Certainly! Let's consider an ADC with a full-scale range of 7 volts and explain the concepts again.

Full-Scale Range

The full-scale range of an ADC refers to the maximum range of analog input signals that it can convert to a digital output. For this example, the ADC can handle voltages from 0 to 7 volts, so the full-scale range is 7 volts.

Quantization Levels and Resolution

The resolution of an ADC, given in bits, determines how many discrete levels (quantization levels) the full-scale range is divided into. An N-bit ADC has 2^N quantization levels.

Range of Analog Signal for Each Quantization Level

Each quantization level corresponds to a specific range of the analog signal. This range is often referred to as the **quantization interval** or **quantization step size**.

Example with Full-Scale Range

Let's consider an ADC with:

- Full-scale range: 0 to 7 volts
- Resolution: 3 bits

A 3-bit ADC has $2^3 = 8$ quantization levels. The full-scale range is divided into 8 equal intervals (quantization intervals).

Quantization Interval Calculation:
$$\text{Quantization Interval} = \frac{\text{Full-Scale Range}}{\text{Number of Quantization Levels}}$$

For our example:
$$\text{Quantization Interval} = \frac{7\text{ volts}}{8} = 0.875\text{ volts}$$

Quantization Levels and Corresponding Intervals:

- Level 0: 0 to 0.875 volts
- Level 1: 0.875 to 1.75 volts
- Level 2: 1.75 to 2.625 volts
- Level 3: 2.625 to 3.5 volts
- Level 4: 3.5 to 4.375 volts
- Level 5: 4.375 to 5.25 volts
- Level 6: 5.25 to 6.125 volts
- Level 7: 6.125 to 7 volts

Mapping Analog to Digital

When the ADC samples the analog signal, it maps each sampled value to the nearest quantization level based on these intervals. For example, an input voltage of 3 volts would be mapped to Level 3, as it falls within the 2.625 to 3.5 volts interval.

Quantization Error

Quantization error is the difference between the actual analog value and the quantized digital value. It arises because the analog signal is approximated to the nearest quantization level. The error can be reduced by increasing the resolution (more bits), which decreases the quantization interval.

Summary with Full-Scale Range

- **Full-scale range:** The maximum range of analog input signals that the ADC can convert (e.g., 0 to 7 volts).
- **Resolution (in bits):** Determines the number of quantization levels, 2^N.
- **Quantization levels:** Discrete values to which the analog signal is mapped.
- **Quantization interval:** The range of analog signal values corresponding to each quantization level.
- **Quantization error:** The difference betwee the actual analog value and the quantized digital value.

Understanding these concepts is essential for effectively using ADCs in various applications, ensuring accurate digital representation of analog signals.

Fullscale Range

Maximum range of analog input signals that the ADC can convert to a digital output.

Example: the ADC can handle voltages from 0 to 7 volts, so the full-scale range is 7V.

Resolution = Number of bits.

The resolution of a N-bit ADC is given in bits and determines the number of (discrete) quantization levels the full-scale range is divided into. Example: 3-bits resolution

Number of Discrete Quantization Levels

An N-bit ADC has 2**N discrete Quantization Levels that go from Level 0 to Level 2**N-1

Example: 2**3 = 8 discrete Quantization Levels

Quantization Interval or Quantization Step Size

The full-scale range is divided into 2**N equal intervals (discrete quantization intervals).

Quantization Interval or Quantization Step Size = Fullscale Range/Number of Discrete Quantization Levels

Example: Quantization Interval or Quantization Step Size = 7V/8 = 0.875V

Quantization Levels and Corresponding Intervals:

Level 0: 0 to 0.875 volts

Level 1: 0.875 to 1.75 volts

Level 2: 1.75 to 2.625 volts

Level 3: 2.625 to 3.5 volts

Level 4: 3.5 to 4.375 volts

Level 5: 4.375 to 5.25 volts

Level 6: 5.25 to 6.125 volts

Level 7: 6.125 to 7 volts

For Discrete Quantization Level x the corresponding interval varies

FROM x * (Quantization Step Size) TO (x+1) * (Quantization Step Size)

Example: Level x varies FROM 3*0.875=2.625V TO (3+1)*0.875=3.5V