Pulse Code Modulation (PCM)

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Important Instructions

- Try to complete all tasks within 2 hours. After 2 hrs, evaluation starts.
- For each subtask, create mfiles (eg. CT_HT.m) and save them with suitable name.
- Prepare a word document naming your name and ID. In it, save all results including plots.
- In all plots, put x-label, y-label, legend, font 'Arial'(Size = 10), and, Width '2'.

Pulse Code Modulation (PCM)

- Important steps involved in PCM
  - Sampling, Quantization, and Encoding

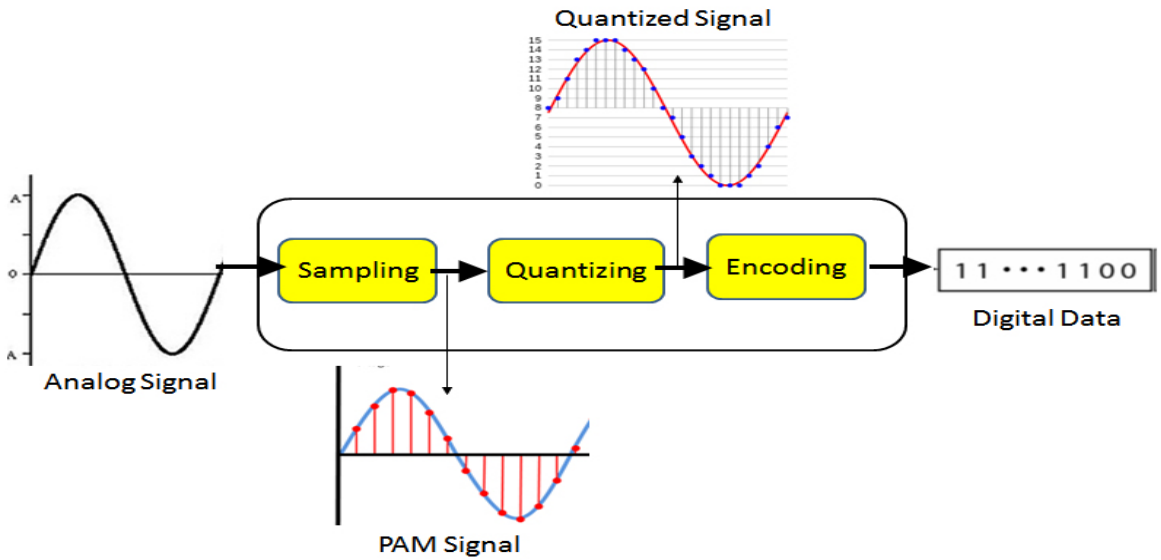

Figure: Operations in PCM. Source:`https://blogs.synopsys.com/vip-central/2015/04/28/1787/`

- Application of PCM
  - Standard form of digital audio in computers, CDs, digital telephony

Task 1.a: Uniform PCM

- Understand following library functions/commands
  - quantiz
  - de2bi(ind,'left-msb');
  - reshape
  - stairs
- Use the following
  - Message signal frequency $f_m = 3$ Hz; Sampling frequency $f_s = 30$ Hz;
  - $t = 0 : \frac{0.01}{f_m} : 1$;
  - Message peak amplitude $A_m = 2$ volt;
  - Number of bits $n = 3$;
  - Message signal= $A_m \sin(2\pi f_m t)$;
  - $t_s = 0 : \frac{1}{f_s} : 1$;
  - Sampled signal $x_s = A_m \sin(2\pi f_m t_s)$;
  - Quantization levels $L = 2^n$;
  - $V_{\max} = A_m; V_{\min} = -A_m$
  - Step size $\delta = \frac{V_{\max} - V_{\min}}{L}$
  - Steps= $V_{\min} : \delta : V_{\max}$;
  - Quant= $\left(V_{\min} - \frac{\delta}{2}\right) : \delta : \left(V_{\max} + \frac{\delta}{2}\right)$;

Task 1. (a): Uniform PCM

- Question: Write a program to plot the following
  1. Original message signal $x(t)$, sampled signal,
  2. Sampled values vs quantized values (Hint: use 'plot' and stem commands).
  3. Sampled signal vs quantized signal (Hint: use 'stem' command)
  4. Encoded digital signal (Hint: use 'stairs' command)
     - Show all in single plot. In the plot, provide x-label, y-label, title, and legend.
  - Hints
    - After running 'quantiz' command, you get index ranging from 1 to 8. Update index from 0 to 7
    - Make the minimum quantized value between the quantized levels. That is, bring $\left(V_{\min} - \frac{\delta}{2}\right)$ to $\left(V_{\min} + \frac{\delta}{2}\right)$
    - Transform encoded matrix to a row vector of encoded bits

Task 1. (b): Computations

- Question (i): Using MATLAB compute the following
  - Bit rate R_b
  - Bit duration T_b
  - Step size δ
  - Maximum quantization error $Q_e(\max)$
  - Signal power in dB
  - Quantization noise power in dB
  - SQNR in dB
  - SQNR from formula
- Question (ii): Compute mean square error (MSE). Compare this value with quantization noise power (Hint:) Use samples of original signal & corresponding quantized values supplied by 'quantiz' command.

Task 2: Quantizer Characteristic Curve

- Question: Write a program to plot quantizer characteristic curve for the uniform PCM in Task 1. (a). In the plot, provide x-label, y-label, title, and legend.
  - Hint
    - Plot ‘steps’ on x-axis and ‘quant’ on y-axis using stairs command. Make sure that vector lengths match