DIGITAL TO ANALOG CONVERTERS

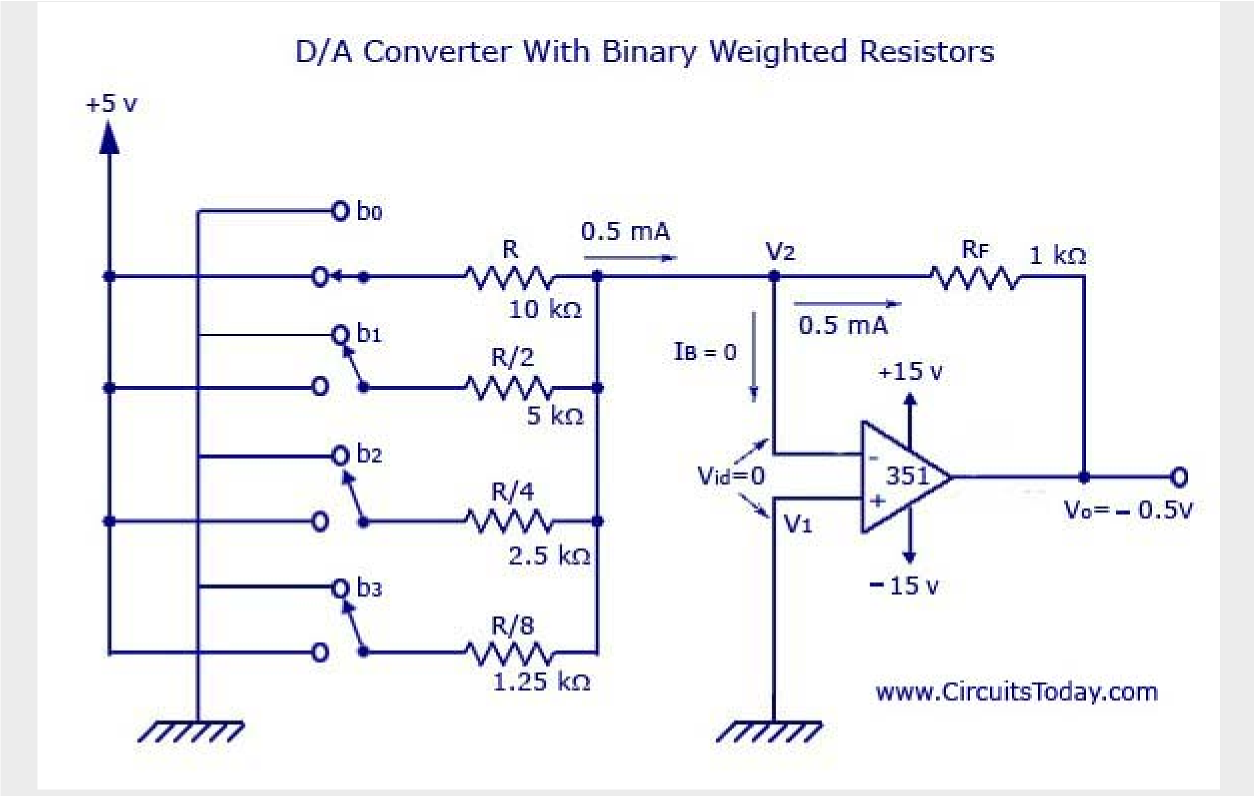
A D/A Converter is used when the binary output from a digital system is to be converted into its equivalent analog voltage or current.

The binary output will be a sequence of 1′s and 0′s. Thus they ma be difficult to follow. But, a D/A converter help the user to interpret easily.

Basically, a D/A converter have an op-amp. It can be classified into 2 types. They are

1. Digital to Analog Converter using Binary-Weighted Resistors

A D/A converter using binary-weighted resistors is shown in the figure below. In the circuit, the op-amp is connected in the inverting mode. The op-amp can also be connected in the non-inverting mode. The circuit diagram represents a 4-digit converter. Thus, the number of binary inputs is four.



Digital-to-Analog Converter Circuit - Binary-Weighted Resistors Method

We know that, a 4-bit converter will have $2^4 = 16$ combinations of output. Thus, a corresponding 16 outputs of analog will also be present for the binary inputs.

Four switches from b0 to b3 are available to simulate the binary inputs: in practice, a 4-bit binary counter such as a 7493 can also be used.

Working

The circuit is basically working as a current to voltage converter.

- b0 is closed

It will be connected directly to the +5V.

Thus, voltage across R = 5V

Current through R = 5V/10kohm = 0.5mA

Current through feedback resistor, Rf = 0.5mA (Since, Input bias current, I_B is negligible)

Thus, output voltage = -(1kohm)*(0.5mA) = -0.5V

- b1 is closed, b0 is open

R/2 will be connected to the positive supply of the +5V.

Current through R will become twice the value of current (1mA) to flow through Rf.

Thus, output voltage also doubles.

- b0 and b1 are closed

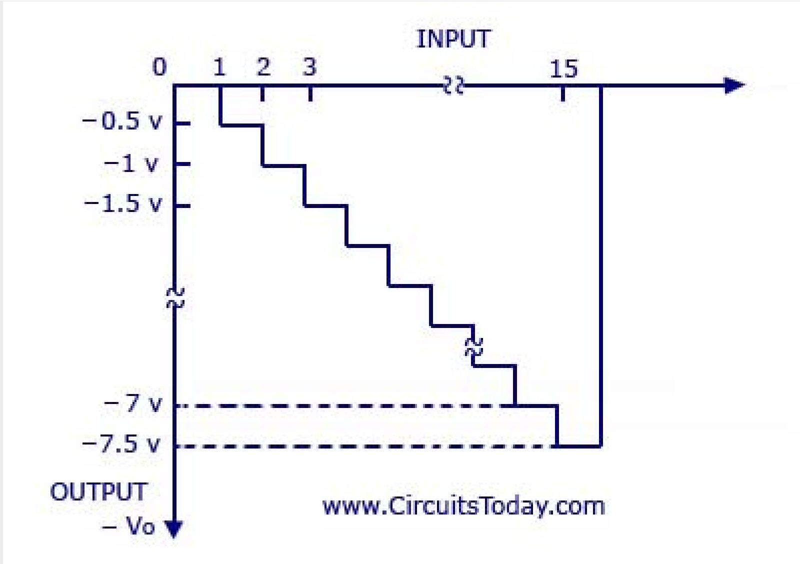
Current through Rf = 1.5mA

Output voltage = -(1kohm)*(1.5mA) = -1.5V

Thus, according to the position (ON/OFF) of the switches (bo-b3), the corresponding “binary-weighted” currents will be obtained in the input resistor. The current through Rf will be the sum of these currents. This overall current is then converted to its proportional output voltage. Naturally, the output will be maximum if the switches (b0-b3) are closed

V0 = -Rf *([b0/R][b1/(R/2)][b2/(R/4)][b3/(R/8)]) – where each of the inputs b3, b2, b1, and b0 may either be HIGH (+5V) or LOW (0V).

The graph with the analog outputs versus possible combinations of inputs is shown below.



Digital-to-Analog Converter Circuit - Binary-Weighted Resistors Method Graph

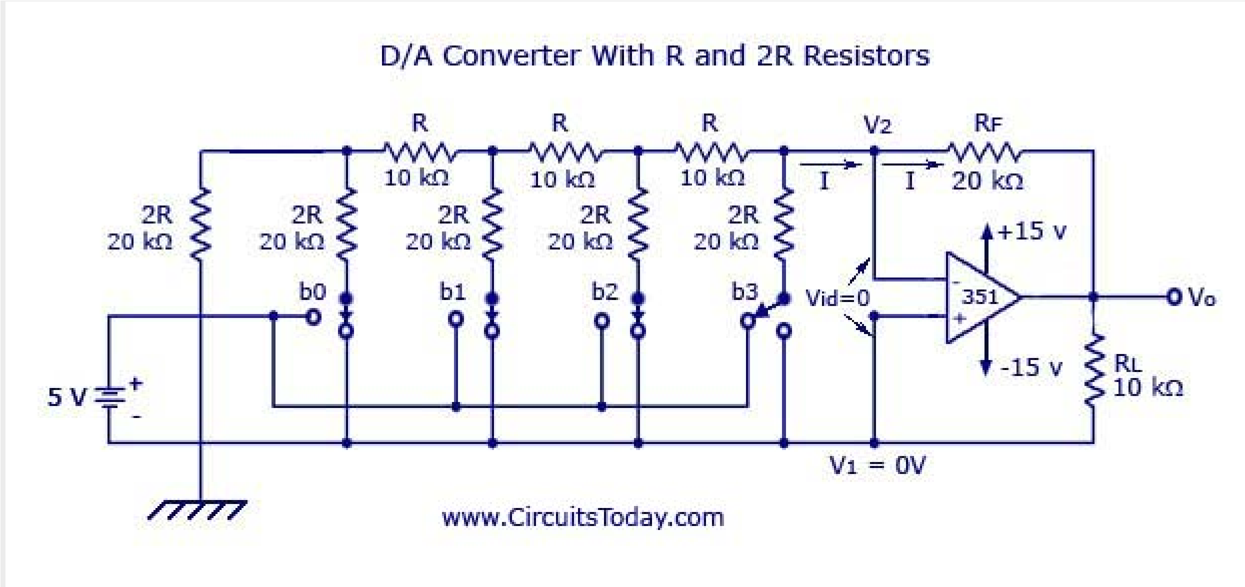
The output is a negative going staircase waveform with 15 steps of -).5V each. In practice, due to the variations in the logic HIGH voltage levels, all the steps will not have the same size. The value of the feedback resistor Rf changes the size of the steps. Thus, a desired size for a step can be obtained by connecting the appropriate feedback resistor. The only condition to look out for is that the maximum output voltage should not exceed the saturation levels of the op-amp. Metal-film resistors are more preferred for obtaining accurate outputs.

Disadvantages

If the number of inputs (>4) or combinations (>16) is more, the binary-weighted resistors may not be readily available. This is why; R and 2R method is more preferred as it requires only two sets of precision resistance values.

2. Digital to Analog Converter with R and 2R Resistors

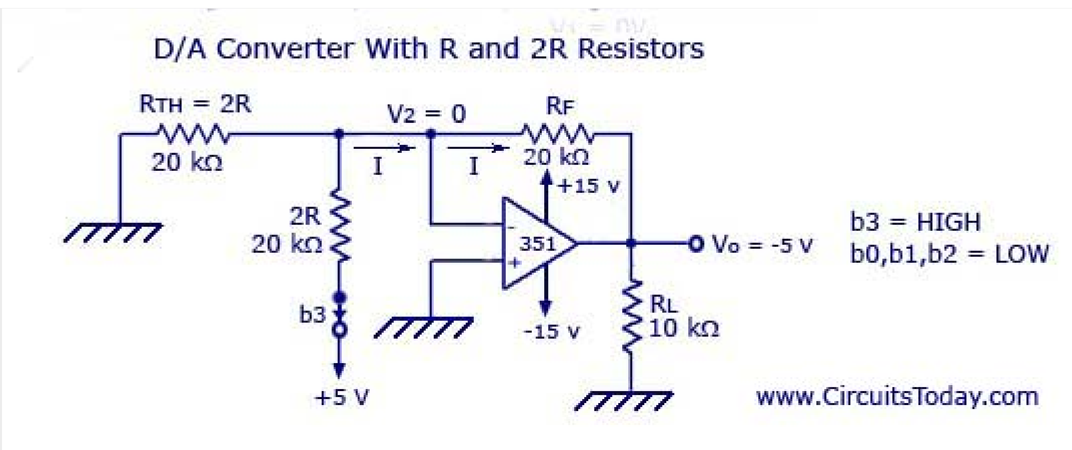
A D/A converter with R and 2R resistors is shown in the figure below. As in the binary-weighted resistors method, the binary inputs are simulated by the switches (b0-b3), and the output is proportional to the binary inputs. Binary inputs can be either in the HIGH (+5V) or LOW (0V) state. Let b3 be the most significant bit and thus is connected to the +5V and all the other switchs are connected to the ground.



Digital to Analog Converter with R and 2R Resistors

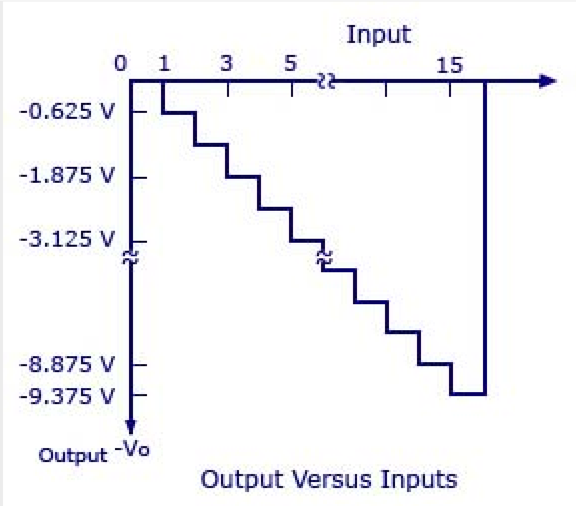
Thus, according to Thevenin's equivalent resistance, R_{TH},

R_{TH} = [{[(2RII2R + R)} II2R] + R}II2R] + R = 2R = 20kOhms.
The resultant circuit is shown below.



Digital to Analog Converter with R and 2R Resistors - Resultant Circuit

Graph is given below.



Digital to Analog Converter with R and 2R Resistors - Graph

In the figure shown above, the negative input is at virtual ground, therefore the current through R_{TH}=0**.**

Current through 2R connected to +5V = 5V/20kohm = 0.25 mA

The current will be the same as that in Rf.

V_o **= -**(20kohm)*(0.25mA) = -5V

Output voltage equation is given below.

V_0 = -Rf (b3/2R+b2/4R+b1/8R+b0/16R)

Source : http://www.circuitstoday.com/digital-to-analog-converters-da