SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

23ECB202 – LINEAR INTEGRATED CIRCUITS

II YEAR/ IV SEMESTER

UNIT 4 – ANALOG TO DIGITAL AND DIGITAL TO ANALOG CONVERTER

TOPIC – Design Thinking Approach to Over-Sampling & Sigma–Delta ADCs

INTRODUCTION

- Welcome to this deep dive on Over-Sampling Analog-to-Digital Converters (ADCs) and Sigma–Delta Converters. Rather than just covering the basics, we're going to explore this technology through the lens of Design Thinking — a human-centered problem-solving approach. This journey will help you understand not only how these converters work but why they matter in real-world applications.

EMPATHY

- In the modern world, ADCs are everywhere: in your mobile phones, fitness trackers, ECG machines, and even smart thermostats.
- What do these devices need?
- High resolution
- Accurate signal conversion
- Low power consumption
- Low cost
- But here's the problem: Traditional ADCs like SAR and Flash types struggle to provide both high resolution and low noise without significantly increasing design complexity or power.

DEFINE

- Problem Statement: "Design a low-power, high-resolution ADC suitable for precision applications, without the overhead of complex analog components."

- We define this challenge as the core of our innovation journey. Our goal is to achieve 16-bit resolution with minimal analog complexity.

IDEATE

- Let’s think outside the box. What if we sample more frequently than the Nyquist rate? That’s called Oversampling.

- **Oversampling Advantages:**
- Spreads quantization noise across a wider spectrum.
- Enables effective noise reduction via digital filtering.

- Next, we enhance this with Sigma–Delta Modulation.

IDEATE

How Sigma–Delta Works:

- **1. Integrator:** Accumulates signal changes.
- **2. Quantizer:** Converts the signal to a low-bit digital format (often 1-bit).
- **3. DAC Feedback:** Feeds back the digital signal to the input to correct errors.
- **4. Digital Filter:** Removes out-of-band noise and decimates the signal to its final output rate.

IDEATE

Real-Life Use Cases:

- Audio recording (CD quality sound)
- Digital thermometers
- Precision measurement systems

PROTOTYPE

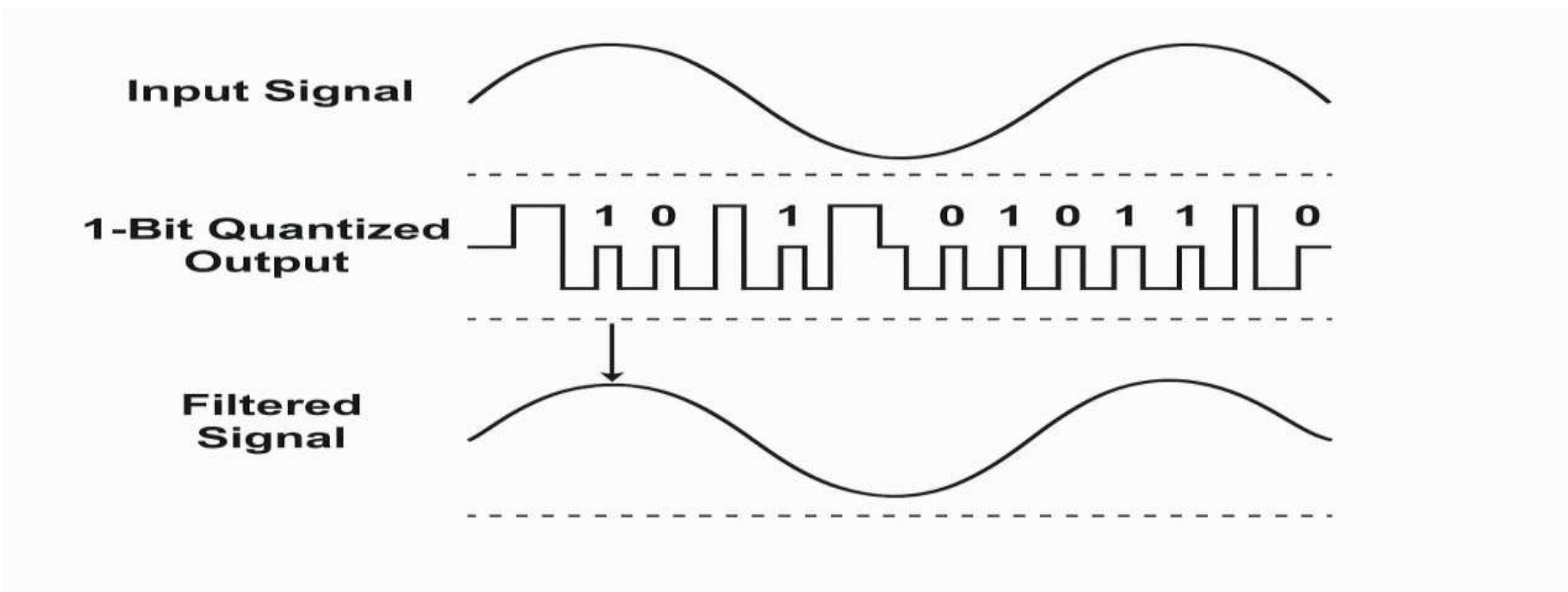
- We model a 1st-order Sigma–Delta modulator in MATLAB/Simulink:

- Oversampling Ratio (OSR): 256
- Input: A sinusoidal signal
- Output: Bitstream after quantization
- Filter: Digital low-pass filter + decimator

PROTOTYPE

Visualization:

- Waveform 1: Smooth analog input
- Waveform 2: 1-bit quantized bitstream (noisy)
- Waveform 3: Clean, filtered output resembling the original input



TESTING

Performance Metrics:

- SNR (Signal-to-Noise Ratio)
- THD (Total Harmonic Distortion)
- ENOB (Effective Number of Bits)

TESTING

- **Visual Outcome:**

- Graph comparing SNR across multiple ADC architectures

- Table showcasing ENOB improvements with oversampling

- Power consumption bar graph for SAR, Flash, and Sigma–Delta ADCs

TESTING

- **Test Result Summary:**

- High resolution is achievable even with simple analog circuits
- Power consumption remains low
- Excellent noise shaping performance in the presence of environmental noise

- **Iteration:** Based on initial test results:

- OSR was fine-tuned to 512 for better noise reduction.
- Filter coefficients were optimized to reduce aliasing.
- Modulator order was upgraded to second-order for improved resolution without extra power.
- Comparison with traditional SAR ADCs confirms our design offers better resolution for low-frequency signals.

CONCLUSION

By applying the Design Thinking process, we transformed a challenging technical problem into an elegant engineering solution. From empathizing with users to testing our prototype, every step added clarity and purpose to our design.

- **Key Takeaway:** Sigma–Delta Converters, paired with Oversampling, are powerful tools for high-resolution, low-power digital conversion. When developed using a design-thinking mindset, they become even more impactful.

- **Call to Action:** Stay curious, keep experimenting, and apply design thinking to all your engineering challenges

THANK YOU