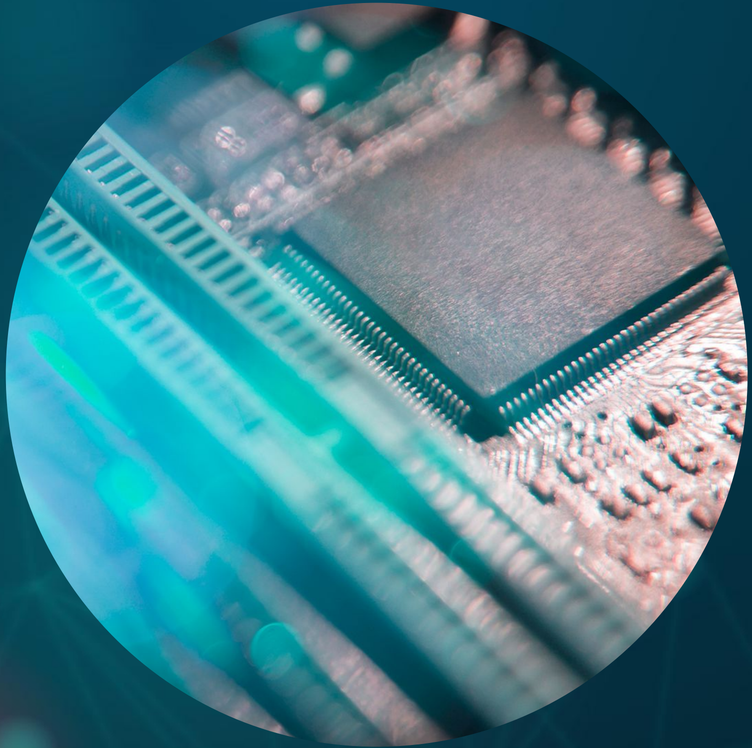
ARM Based Microcontroller

DAC

Lecture 9



Advanced
RISC
Machines

Introduction 01

Digital to Analog Converter

Introduction

When talking about signals, they can be broadly classified into analog signals and digital signals.

All digital Electronics like Logic Gates, Flip-Flops, Microcontroller, Microprocessor etc work with Digital Signals, while the Analog Electronics are like Op-Amp, Power switches etc.

In a typical electronics design, these two signals often have to be converted from one form to another.

Here we will learn how Digital signals can be converted to Analog voltages using DACs.

Note that the ADC (Analog to Digital Converter) performs the opposite function of the DAC, it converts the analog signal to digital.

Introduction

We live in an analog world. Every parameter in our life can have infinite possibilities of values. Temperature, pressure, colors , etc. ... even between the value 0 and the value 1 there are infinite values.

But in the Embedded System world, we can process only digital values. Therefor, we need a translation unit that can convert any signal from its original analog form, to a digital form that can be processed by the processor.

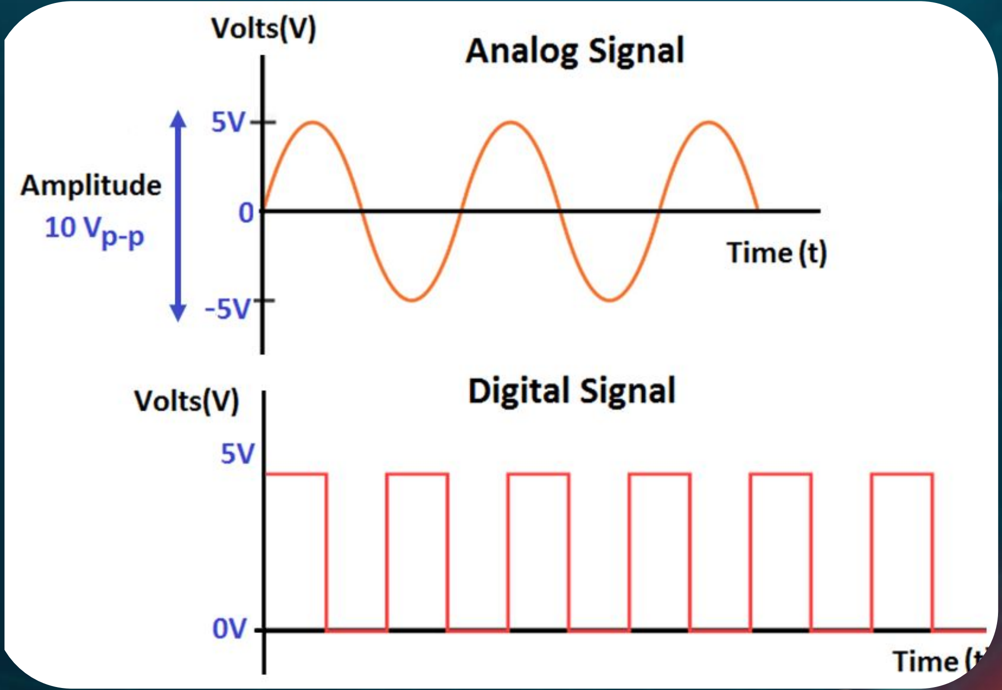
Introduction

01
Analog Signal

An analog signal is time-varying and generally bound to a range (e.g. +12V to -12V), but there is an infinite number of values within that continuous range. An analog signal uses a given property of the medium to convey the signal's information, such as electricity moving through a wire.

02
Digital Signal

A digital signal is a signal that represents data as a sequence of discrete values. A digital signal can only take on one value from a finite set of possible values at a given time.



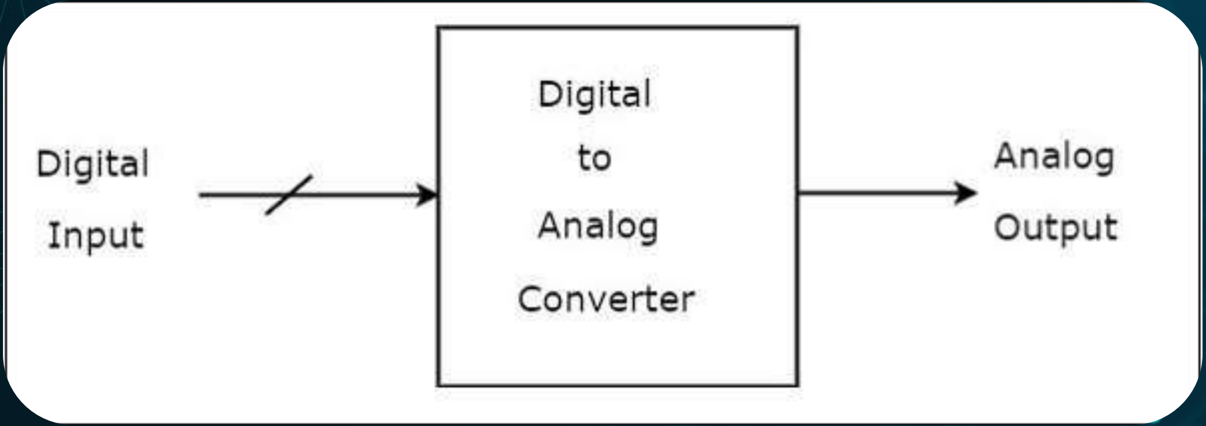
DAC 02

Digital to Analog Converter

DAC

A Digital to Analog Converter (DAC) converts a digital input signal into an analog output signal. The digital signal is represented with a binary code, which is a combination of bits 0 and 1.

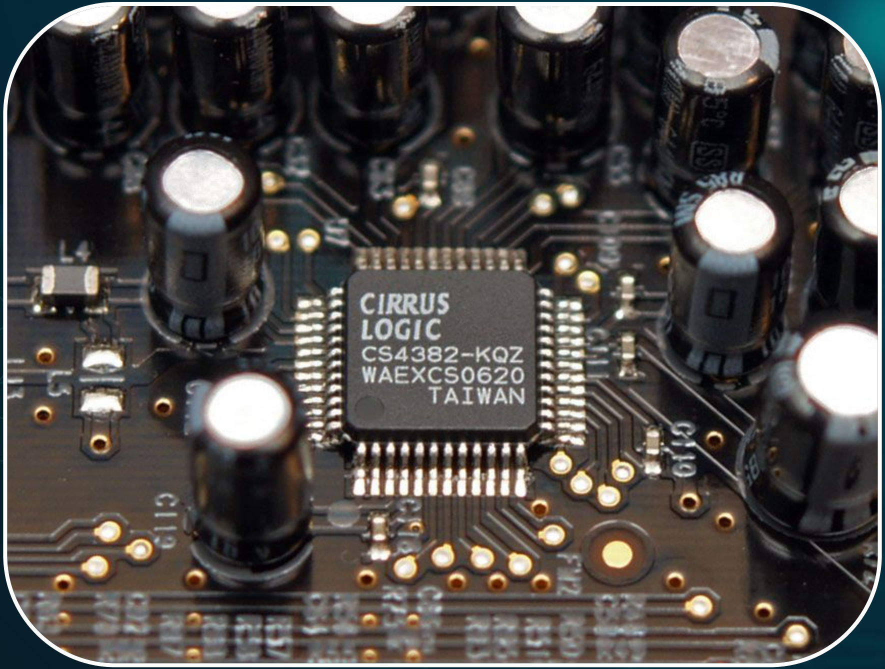
A Digital to Analog Converter (DAC) consists of a number of binary inputs and a single output. In general, the number of binary inputs of a DAC will be a power of two.



Types of DAC

There are two types of DACs

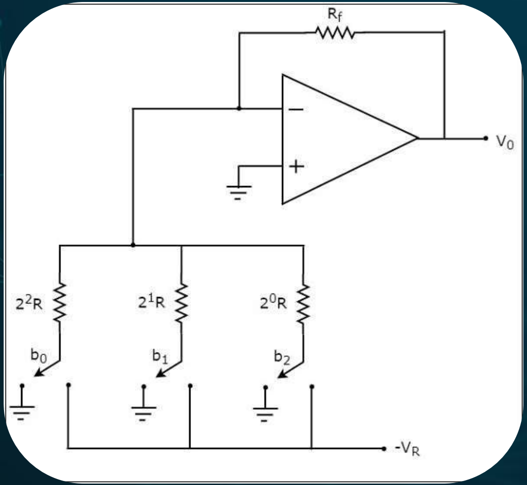
- **Weighted Resistor DAC**
- **R-2R Ladder DAC**



Weighted Resistor DAC

A weighted resistor DAC produces an analog output, which is almost equal to the digital (binary) input by using binary weighted resistors in the inverting adder circuit. In short, a binary weighted resistor DAC is called as weighted resistor DAC.

The circuit diagram of a 3-bit binary weighted resistor DAC is shown in the following figure



Weighted Resistor DAC

Recall that the bits of a binary number can have only one of the two values. i.e., either 0 or 1. Let the 3-bit binary input is b2 b1 b0. Here, the bits b2 and b0 denote the Most Significant Bit (MSB) and Least Significant Bit (LSB) respectively.

The digital switches shown in the above figure will be connected to ground, when the corresponding input bits are equal to '0'. Similarly, the digital switches shown in the above figure will be connected to the negative reference voltage, −VR when the corresponding input bits are equal to '1'.

In the above circuit, the non-inverting input terminal of an op-amp is connected to ground. That means zero volts is applied at the non-inverting input terminal of op-amp.

According to the virtual short concept, the voltage at the inverting input terminal of opamp is same as that of the voltage present at its non-inverting input terminal.
So, the voltage at the inverting input terminal's node will be zero volts.

Weighted Resistor DAC

The nodal equation at the inverting input terminal's node is:

$$\frac{0 + V_R b_2}{2^0 R} + \frac{0 + V_R b_1}{2^1 R} + \frac{0 + V_R b_0}{2^2 R} + \frac{0 - V_0}{R_f} = 0$$

$$=> \frac{V_0}{R_f} = \frac{V_R b_2}{2^0 R} + \frac{V_R b_1}{2^1 R} + \frac{V_R b_0}{2^2 R}$$

$$=> V_0 = \frac{V_R R_f}{R} \left\{ \frac{b_2}{2^0} + \frac{b_1}{2^1} + \frac{b_0}{2^2} \right\}$$

Weighted Resistor DAC

Substituting, R=2Rff in above equation.

$$=> V_0 = \frac{V_R R_f}{2R_f}\left\{\frac{b_2}{2^0} + \frac{b_1}{2^1} + \frac{b_0}{2^2}\right\}$$

$$=> V_0 = \frac{V_R}{2}\left\{\frac{b_2}{2^0} + \frac{b_1}{2^1} + \frac{b_0}{2^2}\right\}$$

Weighted Resistor DAC

The above equation represents the output voltage equation of a 3-bit binary weighted resistor DAC. Since the number of bits are three in the binary (digital) input, we will get seven possible values of output voltage by varying the binary input from 000 to 111 for a fixed reference voltage, VR.

We can write the generalized output voltage equation of an N-bit binary weighted resistor DAC as shown below based on the output voltage equation of a 3-bit binary weighted resistor DAC.

$$=> V_0 = \frac{V_R}{2}\left\{\frac{b_{N-1}}{2^0} + \frac{b_{N-2}}{2^1} + \ldots + \frac{b_0}{2^{N-1}}\right\}$$

Weighted Resistor DAC

The disadvantages of a binary weighted resistor DAC are as follows –

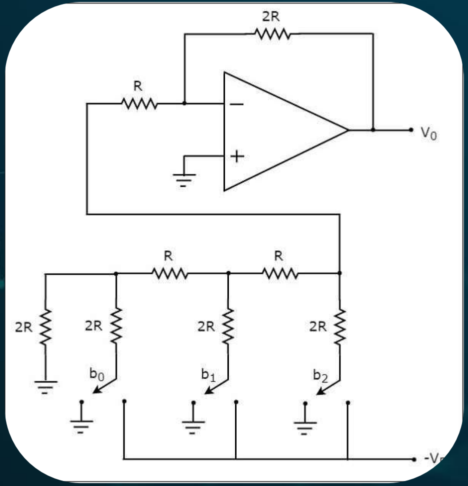
The difference between the resistance values corresponding to LSB & MSB will increase as the number of bits present in the digital input increases.

It is difficult to design more accurate resistors as the number of bits present in the digital input increases.

R-2R Ladder DAC

The R-2R Ladder DAC overcomes the disadvantages of a binary weighted resistor DAC. As the name suggests, R-2R Ladder DAC produces an analog output, which is almost equal to the digital (binary) input by using a R-2R ladder network in the inverting adder circuit.

The circuit diagram of a 3-bit R-2R Ladder DAC is shown in the following figure



R-2R Ladder DAC

Recall that the bits of a binary number can have only one of the two values. i.e., either 0 or 1. Let the 3-bit binary input is b2 b1 b0. Here, the bits b2 and b0 denote the Most Significant Bit (MSB) and Least Significant Bit (LSB) respectively.

The digital switches shown in the above figure will be connected to ground, when the corresponding input bits are equal to ‘0’. Similarly, the digital switches shown in above figure will be connected to the negative reference voltage, –VR when the corresponding input bits are equal to ‘1’.

R-2R Ladder DAC

It is difficult to get the generalized output voltage equation of a R-2R Ladder DAC. But, we can find the analog output voltage values of R-2R Ladder DAC for individual binary input combinations easily.

The advantages of a R-2R Ladder DAC are as follows –

R-2R Ladder DAC contains only two values of resistor: R and 2R. So, it is easy to select and design more accurate resistors.

If more number of bits are present in the digital input, then we have to include required number of R-2R sections additionally.

Due to the above advantages, R-2R Ladder DAC is preferable over binary weighted resistor DAC.

DSP 03

Digital to Analog Converter

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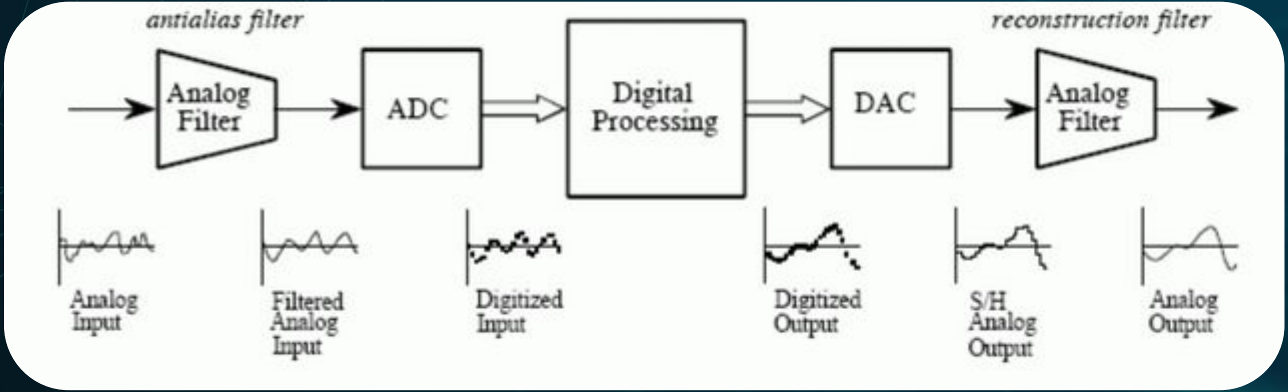
DSP

an ADC converts the analog data collected by audio input equipment such as a microphone (sensor), into a digital signal that can be processed by a computer or a microcontroller.

The microcontroller may add sound effects like amplification. Now a DAC will process the amplified digital sound signal back into the analog signal that is used by audio output equipment such as a speaker.



DSP

This process can be broken down into these steps:

1. During the recording process, an artist lays down a track. Microphones pick up the sounds of voices and instruments as analog audio signals.

2. Recording engineers store the analog signals as digital. Recording equipment uses analog-to-digital converters to transform the analog signals to digital signals for storage. Nowadays, this usually means storing them as digital signals as a digital audio file.

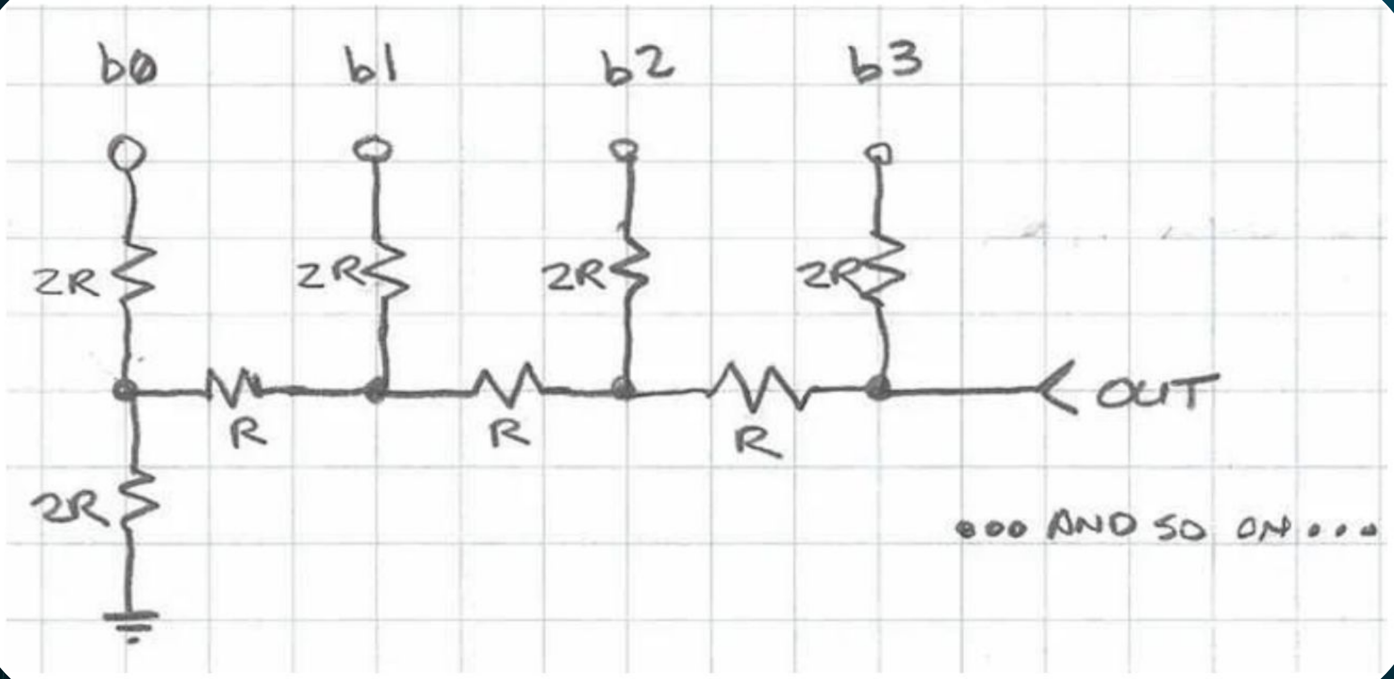
3. During playback, a DAC decodes the stored digital signals. In doing so, the DAC converts those signals back into analog audio.

4. A DAC sends the converted analog signals to an amplifier. The amplifier, in turn, sends music through your headphones or stereo speakers.

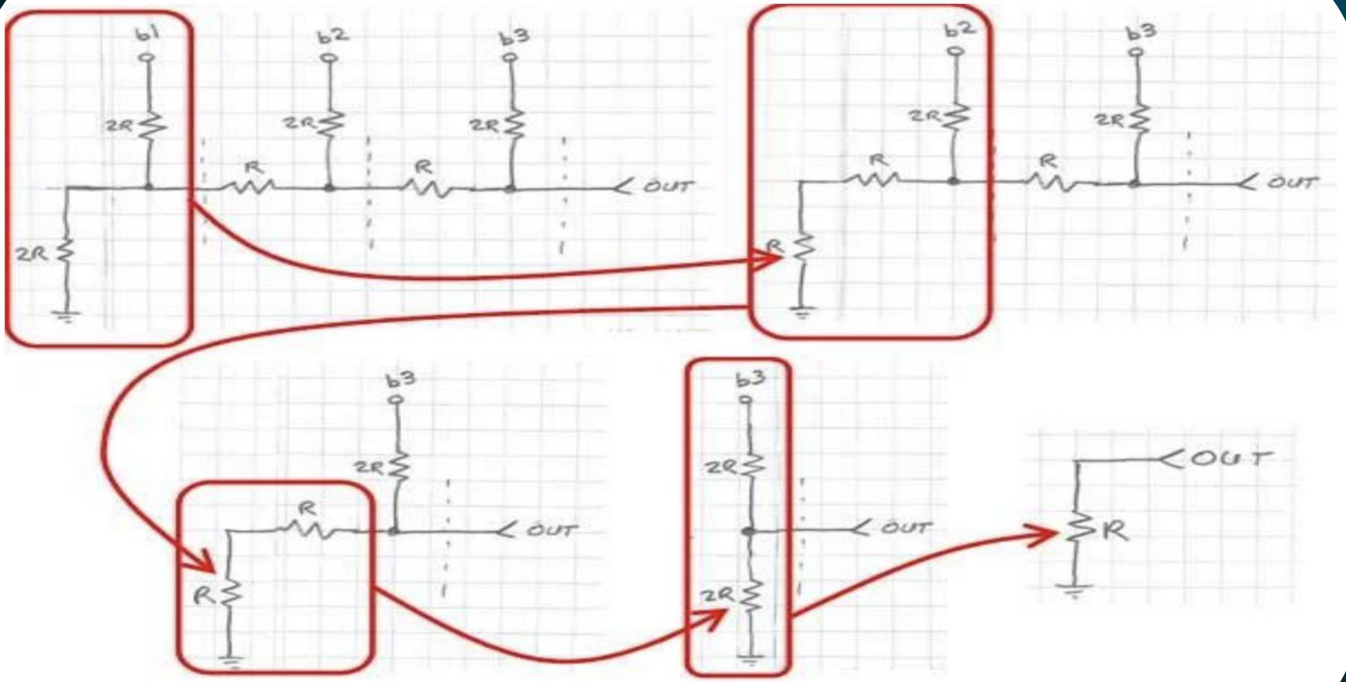
DAC Example 04

Digital to Analog Converter

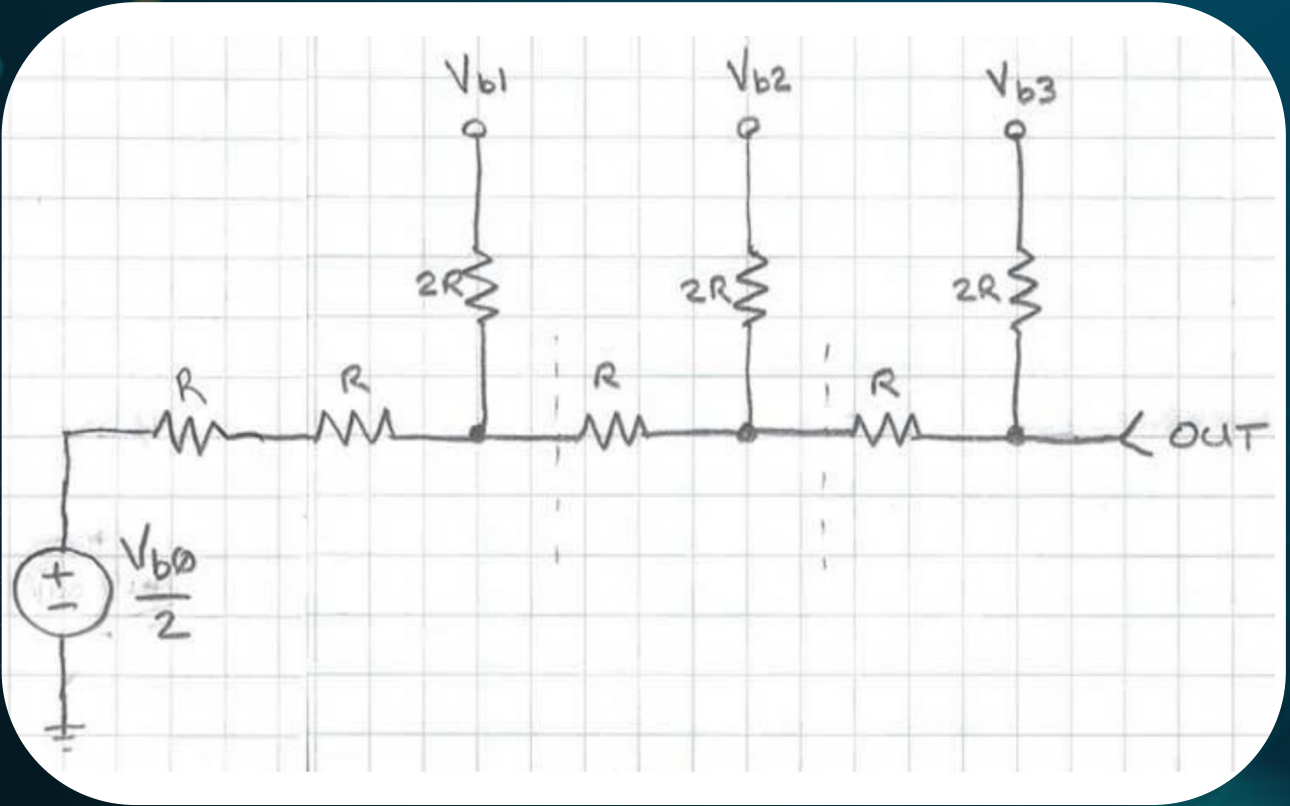
R2R



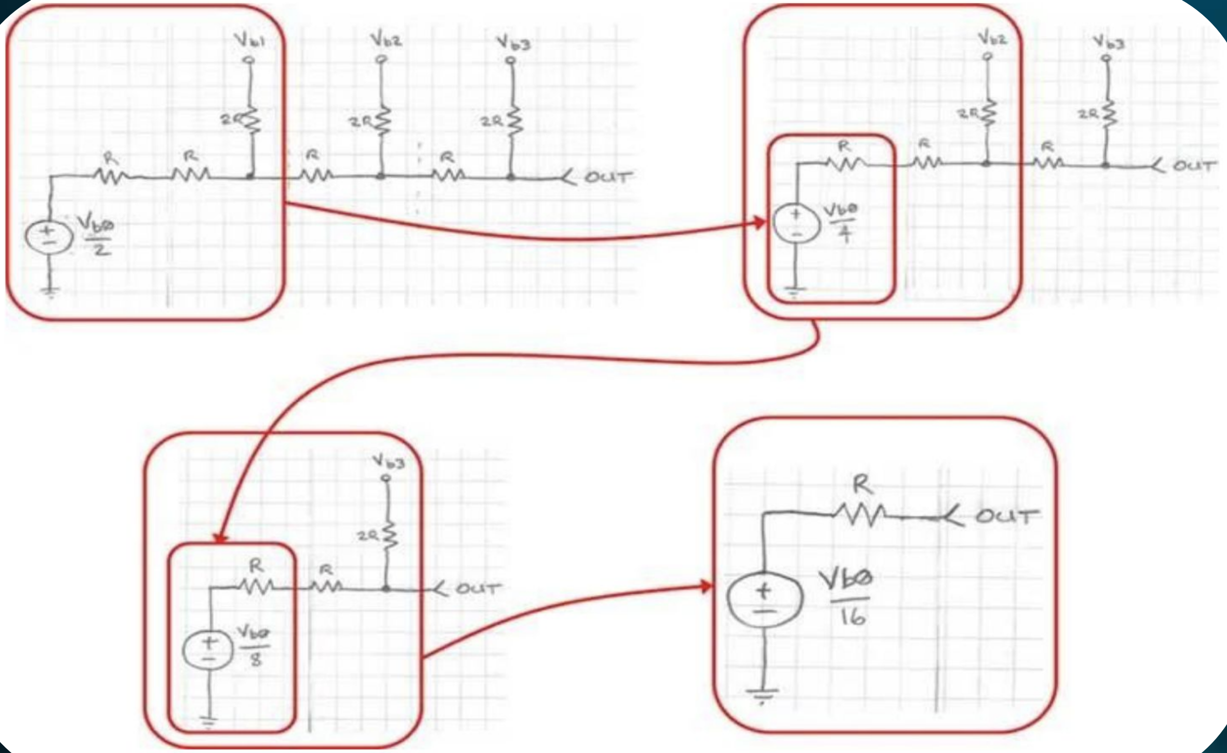
R2R



R2R



R2R



R2R

In a more general sense, the contribution of each bit to the output is a simple binary weighting function of each bit.
As you work back from the MSB to the LSB, the voltage contribution each bit is cut in half. Thus, the general form of the equation to calculate the output voltage :

$$Vout = Vb0 / 16 + Vb1 / 8 + Vb2 / 4 + Vb3 / 2 .$$

The R-2R resistor ladder based digital-to-analog converter (DAC) is a simple, effective, accurate and inexpensive way to create analog voltages from digital values.

IMT has provided an 8-bit DAC on its kit using a series of 5k, 10k ohms,

STM32
Is AWESOME

Session LAb

Create **DAC** Driver

Time To Code

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THANKS!

Do you have any questions?

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