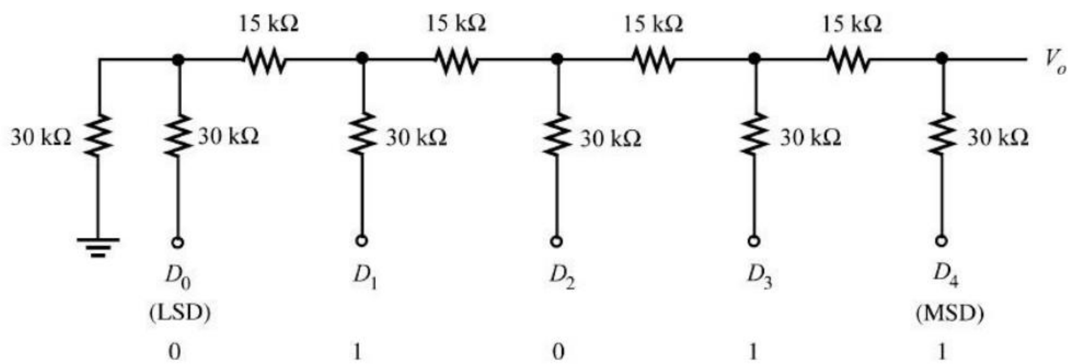
Digital–Analog Converters

1. Sketch a five-stage ladder network using 15-kΩ and 30-kΩ resistors.
2. For a reference voltage of 16 V, calculate the output voltage for an input of 11010 to the circuit of Problem .
3. What voltage resolution is possible using a 12-stage ladder network with a 10-V reference voltage?

1.



2. $$\frac{11010}{2^5}(16\text{ V}) = \frac{26}{32}(16\text{ V}) = \mathbf{13\ V}$$

3. $$\text{Resolution} = \frac{V_{REF}}{2^n} = \frac{10\text{ V}}{2^{12}} = \frac{10\text{ V}}{4096} = \mathbf{2.4\ mV/count}$$

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