Waveshapping Circuits and Data Converters

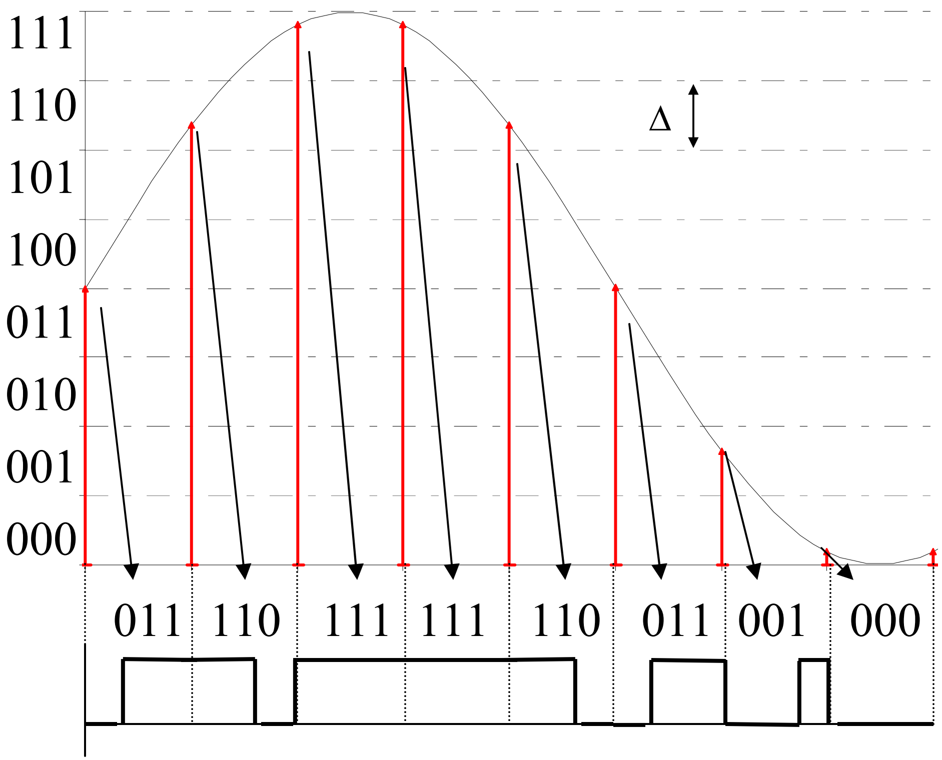
Lesson #21
D/A and A/D Converters
Section 12.8-10

Data Conversion

- Analog to Digital Conversion or Pulse code Modulation
  - Sample the analog signal at a frequency which is at least twice the highest frequency of the signal (Nyquist Sampling rate - f_s)
  - The amplitude range of the signal which is divided into 2^n regions and each sample is assigned a n-bit value associated with the region which the sample falls into.
  - A digital signal of bit rate nf_s is sent

Analog to Digital Coding

- This an example of sampling with 8 regions or zones
- There are 3 bits per sample
- The zones are Δ units wide

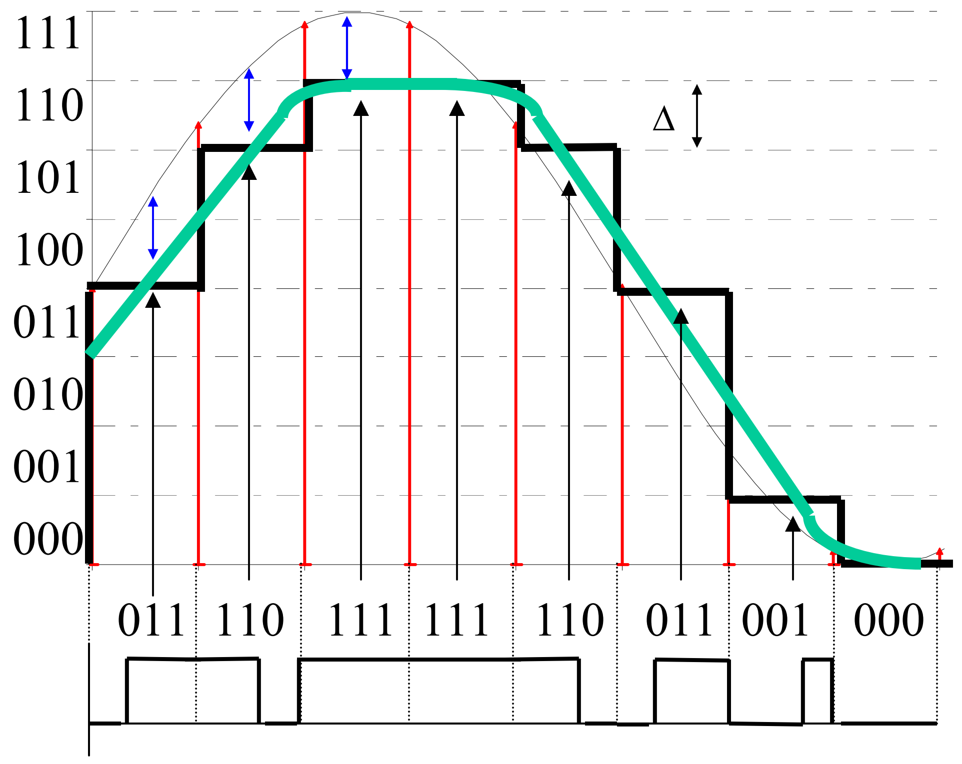


Digital-to-Analog

- Digital to Analog Conversion
  - The process of reconstructing the original signal from the coded samples.
  - First a staircase approximation is constructed.
  - A low pass filter is applied to the staircase approximation to smooth the waveform.
  - This process yields errors called quantization error and is proportional to the width of the quantization zone Δ.
  - The more zones the smaller the width of each zone and the smaller the quantization error.
  - We also call this error quantization noise.

Digital to Analog Reconstruction

- This an example of the reconstruction of the original signal from the coded samples
- This line ▬▬ is the staircase approximation of the samples from the codes
- This line ▬▬ is the approximation as a result of the applying a low pass filter to the staircase approximation
- Note the quantization error/noise ↕



Signal-to-Noise Ratio

It can be shown that the rms value of the quantization noise is :

$$V_{q,rms} = \sqrt{\frac{\Delta^2}{12}}$$

Therefore, the quantization noise power delivered to a load resistor, R_L

$$P_{noise} = \frac{V_{q,rms}^2}{R_L} = \frac{\Delta^2}{12R_L}$$

$$P_{signal} = \frac{V_{rms}^2}{R_L} = \frac{V_m^2}{2R_L}$$

But

$$\Delta = \frac{2V_m}{2^n} = \frac{V_m}{2^{n-1}}$$

$$P_{signal} = \frac{V_m^2}{2R_L} = \frac{(2^{n-1})^2\Delta^2}{2R_L} = \frac{2^{2n-3}\Delta^2}{R_L}$$

$$SNR = 10\log\left(\frac{\frac{2^{2n-3}\Delta^2}{R_L}}{\frac{\Delta^2}{12R_L}}\right) = 10\log(12\times 2^{2n-3}) = 10\log(3\times 2^2\times 2^{2n-3})$$

$$= 10\log(3) + 10\log(2^{2n-1}) = 10\log(3) + (2n-1)10\log(2)$$

$$= 4.8 + (2n-1)3 = 6n + 1.8$$

$$SNR = 6n + 1.8$$

For n = 8

$$SNR = 6\times 8 + 1.8 = 49.8$$

For n = 16

$$SNR = 6\times 16 + 1.8 = 97.8$$

Homework

- D/A and A/D Converters
  – Problems: 12.34-36