UNIT 4:

MIXED SIGNALS

The communication that takes place in our everyday lives takes the form of signals. Generally speaking, these signals, such as sound signals, are analog. If the communication needs to be established over a distance, then the analog signals are transmitted via wire, using various techniques for effective transmission.

All the quantities in the physical world are of analog in nature. We may electrically reflect certain quantities as analog signals. An analog signal is a time-varying signal with a given time slot having any number of values (variations). Apart from this, a digital signal unexpectedly differs from one level to another, and will only have a finite number of values (variations) for a given period.

This unit will cover the discussion on data converters including analog to digital conversion and digital to analog conversion. Also, it will give you a glimpse of other mixed signals.

After studying this unit, the student must be able to:

- Develop an understanding of the types of data converter
- Defined what a data converter is
- Understand the basic of ADC and DAC conversion
- Develop understanding in different types of ADC and DAC converter
- Understand the method used in the construction ADC and DAC converter
- Calculate the output voltage for a given converter circuit

LESSON 4.1: DATA CONVERTER

DURATION: 60 minutes

LEARNING OBJECTIVES

After the lesson, the student must be able to:

- Develop an understanding of the types of data converter
- Defined what a data converter is
- Understand the specifications related to data conversion

LET'S HAVE A SELF ASSESSMENT!

Let us find out how much you already know about this topic. Choose the letter that you think best answers the questions. Please answer all items. Take note of the items that you were not sure of the answer and look for the right answer as you go through this lesson.

__g__1. It is a time-varying signal that has any number of values (variations) for a given time slot.

g. Analog Signal
h. Digital Signal
i. Data Converter

__b__2. It varies suddenly from one level to another level and will have only a finite number of values (variations) for a given time slot.

a. Analog Signal
b. Digital Signal
c. Data Converter

__i__3. The ratio of maximum analog input voltage that can be represented in binary and the equivalent binary number.

g. Conversion Time
h. Resolution
i. Voltage Regulator

__a__4. It is the amount of time required for a data converter to convert the data (information) of one form into its equivalent data in another form

a. Conversion Time
b. Resolution
c. Voltage Regulator

__i__5. the electronic circuits, which can be operated with digital signals are called .

g. Digital to Analog Converter
h. Analog Circuits
i. Digital Circuits

LESSON 11: DATA CONVERTER

DURATION: 60 minutes

LEARNING OBJECTIVES
After the lesson, the student must be able to:

- Develop an understanding of the types of data converter
- Defined what a data converter is
- Understand the specifications related to data conversion

LET'S HAVE A SELF ASSESSMENT!

Let us find out how much you already know about this topic. Choose the letter that you think best answers the questions. Please answer all items. Take note of the items that you were not sure of the answer and look for the right answer as you go through this lesson.

___g_1. It is a time-varying signal that has any number of values (variations) for a given time slot.

g. Analog Signal
h. Digital Signal
i. Data Converter

___e_2. It varies suddenly from one level to another level and will have only a finite number of values (variations) for a given time slot.

d. Analog Signal
e. Digital Signal
f. Data Converter

___l_3. The ratio of maximum analog input voltage that can be represented in binary and the equivalent binary number.

j. Conversion Time
k. Resolution
l. Voltage Regulator

___d_4. It is the amount of time required for a data converter to convert the data (information) of one form into its equivalent data in another form

d. Conversion Time
e. Resolution
f. Voltage Regulator

___l_5. the electronic circuits, which can be operated with digital signals are called ______.

j. Digital to Analog Converter
k. Analog Circuits
l. Digital Circuits

WHAT IS IT?

In this physical world or real world, most of the signals are analog signals. Analog signals are those signals which change continuously with the time, which means at every instant of time we will be having different values for the analog signal. Most of the signals which are present in the physical world are analog signals but nowadays though, instruments and equipments which are used are all using the technologies based on the digital signals. If we see a digital signal, it has only two values, either it will be 0 or it will have 1.

The electronic circuits that can be controlled with analog signals are referred to as analog circuits. Similarly, the electronic circuits that can be controlled with digital signals are referred to as digital circuits. An electronic circuit that converts data of one form to another is called a data converter.

Types of Data Converter

1. Analog to Digital Converter
2. Digital to Analog Converter

If we want to connect the output of an analog circuit as the input of a digital circuit, then we need to place between them an interfacing circuit. This interfacing circuit is called **Analog to Digital Converter** (ADC) which converts the analog signal into a digital signal.

Similarly, if we want to connect the output of a digital circuit as an input of an analog circuit, then an interfacing circuit must be placed between them. This interfacing circuit is called **Digital to Analog Converter** (DAC) which converts the digital signal into an analog signal.

Note that some Analog to Digital Converters may require Digital to Analog Converter as an internal block for their operation.

Specifications

There are two specifications related to data conversion.

1. Resolution
2. Conversion Time

Resolution

The minimum amount of change needed in an analog input voltage for binary (digital) output to be reflected in is called **resolution**. It is dependent on the number of bits used in the digital output.

We can represent resolution as,

$$Resolution = \frac{1}{2^N}$$

N = the number of bits that are present in the digital output.

We will note from the above formula that there is an inverse relationship between the resolution and the number of bits. As the number of bits increases, resolution decreases, and vice-versa.

Another way to define resolution is as the ratio of the maximum analog input voltage which can be expressed in binary and the binary number equivalent.

We can also represent resolution as,

$$Resolution = \frac{V_{FS}}{2^N - 1}$$

V_{FS} = full-scale input voltage or maximum analog input voltage,

N = the number of bits that are present in the digital output.

Conversion Time

Conversion time is the amount of time needed for a data converter to convert one form's data (information) into its equivalent data in another form. Since we have two types of data converters, the following two types of conversion times exist.

1. Analog to Digital Conversion Time
2. Digital to Analog Conversion Time

Analog to Digital Conversion Time is the amount of time required for an Analog to Digital Converter (ADC) to convert the analog input voltage into its equivalent binary (digital) output which depends on the number of bits that are used in the digital output.

Digital to Analog Conversion Time is the amount of time required for a Digital to Analog Converter (DAC) to convert the binary (digital) input into its equivalent analog output voltage which depends on the number of bits that are present in the binary (digital) input.

SUM IT UP

- ✓ Analog signals are those signals which change continuously with the time, which means at every instant of time we will be having different values for the analog signal.
- ✓ Digital signal has a finite number of values (variations) for a given period.

- ✓ Data Converter is an electronic circuit that converts data from one form to another.
- ✓ There are two types of data converter: Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC).
- ✓ ADC converts analog signals to digital signals.
- ✓ DAC converts digital signals to analog signals
- ✓ There are specifications related to data converter: resolution and conversion time.
- ✓ Resolution is the minimum amount of change needed in an analog input voltage for binary (digital) output to be reflected in
- ✓ Conversion time is the amount of time needed for a data converter to convert one form's data (information) into its equivalent data in another form.

LESSON 4.1.1: ANALOG TO DIGITAL CONVERSION

DURATION: 60 minutes

LEARNING OBJECTIVES

After the lesson, the student must be able to:

- Understand the basic of analog to digital conversion
- Develop understanding in different types of analog to digital converter
- Understand the method used in the construction of analog to digital converter

LET'S HAVE A SELF ASSESSMENT!

Let us find out how much you already know about this topic. Choose the letter that you think best answers the questions. Please answer all items. Take note of the items that you were not sure of the answer and look for the right answer as you go through this lesson.

__a__1. It refers to ADC performs the analog to digital conversion directly by utilizing the internally generated equivalent digital (binary) code for comparing with the analog input

a. Indirect Type ADC
b. Direct Type ADC
c. Counter Type

__c__2. It produces an equivalent digital output for a corresponding analog input in no time.

a. Counter Type
b. Successive Approximation
c. Flash Type

___a_3. It produces a digital output, which is approximately equal to the analog input by using counter operation internally.

a. Counter Type
b. Successive Approximation
c. Flash Type

___a_4. It produces an equivalent digital output for a corresponding analog input by using two (dual) slope technique.

a. Dual Slope
b. Digital Signal
c. Flash Type

__b_5. It produces a digital output, which is approximately equal to the analog input by using a successive approximation technique internally.

a. Counter Type

b. Successive Approximation
c. Flash Type

WHAT IS IT?

From the previous lesson, we already understand that an Analog to Digital Converter (ADC) converts an analog signal into a digital signal in which the digital signal is represented with a binary code, 0 and 1 bits.

In this lesson, we will present a detailed discussion of different types of ADC or the method of how these converters are constructed.

Block Diagram of an ADC

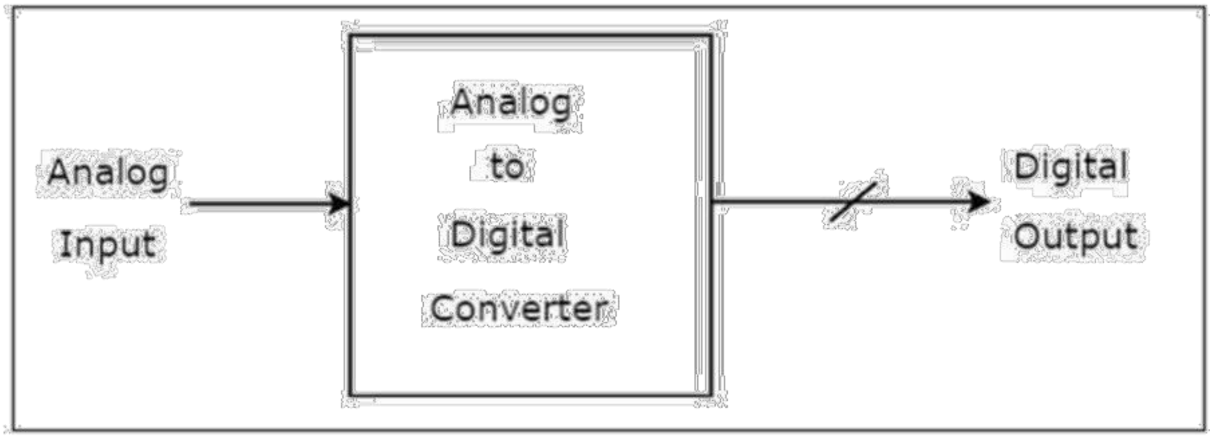

Figure 4.1 Block diagram of an ADC

Notice that an Analog to Digital Converter (ADC) consists of one analog input and several binary outputs in Figure 4.1 shown above. The number of ADC's binary outputs would normally be a power of two.

Types of ADC

1. Direct Type ADC – If the ADC directly performs the analog to digital conversion by using the internal generated equivalent digital (binary) code for comparison with the analog input
    - Counter Type ADC
    - Successive Approximation ADC
    - Flash Type ADC
2. Indirect Type ADC – if first it converts the analog input into a linear function of time (or frequency) and then it will produce the digital (binary) output
    - Dual Slope ADC

Counter Type ADC

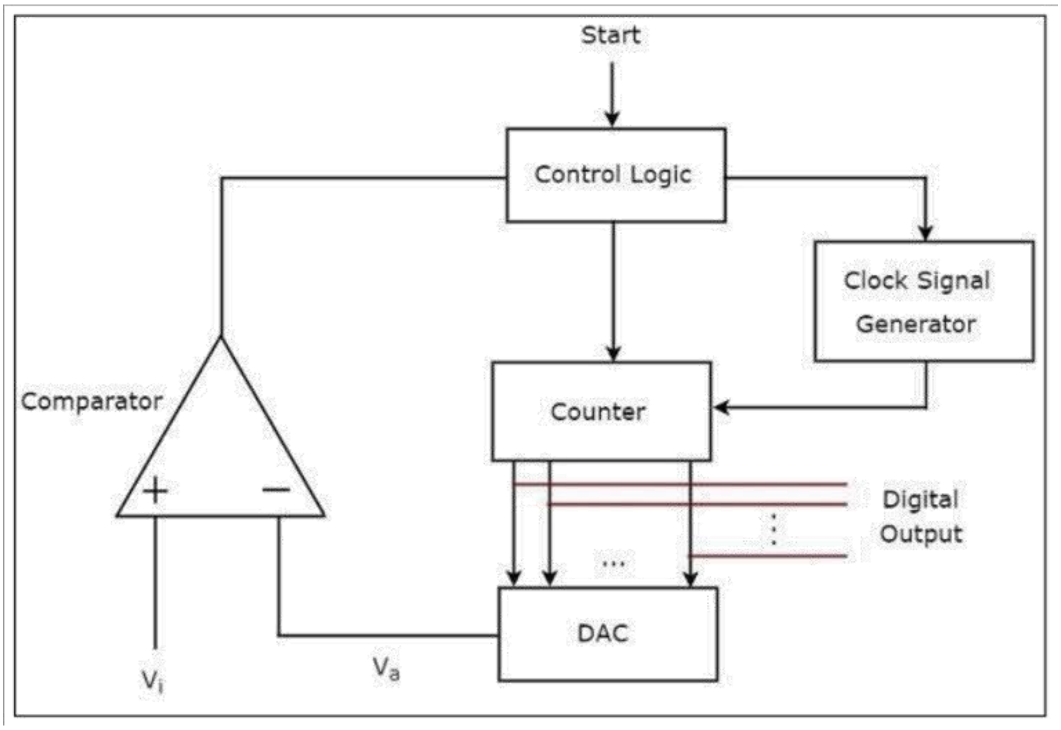

Figure 4.2 Block Diagram of Counter Type ADC

A counter type ADC generates a digital output that is roughly equivalent to the analog input by using internal counter operation. The block diagram of counter type ADC is shown in figure 4.2, which consist of a Clock signal generator, Counter, DAC, Comparator, and Control logic.

The control logic resets the counter and allows the clock signal generator to deliver the clock pulses to the counter when it gets the start commanding signal. For each clock pulse, the counter is incremented by one, and its value is in binary (digital) format. The counter output is implemented as a DAC input. DAC transforms the obtained binary (digital) input, which is the output counter, into an analog output. Comparator compares this analog value, Va with the external analog input value Vi. As long as is greater than the output of the comparator will be 1. The operations mentioned previously will be continued as long as the control logic receives 1 from the output of the comparator. When Vi is less than or equal to Va, the output of the comparator will be 0. So, from the output of the comparator, the control logic receives 0. The control logic then deactivates the clock signal generator so that no clock pulse is sent to the counter. The output of the counter will then be shown as the digital output at this moment. The corresponding external analog input value Vi is approximately equal to that.

Successive Approximation ADC

A successive approximation type ADC generates a digital output that is roughly equivalent to the analog input by the internal use of successive approximation technique. The block diagram of successive approximation ADC is shown in Figure

4.3, which consists of a Clock signal generator, Successive Approximation Register (SAR), DAC, comparator, and control logic.

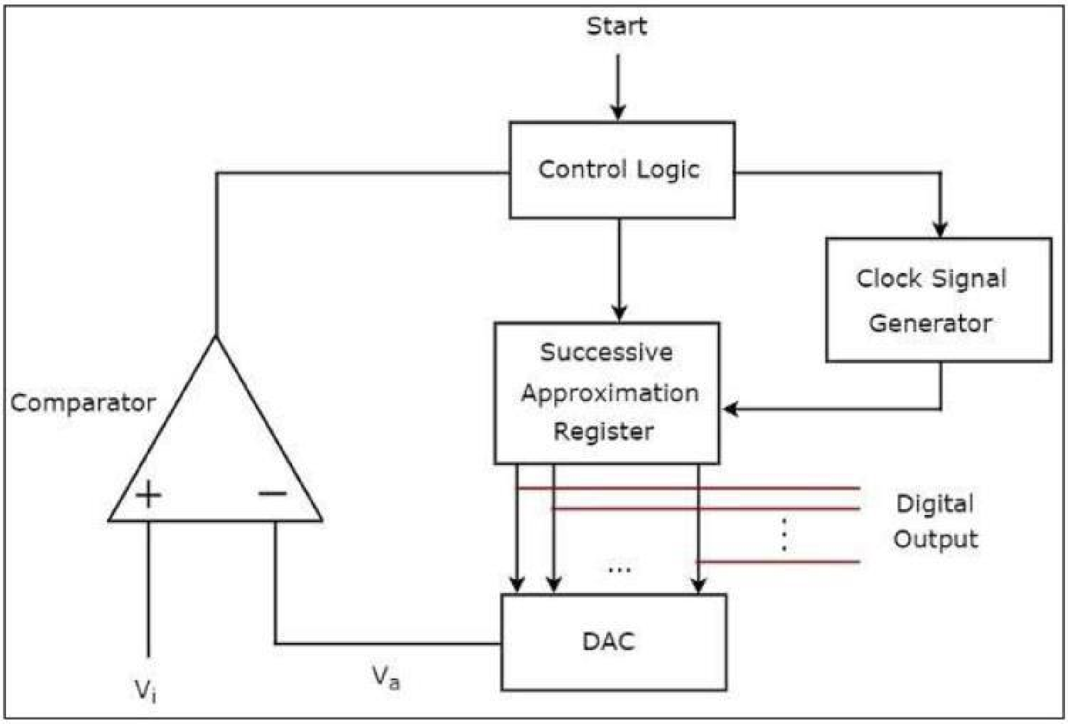

Figure 4.3 Block Diagram of successive approximation ADC

So, this is the how of the successive approximation ADC works. The control logic resets all bits of SAR and allows the clock signal generator to deliver clock pulses to SAR when it gets the start commanding signal. For each clock pulse, the binary (digital) data present in SAR will be adjusted depending on the output comparator. The output of SAR is carried out as an input of DAC. DAC turns the obtained digital input, which is output SAR, into an analog output. This analog value Va is contrasted by the comparator to the external analog input value Vi. As long as Vi is greater than Va, the output of a comparator will be 1. When Vi is less than or equal to Va, the output of the comparator will be 0. Until the digital output is a valid one (when it is almost equivalent to the corresponding external analog input value Vi, all the operations mentioned previously will be continued.

Flash Type ADC

Flash type ADC is the fastest ADC because it produces an equivalent digital output for a corresponding analog input in no time. The circuit diagram of a 3-bit flash type ADC is shown in Figure 4.4, which consist of a voltage divider network, 7 comparators, and a priority encoder.

So, this is the how of the 3-bit flash type ADC works. The voltage divider network comprises 8 resistors of equal size. Concerning the field, a reference voltage VR is applied over the entire network. The voltage drops through each resistor from bottom to top concerning ground will be the integer multiples (from 1 to 8) of VR/8. The external input voltage Vi is implemented to any comparator's non-inverting terminal. Concerning ground, the voltage drop through each resistor from bottom to top is applied to the inverting terminal of comparators from bottom to top. All the comparators compare the external input voltage with the voltage drops present at the other respective input terminal. Such that, the comparison operations are performed in parallel by each comparator. As long as Vi is greater than the voltage drop present at the respective another input terminal, the output of the comparator will be 1. When Vi is less than or equal to the voltage drop present at the respective another input terminal, the output of the comparator will be 0. All outputs of the comparator are linked as the inputs of the priority encoder. This priority encoder generates a binary code (digital output) corresponding to the high priority input with 1. Thus, the output of the priority encoder is nothing but the binary equivalent (digital output) of external analog input voltage, Vi. The flash type ADC has been used in applications at which analog input conversion speed into digital data should be very high

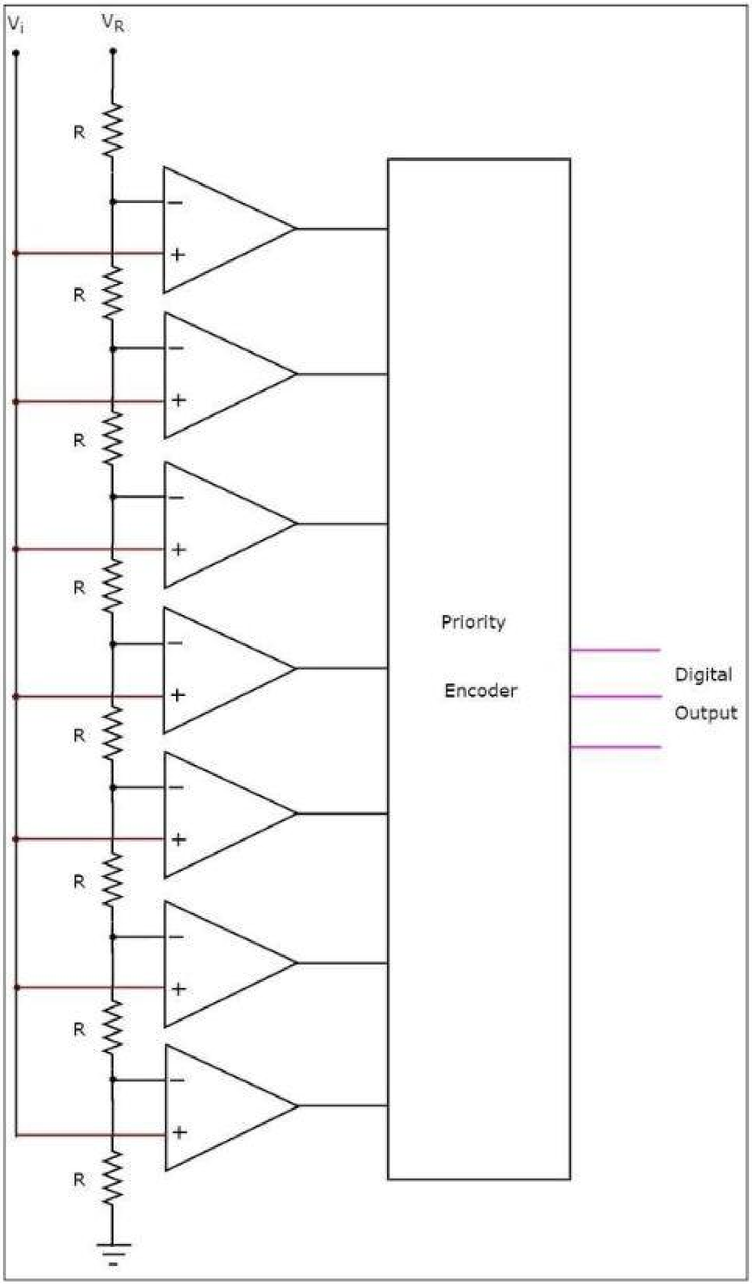

Figure 4.4 Circuit Diagram of a 3-bit flash type ADC

Dual Slope ADC

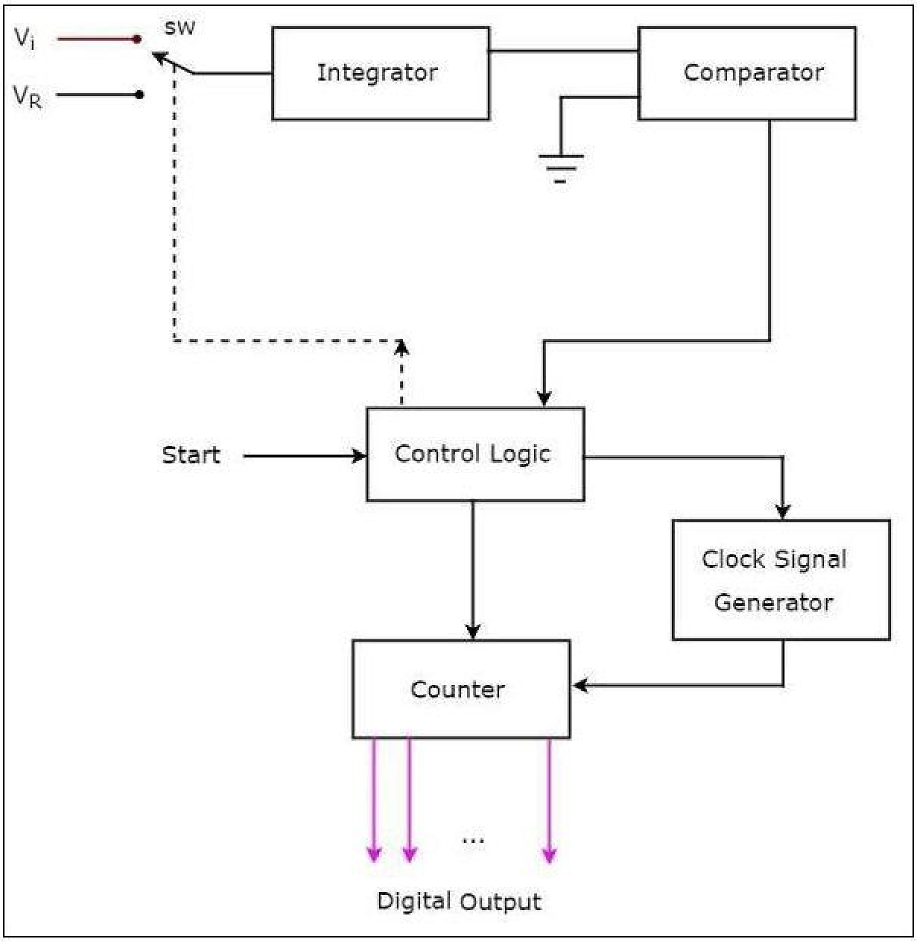

Figure 4.5 Block Diagram of Dual Slope ADC

Using two (dual) slope techniques, a dual-slope ADC generates an equivalent digital output for a corresponding analog input. The block diagram of a dual-slope ADC is shown in Figure 4.5 which consists of Integrator, Comparator, Clock signal generator, Control logic, and Counter.

So, this is the how of the dual-slope ADC works. The control logic resets the counter and allows the clock signal generator to transmit the clock pulses to the counter when the start commanding signal is received. Control logic turns the switch sw to connect to the external analog input voltage Vi when the start commanding signal is received. This input voltage is implemented to an integrator. The integrator output is connected to one of the comparator's two inputs, and the other comparator input is connected to the ground. The comparator compares the integrator output to zero volts (ground) and generates an output that is added to the control logic. For each clock pulse, the counter is incremented by one, and its value is in binary (digital) format. It generates an overflow signal to the control logic if incremented after the maximum count value is reached. At this point, all counter bits will only have zeros. Now the control logic forces the switch sw to link to the negative voltage reference −Vref. It applies this negative reference voltage to an integrator. It eliminates the charge that is held in the capacitor until it becomes zero. At this point, both of a comparator's inputs have zero volts. So the comparator gives the control logic a signal.