Lecture-3

A/D and D/A converters

Digital-to-Analog Conversion [DAC]

Digital-to-Analog Conversion

- When data is in binary form, the 0's and 1's may be of several forms such as the TTL form where the logic zero may be a value up to 0.8 volts and the 1 may be a voltage from 2 to 5 volts.
- The data can be converted to clean digital form using gates which are designed to be on or off depending on the value of the incoming signal.

Digital-to-Analog Conversion

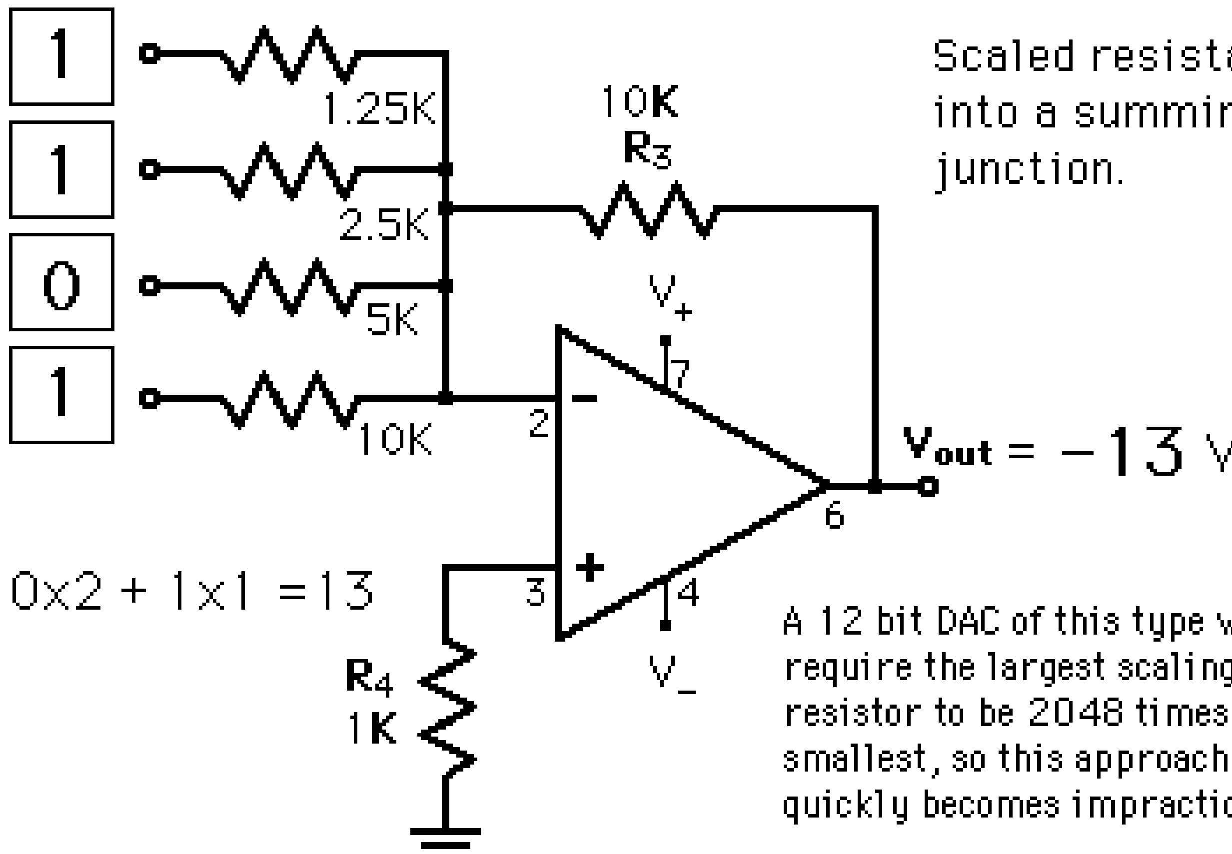
- Data in clean binary digital form can be converted to an analog form by using a summing amplifier.
- For example, a simple 4-bit D/A converter can be made with a four-input summing amplifier.

Weighted Sum DAC

- One way to achieve D/A conversion is to use a summing amplifier.
- This approach is not satisfactory for a large number of bits because it requires too much precision in the summing resistors.
- This problem is overcome in the R-2R network DAC.

Weighted Sum DAC

Inputs in volts are weighted in the summing amplifier to produce the corresponding analog voltage.

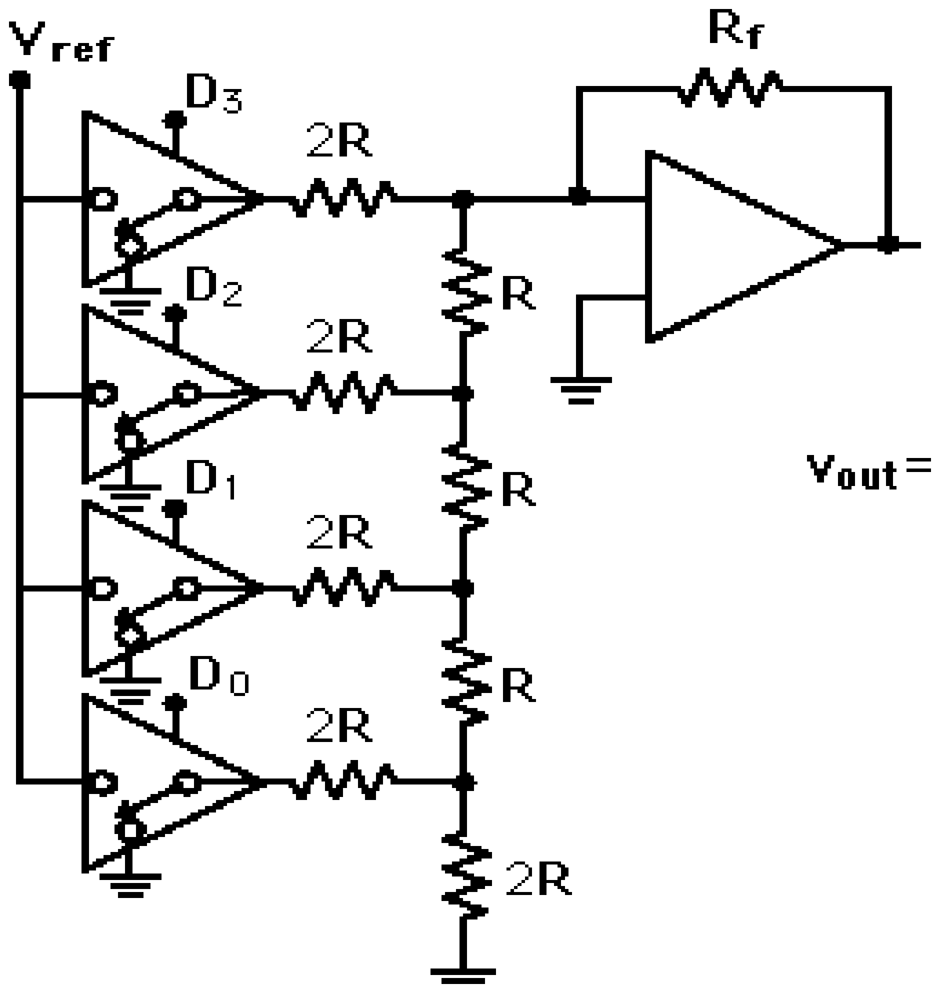


Scaled resistances into a summing junction.

1x8 + 1x4 + 0x2 + 1x1 =13

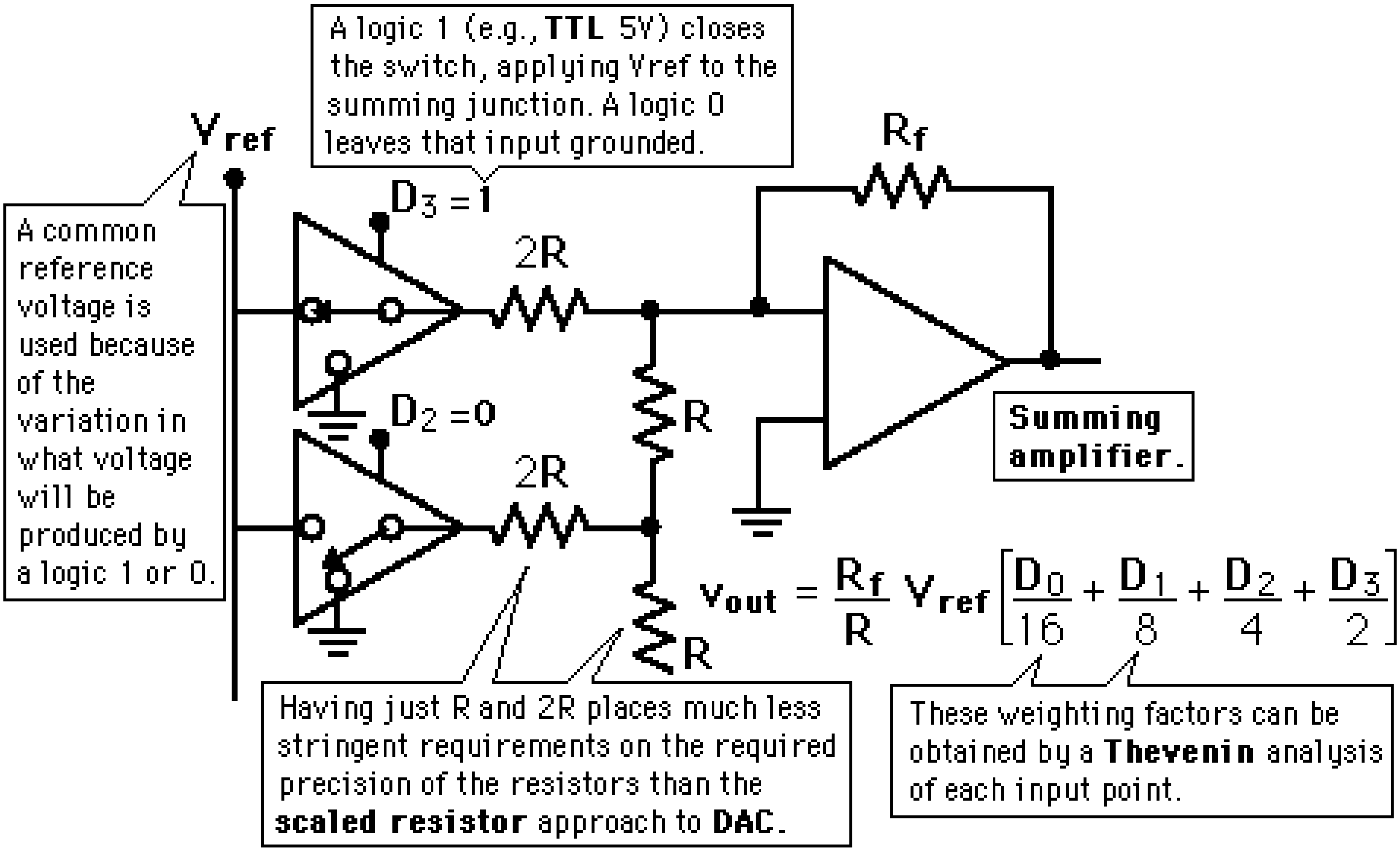
A 12 bit DAC of this type would require the largest scaling resistor to be 2048 times the smallest, so this approach quickly becomes impractical.

R-2R Ladder DAC



$$V_{out} = \frac{R_f}{R} V_{ref} \left[\frac{D_0}{16} + \frac{D_1}{8} + \frac{D_2}{4} + \frac{D_3}{2} \right]$$

R-2R Ladder DAC



R-2R Ladder DAC

- The summing amplifier with the R-2R ladder of resistances shown produces the output where the D's take the value 0 or 1.
- The digital inputs could be TTL voltages which close the switches on a logical 1 and leave it grounded for a logical 0.
- This is illustrated for 4 bits, but can be extended to any number with just the resistance values R and 2R.

Analog to Digital Conversion [ADC]

ADC Basic Principle

- The basic principle of operation is to use the comparator principle to determine whether or not to turn on a particular bit of the binary number output.
- It is typical for an ADC to use a digital-to-analog converter (DAC) to determine one of the inputs to the comparator.

ADC Various Approaches

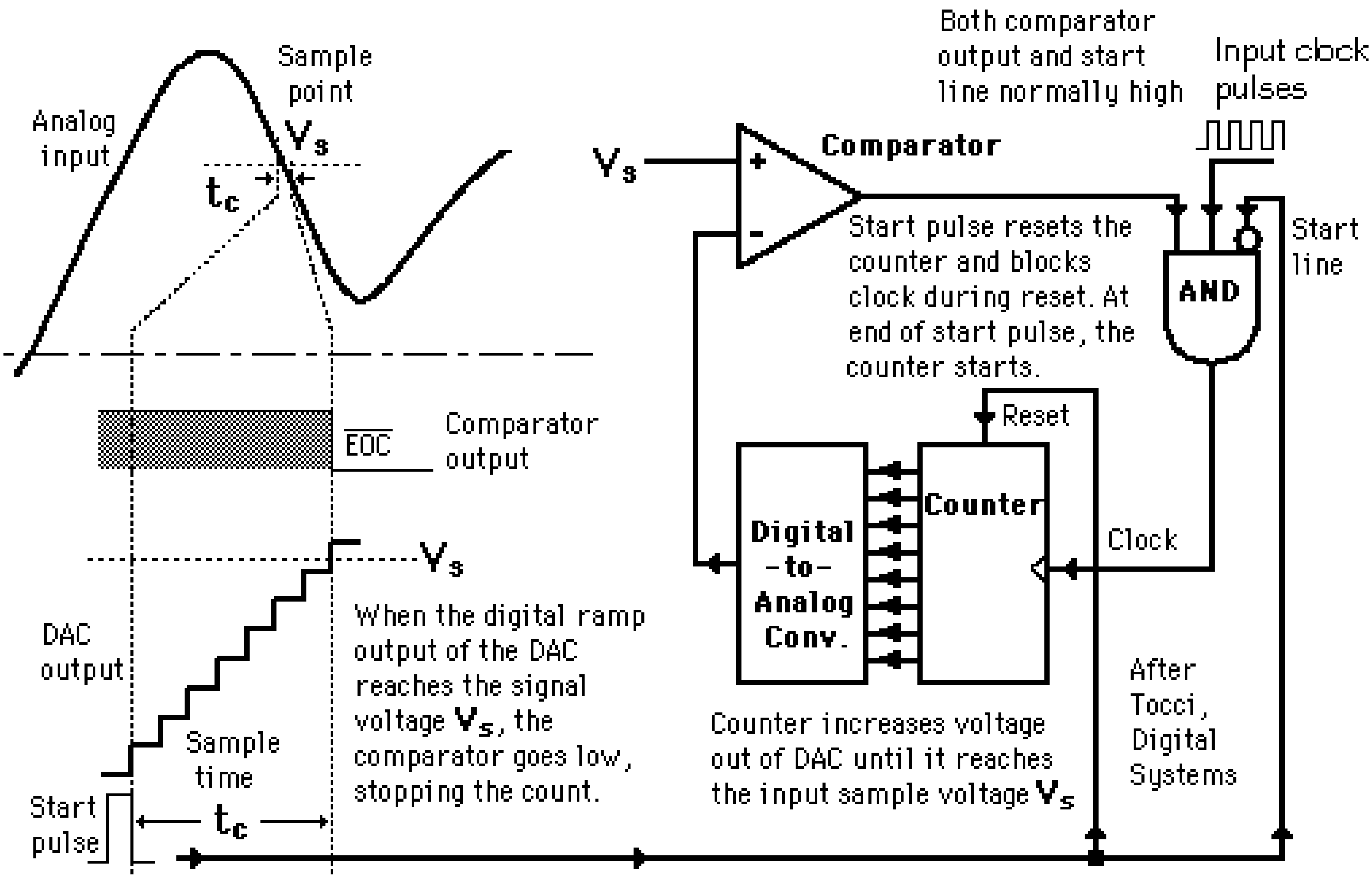
- 3 Basic Types

- Digital-Ramp ADC
- Successive Approximation ADC
- Flash ADC

Digital-Ramp ADC

- Conversion from analog to digital form inherently involves comparator action where the value of the analog voltage at some point in time is compared with some standard.
- A common way to do that is to apply the analog voltage to one terminal of a comparator and trigger a binary counter which drives a DAC.

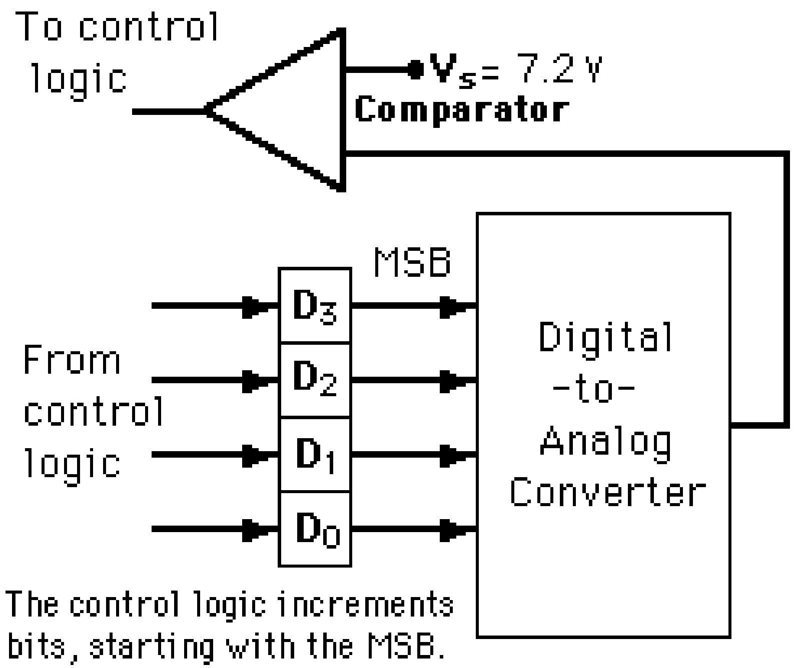
Digital-Ramp ADC



Digital-Ramp ADC

- The output of the DAC is applied to the other terminal of the comparator.
- Since the output of the DAC is increasing with the counter, it will trigger the comparator at some point when its voltage exceeds the analog input.
- The transition of the comparator stops the binary counter, which at that point holds the digital value corresponding to the analog voltage.

Successive approximation ADC



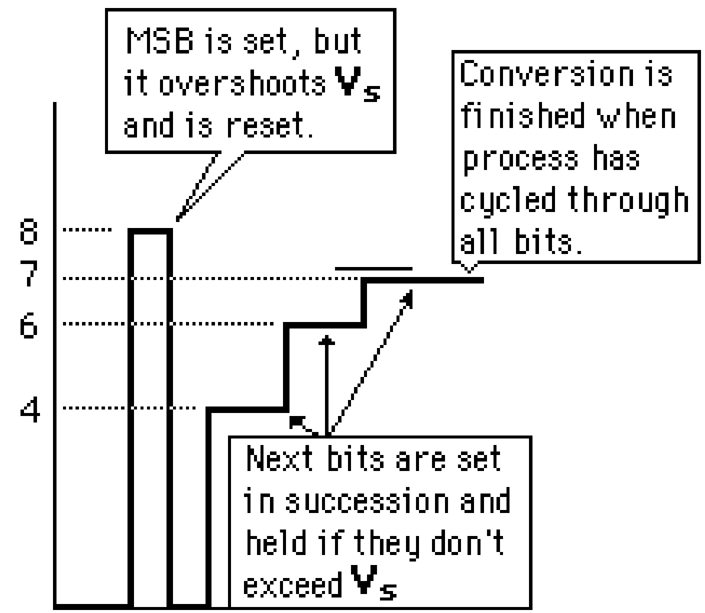
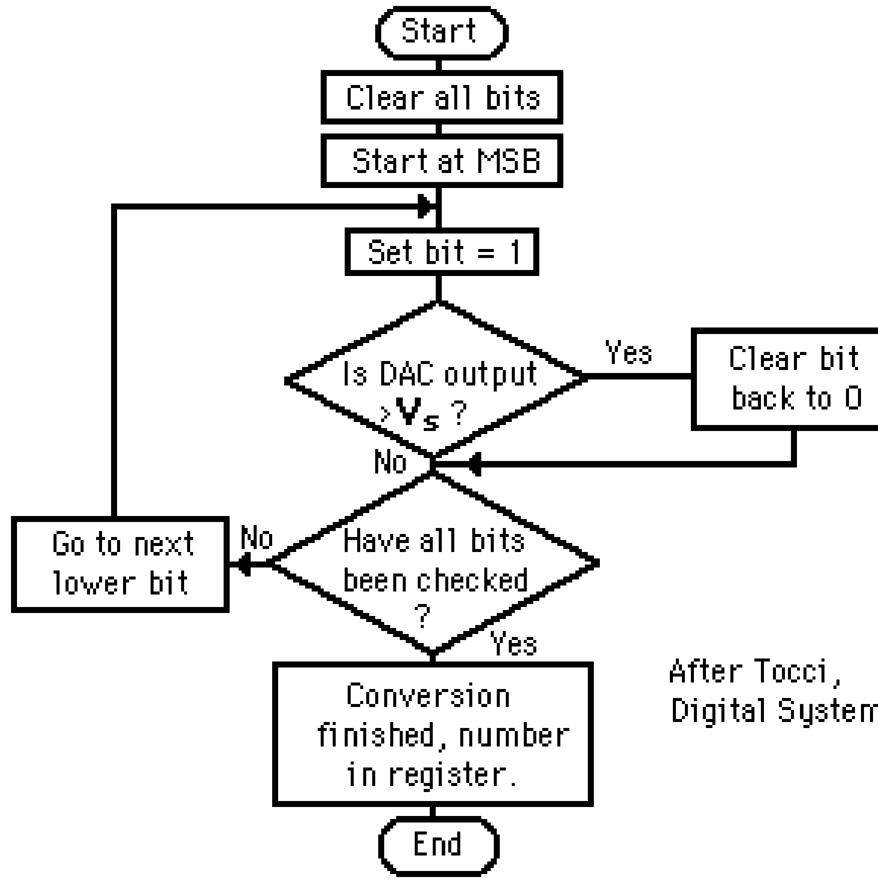


Illustration of 4-bit SAC with 1 volt step size

Successive approximation ADC

- Much faster than the digital ramp ADC because it uses digital logic to converge on the value closest to the input voltage.
- A comparator and a DAC are used in the process.



After Tocci, Digital Systems