Real Time System

Third Level

Types of ADC

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Goals
Up-on completing this lecture, the student should be able to:

1- Identify the different types of A/Ds and their theory of operation
2- Design A/D circuits that meet the different resolution, speed requirements.

Types of A/D Converters

- Flash ADC
- Delta-Sigma ADC
- Dual Slope (integrating) ADC
- Successive Approximation ADC

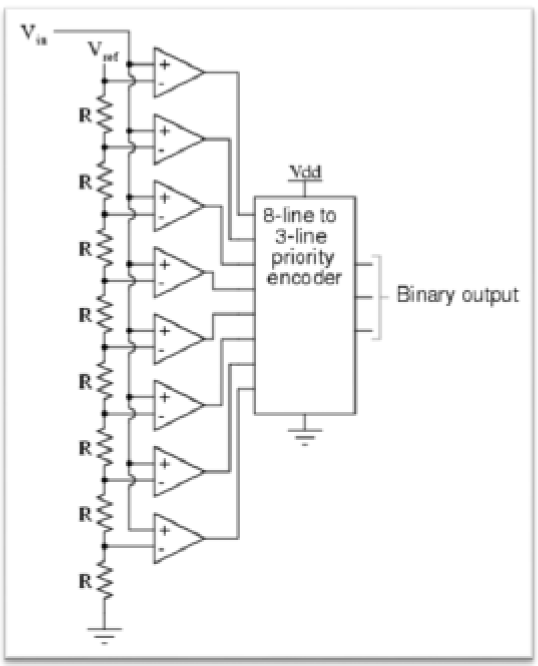
1. Flash A/D Converter

Fundamental Components

Resistors use the resistors to form a ladder voltage divider, which divides the reference voltage into equal intervals.

Comparators Consists of a series of comparators, which comparing the input signal to a unique reference voltage.

Priority encoder the comparator outputs connect to the inputs of a priority encoder circuit, which produces a binary output.



How does it work?

- Uses the comparators to determine in which the input voltage V_{in} is exceed or not the V_{ref}.
- When the analog input voltage exceeds the reference voltage at each comparator, the comparator outputs will sequentially saturate to a high state.
- The priority encoder generates a binary number based on the highest-order active input, ignoring all other active inputs.

Advantages and Disadvantages

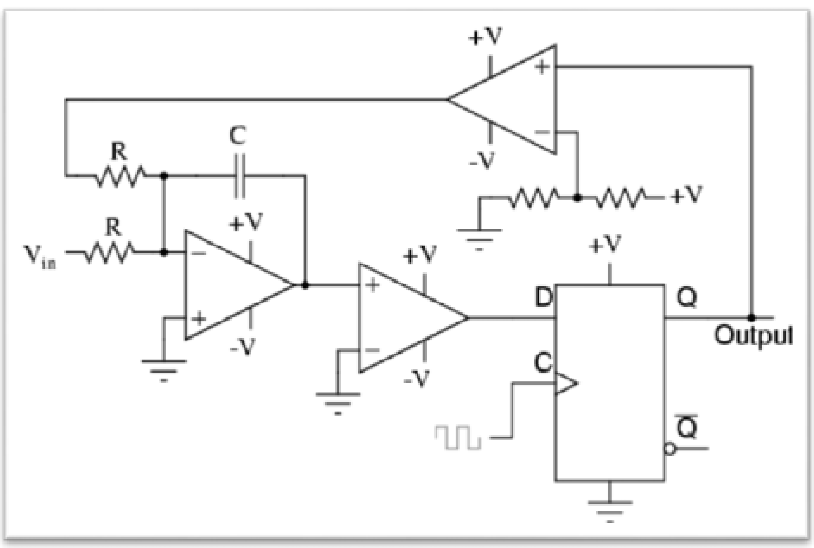
- Simplest in terms of operational theory, most efficient in terms of speed, very fast
- Lower resolution, Expensive, for each additional output bit, the number of comparators is increase.

2. <u>Sigma Delta ADC</u>

To see live demo, go to:
http://www.analog.com/en/design-center/interactive-design-tools/sigma-delta-adc-tutorial.html

Main Components

- Resistors
- Integrator
- Capacitor
- Comparators
- Control Logic



How does it work?

- Input is over sampled, and goes to integrator.
- The integration is then compared to ground.
- Iterates and produces a serial bit stream
- Output is a serial bit stream with # of 1's proportional to V_{in}

Advantages and Disadvantages

- High resolution, No need for precision components external.
- Slow due to oversampling.

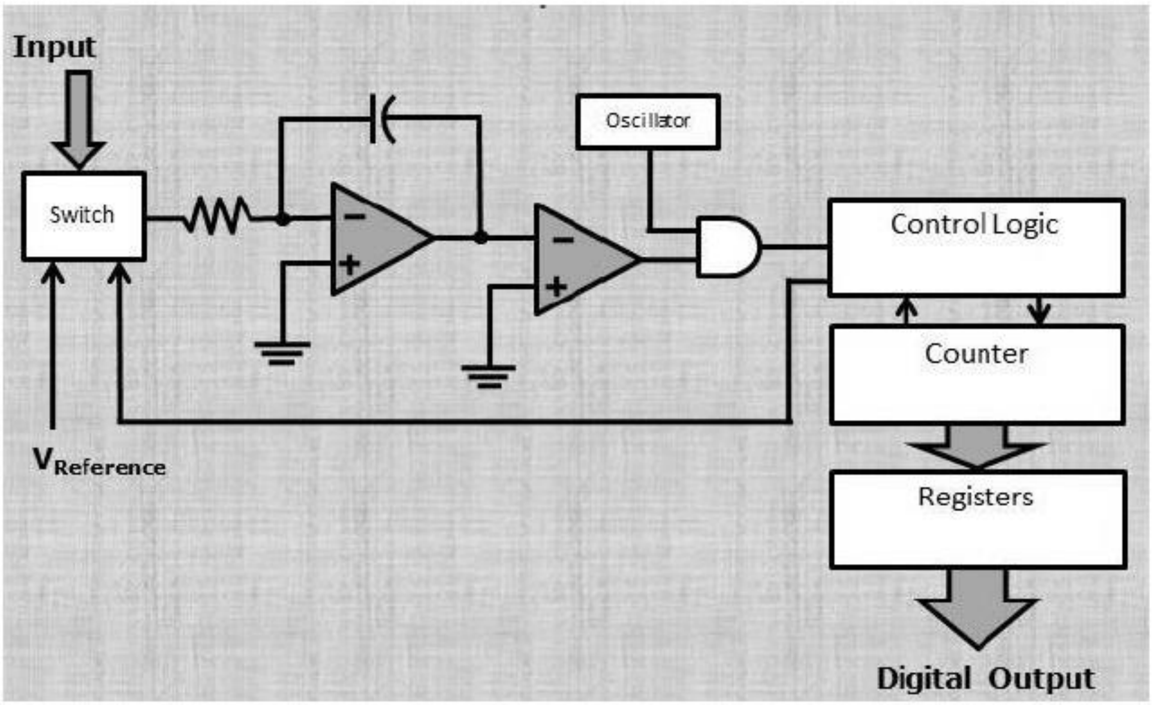
3. Dual Slope Converter

Fundamental components

- Integrator
- Electronically Controlled Switches
- Counter
- Clock
- Control Logic
- Comparator

In details:

Input voltage VIN is first summed with the output of a feedback DAC. An integrator then adds the output of this summing node to a value it has stored from the previous integration step. A comparator outputs a logic 1 if the integrator output is greater than or equal to zero volts and a logic 0 otherwise. A 1-bit DAC feeds the output of the comparator back to the summing node: +VREF for logic 1 and -VREF for logic 0. This feedback tries to keep the integrator output at zero by making the ones and zeros output of the comparator equal to the analog input.



The Dual Slope ADC functions in this manner:

- When an analog value is applied, the capacitor begins to charge in a linear manner and the oscillator passes to the counter.
- The counter continues to count until it reaches a predetermined value. Once this value is reached the count stops and the counter is reset. The control logic switches the input to the first comparator to a reference voltage, providing a discharge path for the capacitor.
- As the capacitor discharges the counter counts.
- When the capacitor voltage reaches the reference voltage the count stops and the value is stored in the register.

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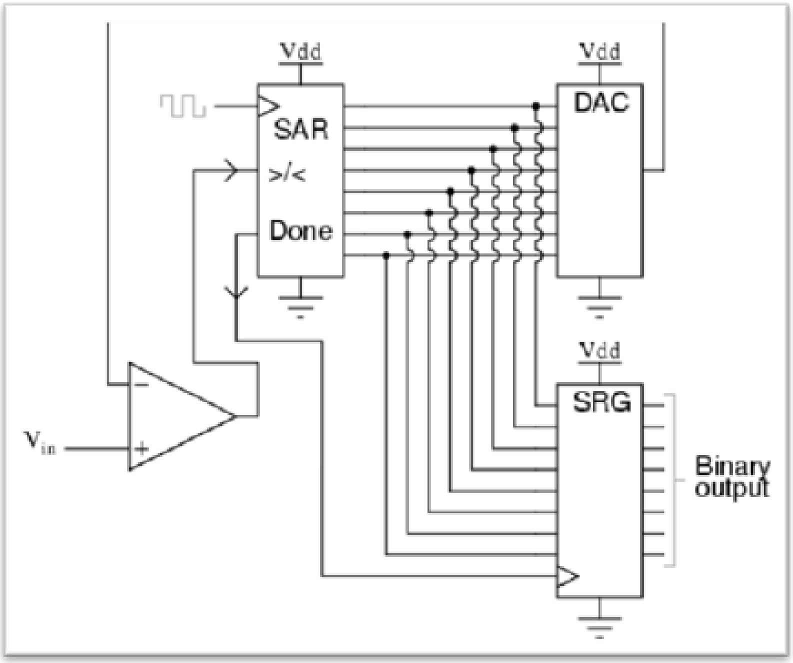
Advantages and Disadvantages

- Conversion result is insensitive to errors in the component values, High Accuracy.
- Slow, Accuracy is dependent on the use of precision external components, Cost.

4. Successive Approximation ADC

- Much faster than the Dual Slope.
- A comparator and a DAC are used in the process.
- A Successive Approximation Register (SAR) is added to the circuit
- Instead of counting up in binary sequence, this register counts by trying all values of bits starting with the MSB and finishing at the LSB.
- The register monitors the comparators output to see if the binary count is greater or less than the analog signal input and adjusts the bits accordingly.



Advantages and Disadvantages

- Capable of high speed and reliable, medium accuracy compared to other ADC types, Good tradeoff between speed and cost.
- Higher resolution successive approximation ADC's will be slower.

Example

10 bit ADC, V_{in}= 0.6 volts (from analog device), V_{ref}=1 volts, Find the digital value of V_{in}?

Solu:

- MSB (bit 9)
  - Divided V_{ref} by 2
  - Compare $V_{ref}/2$ with V_{in}
  - If V_{in} is greater than $V_{ref}/2$, turn MSB on (1)
  - If V_{in} is less than $V_{ref}/2$, turn MSB off (0)
  - V_{in} =0.6V and V=0.5
  - Since V_{in}>V, MSB = 1 (on)

- Calculate the state of MSB-3 (bit 6)
  - Go to the last bit that caused it to be turned on (In this case MSB-1) and add it to $V_{ref}/16$, and compare it to V_{in}
  - Compare V_{in} to $V = 0.5 + V_{ref}/16 = 0.5625$
  - Since 0.6>0.5625, MSB-3=1 (turned on)

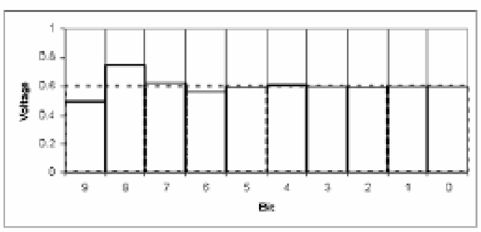
MSB	MSB-1	MSB-2	MSB-3	…					
1	0	0	1						

- This process continues for all the remaining bits.

•Digital Results:

MSB	MSB-1	MSB-2	MSB-3	…					LSB
1	0	0	1	1	0	0	1	1	0

•Results: $\frac{1}{2}+\frac{1}{16}+\frac{1}{32}+\frac{1}{256}+\frac{1}{512}=.599609375\ V$



ADC Specifications:

- Conversion time
- Resolution
- Accuracy
- Linearity
- Missing code

ADC Errors due to Noise and Aliasing.

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ADC Errors due to Noise and Aliasing.

How to choose the ADC according to the resolution?

Two ways for find the resolution needed in ADC, first way is to find the **dynamic range** of input signal and to choose the number of bits based on this.

$N >= \ln (V_{max}/V_{noise})$ --- dynamic range (stage) (sensor)

Another way to choose the number of bits is based on the **resolution required** in input signal.

$N >= \ln (S_{max}/S_{noise})$ --- required resolutions (stage before ADC) (transducer)

Example

A transducer is to be used to find the temperature over a range of 0 to 100 C. we are required to read and display the temperature to a resolution of +- 1 C. the transducer produces a voltage from 0 to 3v over this temperature range with +-3mv noise. Specify the number of bits in ADC: a) Based on dynamic range. b) Based on required resolutions.

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