EE 230
Lecture 36

Data Converters

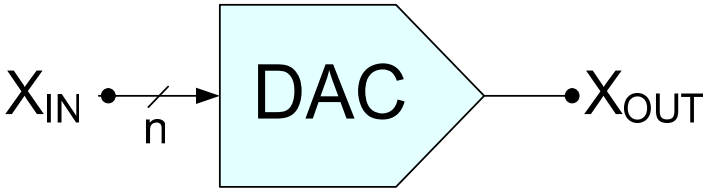
Review from Last Time:

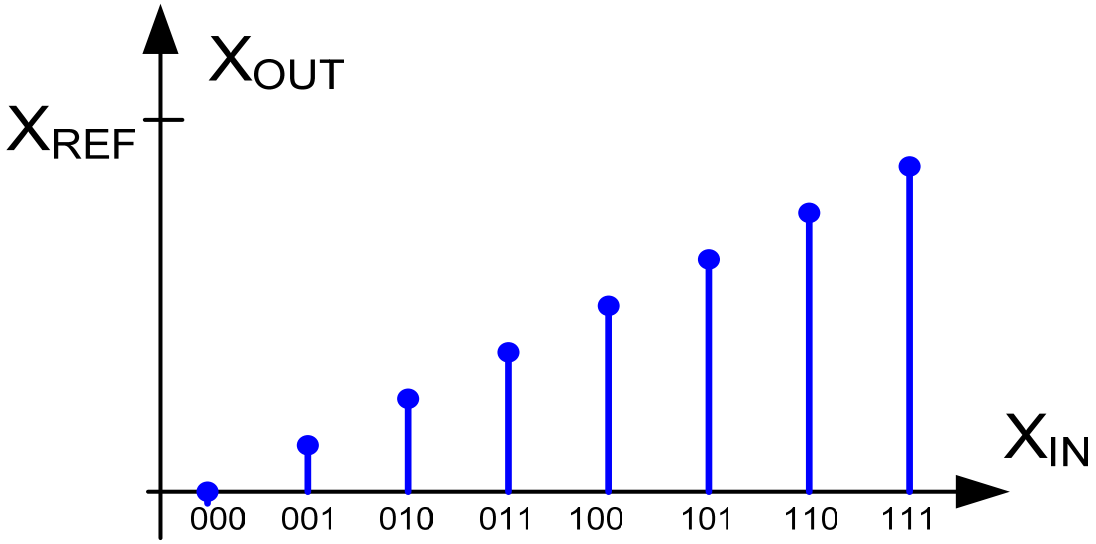
Data Converters

Applications: Dominantly the interface between the continuous-time Continuous-amplitude physical environment and a digital system such as a computer, microprocessor, microcontroller, or finite state machine

Review from Last Time:

Data Converters



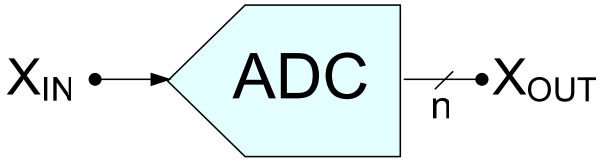


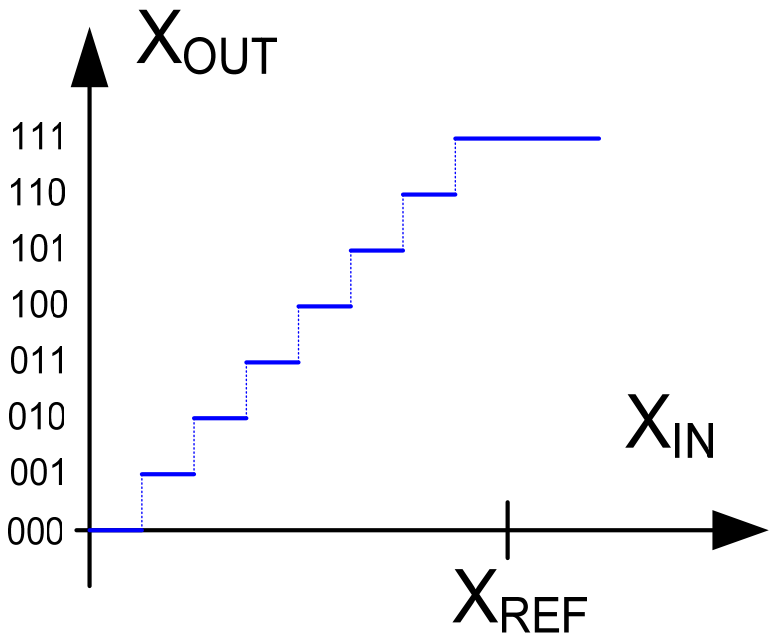
X_{IN}: $[b_1\, b_2 \ldots . b_n]$

Ideal n-bit DAC has 2^n output levels

X_{REF} defines the output range of the DAC

Data Converters



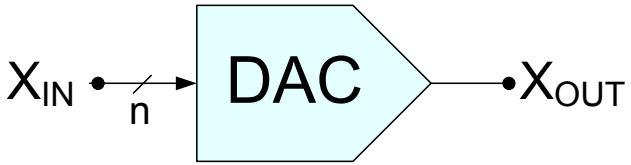


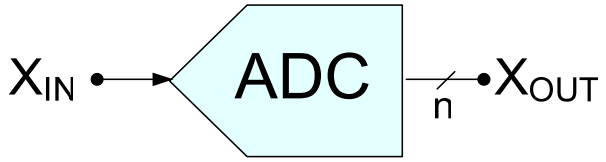
X_{OUT}: $[b_1\, b_2 \ldots b_n]$

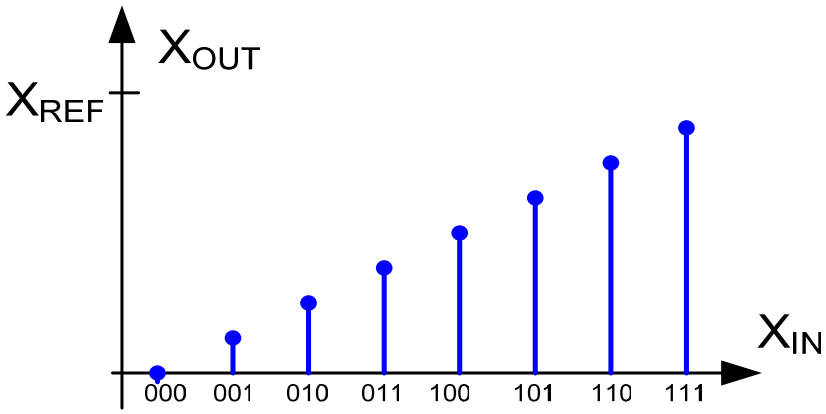
Ideal n-bit ADC has 2^n -1 transition values

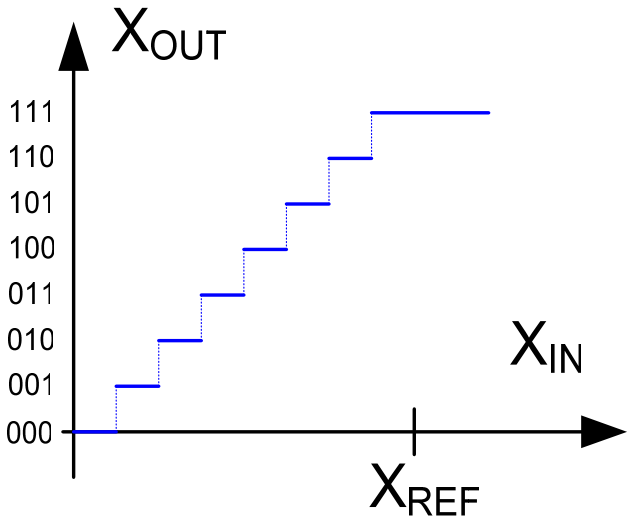
X_{REF} defines the input range of the ADC

Least Significant Bit









The LSB is the nominal value of the smallest change that occurs in the output of an ideal DAC or the nominal value of the smallest increment in the input that causes a change of a single binary digit in an ADC

Continuous Domain

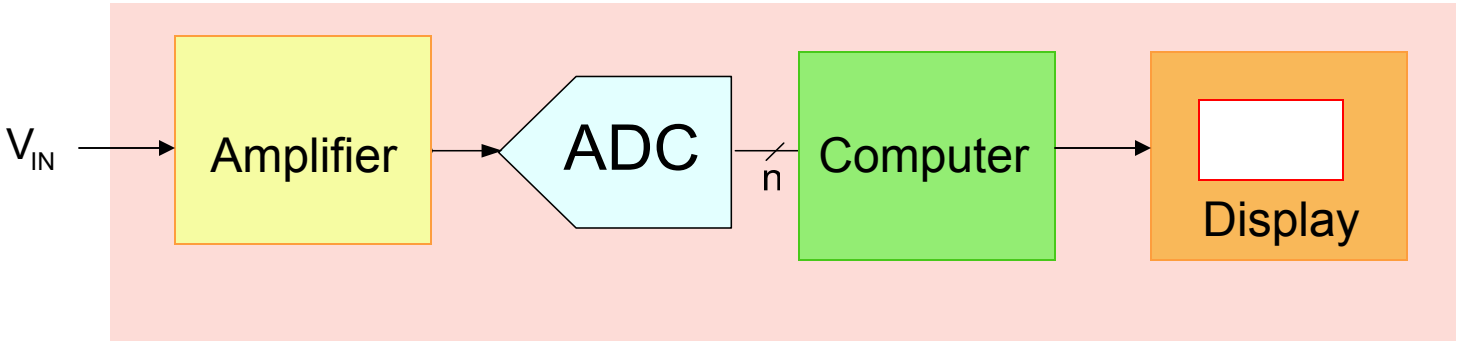
$$X_{LSB} = \frac{X_{REF}}{2^n}$$

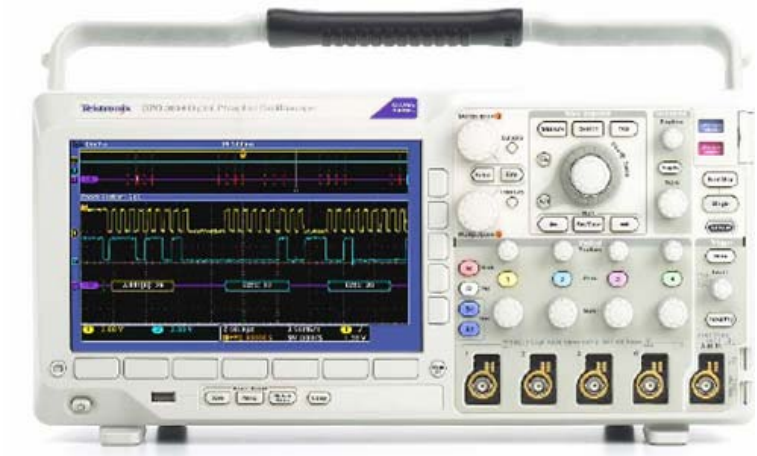
Boolean Domain

X_{LSB}: [0,0,…0,1]

Review from Last Time:

The DMM and the Oscilloscope we have in the laboratory are basically an ADC, amplifier, and a computer with a case and front panel that makes them resemble the mulitmeters and oscilloscopes of the 50's and 60's. Interface is either through buttons and knobs on front or through computer interface.





Data Converter Implementations

- Discrete implementations of data converters are seldom used
  - Not cost effective
  - Too large
  - Vary difficult to maintain acceptable accuracies of components
- Integrated data converters usually have voltage or current as input or output variables
  - If conversion of other physical units is required, a transducer precedes or follows a voltage or current data converter

Types of Data Converters

(by intended application)

Analog to Digital Converters

- A/D Converters
- Audio A/D Converters
- Capacitance to Digital Converters
- Energy Measurement
- Isolated A/D Converters
- Synchro/Resolver to Digital Converters
- Temperature to Digital Converters
- Touchscreen Controllers
- Video Decoders
- Voltage to Frequency Converters

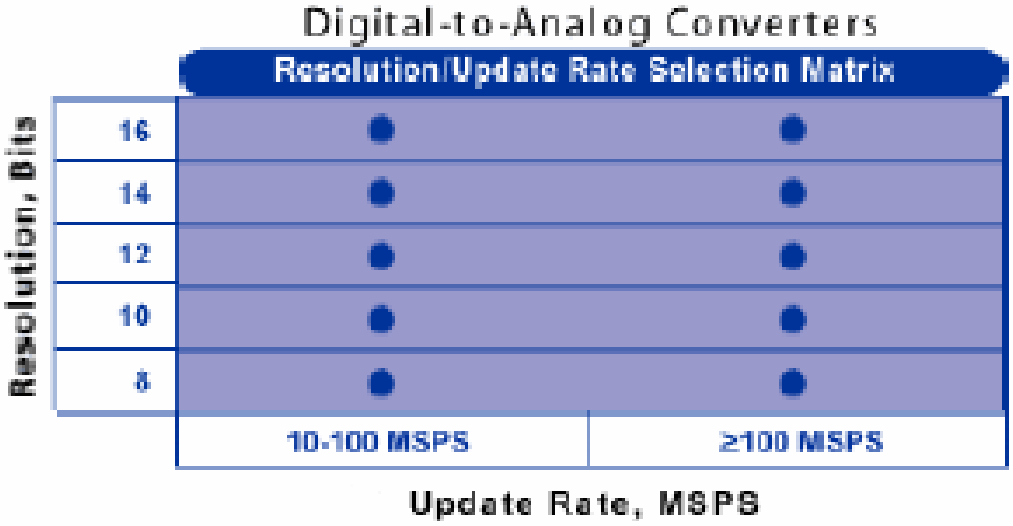
Digital to Analog Converters

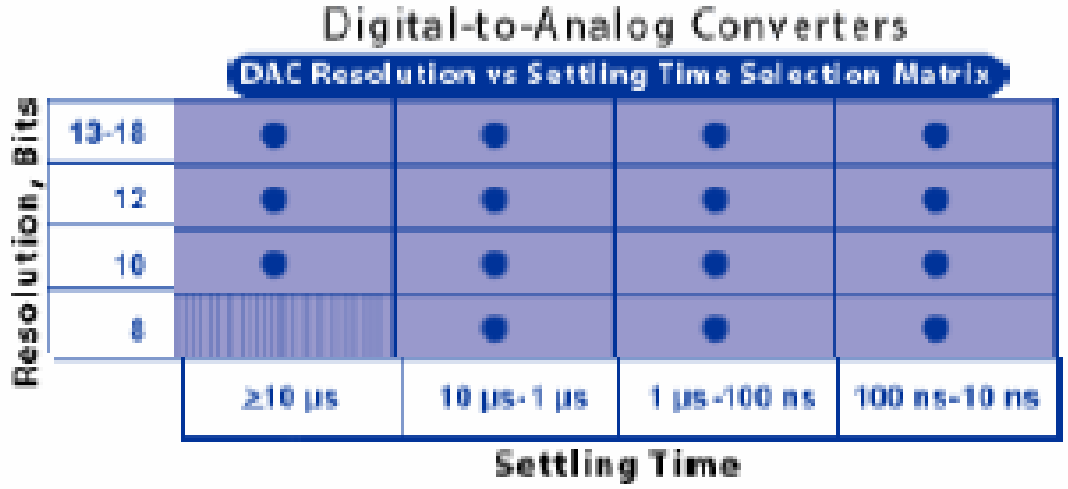
- D/A Converters
- Audio D/A Converters
- Digital Potentiometers
- Video Encoders

(Analog Devices is one of several companies that is a big player in the Data Converter marketplace. Others include TI, National, Maxim and Cyrus)

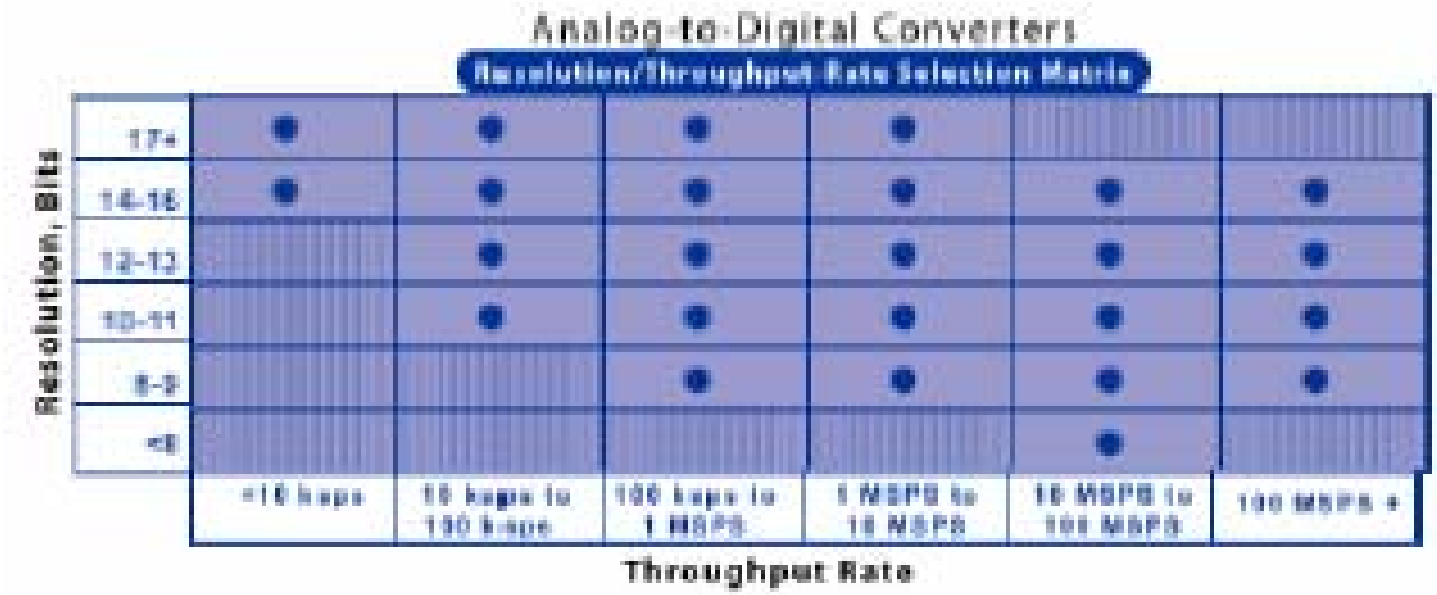
Data Converter Selection

ANALOG DEVICES





Data Converter Selection



Engineering Issues for Using Data Converters

1. Inherent with Data Conversion Process

- Amplitude Quantization
- Time Quantization

(Present even with Ideal Data Converters)

2. Nonideal Components

- Uneven steps
- Offsets
- Gain errors
- Response Time
- Noise

(Present to some degree in all physical Data Converters)

How do these issues ultimately impact performance ?

Engineering Issues for Using Data Converters

Inherent with Data Conversion Process

- Amplitude Quantization
- Time Quantization
- Present even with Ideal Data Converters

- Somewhat challenging to characterize
- Avoid over-specification
  Power
  Cost

- Key questions to ask
  How much resolution is needed ?
  What range is needed ?
  How fast must the converter operate ?
  What are the implications of noise ?

Engineering Issues for Using Data Converters

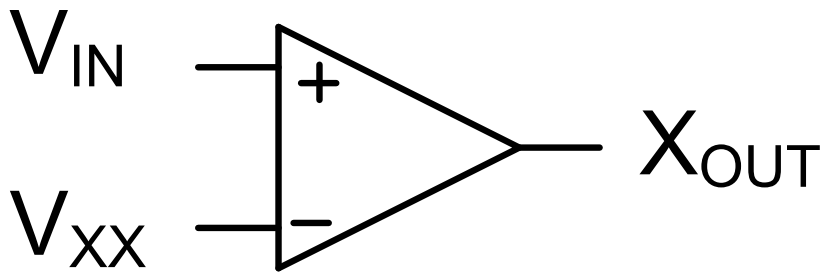
Nonideal Components

- Uneven steps
- Offsets
- Response Time
- Noise
- Present to some degree in all physical Data Converters

- Somewhat challenging to characterize
  - Many parameters (specifications) have been given
  - Mathematical analysis often complicated
  - Often statistical in nature
  - Computer simulations help but still leave some questions unanswered
- Somewhat challenging to predict affects on system performance
  - Depends upon application
  - Computer simulations help but still leave some questions unanswered

ADC Architectures

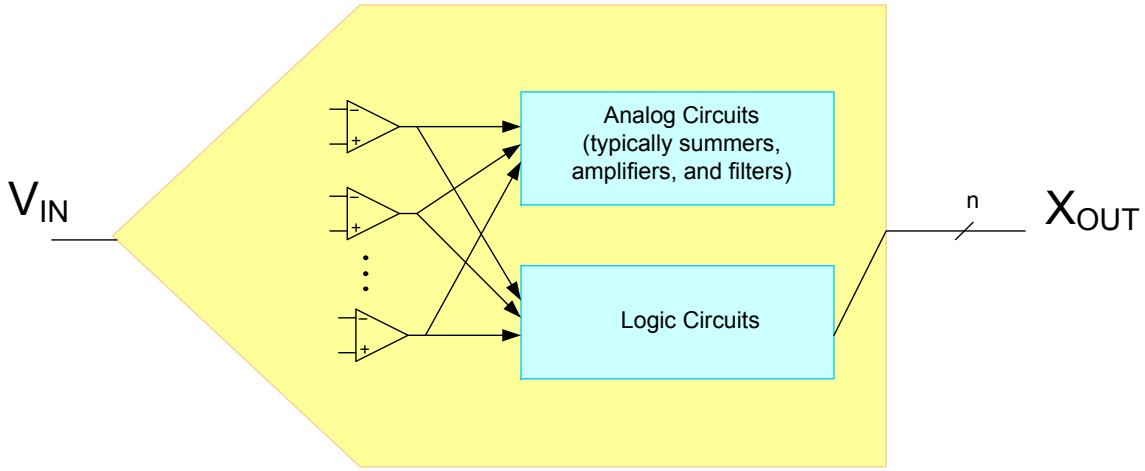
The Comparator is a circuit element that converts an analog signal to a digital signal



Often comparator will have hysteresis (but not always)

ADC Architectures

Essentially all ADCs use one or more comparators to convert an analog signal to a digital signal. They typically include some other analog circuitry and some digital circuitry

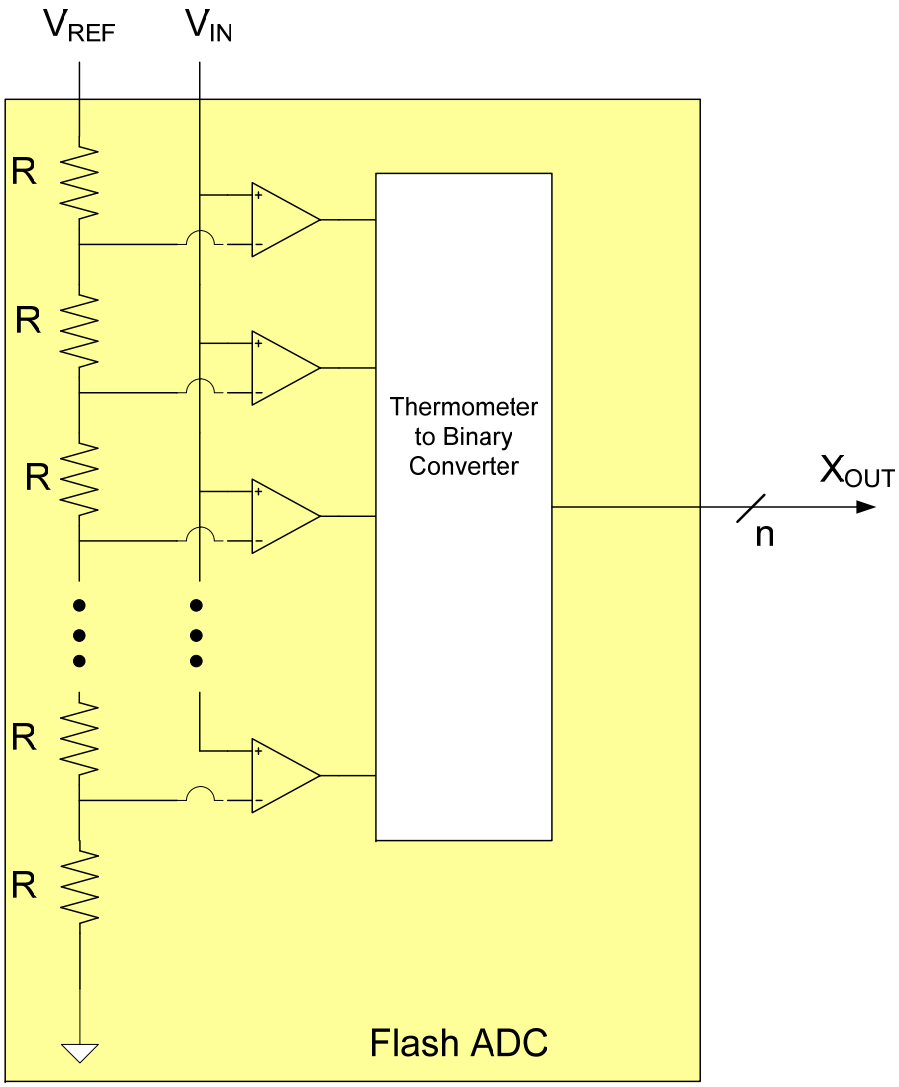


Types of ADCs

- Flash
- Pipelined
- Folded
- Serial
  - Single-slope
  - Dual-slope
- Interpolating
- Iterative (Algorithmic, Cyclic)
- Successive Approximation (SAR)
- Oversampled (Delta-Sigma)
- Charge Redistribution
- Several others

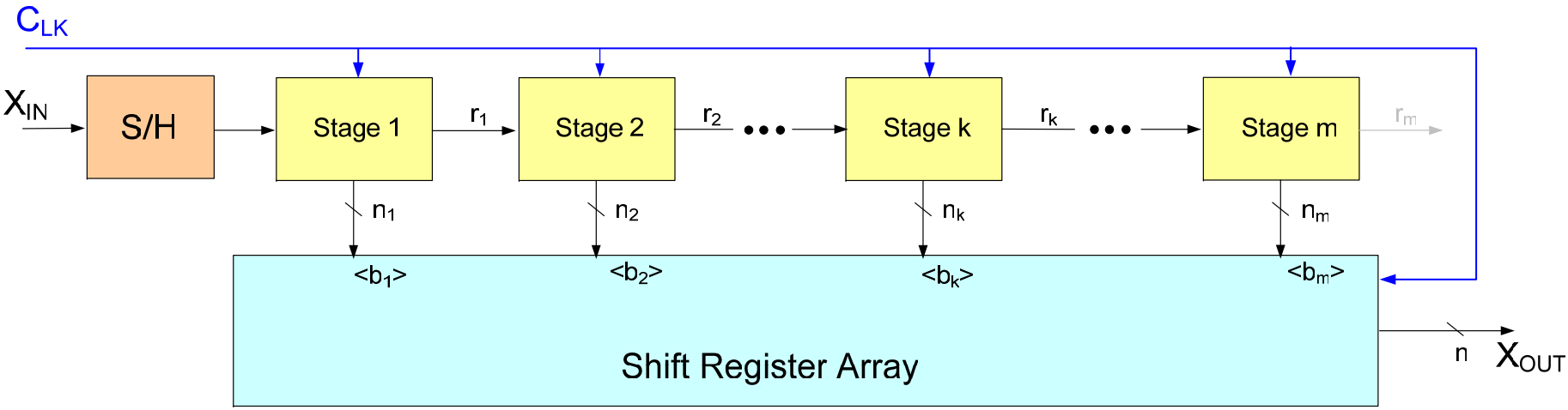
Types of ADCs

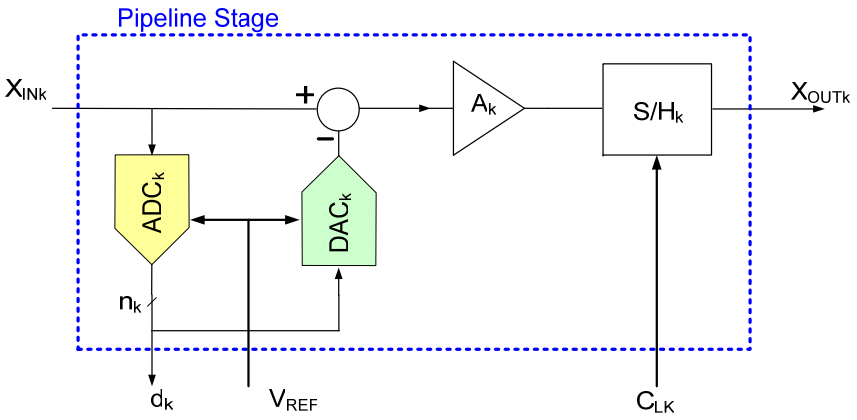
Flash ADC



Types of ADCs

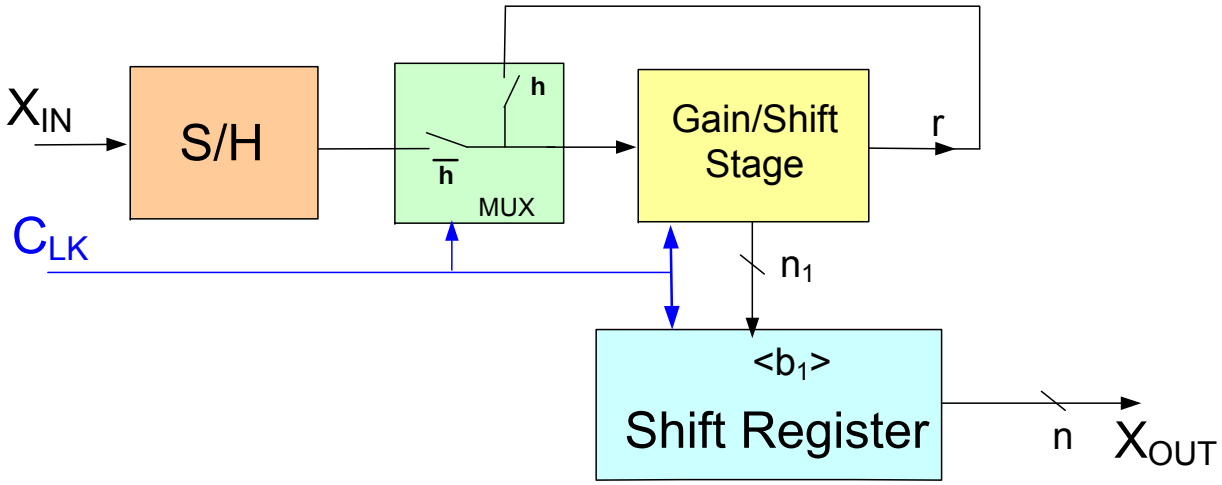
Pipelined ADC

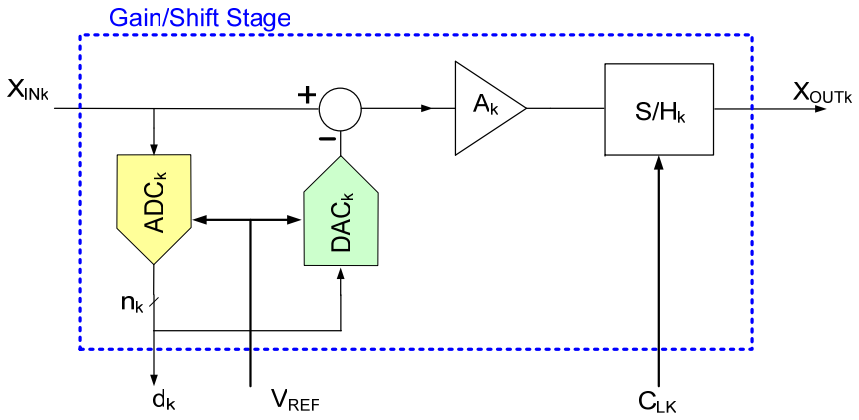




Types of ADCs

Cyclic ADC





End of Lecture 36