Analog to Digital Converter (ADC) – Converting Analog Signals into Digital Data

What is an ADC?

An **Analog-to-Digital Converter (ADC)** is an electronic circuit or device that **converts analog signals (continuous voltage or current)** into **digital values (binary data)** that a microcontroller, processor, or computer can understand.

ADCs are widely used in **sensors, audio processing, communications, and measurement systems**, allowing digital devices to process real-world signals such as **temperature, sound, light, or motion**.

Types of ADCs

1. **Successive Approximation Register (SAR) ADC**
    - Most common in microcontrollers (e.g., Arduino, STM32).
    - Uses a binary search algorithm to determine the input voltage.
    - Fast and efficient, with moderate accuracy.
2. **Flash ADC**
    - Uses a series of comparators to determine the input voltage instantly.
    - Very fast (used in high-speed applications like video processing).
    - Expensive and power-hungry due to large hardware requirements.
3. **Sigma-Delta ADC**
    - Uses oversampling and noise shaping to achieve high precision.
    - Common in **audio processing and precision measurement**.
    - Slower but highly accurate.
4. **Dual Slope ADC**
    - Integrates input voltage over time and then converts it to digital.
    - Used in **multimeters and precision instruments**.
    - Accurate but slow.

Applications of ADCs

1. **Sensor Data Acquisition**
    - Converts temperature, pressure, humidity, light, and other sensor outputs into digital data.
    - Used in **IoT devices, weather stations, industrial monitoring**.
2. **Audio Recording & Processing**
    - Microphones capture sound as **analog signals**, which ADCs convert into digital audio (MP3, WAV).
    - Used in **music production, telecommunication, and voice assistants**.
3. **Medical Equipment**
    - ECG, EEG, and other medical devices use ADCs to convert biological signals into digital form.
4. **Digital Oscilloscopes**
    - Measure **analog waveforms** and display them as digital signals for analysis.
5. **Communication Systems**
    - Used in **wireless and radio transmission** to convert real-world signals into digital data for processing.

ADC vs DAC

- **ADC**: Converts **analog** → **digital** (e.g., microphone signal into digital audio).
- **DAC**: Converts **digital** → **analog** (e.g., digital MP3 file into sound for speakers).

Together, ADCs and DACs allow digital devices to **interface with the real world**, making them essential in modern electronics!

[How Do ADCs Work? - The Learning Circuit]