EXPERIMENT 3

PULSE CODE MODULATION – PCM

1. Objective

Introduction to PCM and Analog-to-Digital & Digital-to-Analog Conversion.

2. General Information

In Pulse Modulation, analog message is transmitted in discrete time. First of all, sampling of the message signal should be performed. Considering the sampling process, the sampled signal appears as a train of samples which is a form of PAM (Pulse Amplitude Modulation) signal. When M levels are used to quantize this signal, this modulation is called M-PAM. If those pulses were converted to digital numbers, then the train of numbers so generated would be called Pulse Code Modulated – PCM signal. In PCM, modulation process is executed in three steps:

1. Sampling
2. Quantizing
3. Coding

These steps are shown in Figure 1 with a block diagram:

![PCM Transmitter Block Diagram](image)

As stated before, in PCM, the information signal $x(t)$ is first sampled with the appropriate sampling frequency (sampling frequency $f_s \geq 2 \times $highest frequency of the information signal ($f_x$)), then the sampled levels are quantized to appropriate quantization levels. In the last step, each quanta level is demonstrated by a two-code word, that is by a finite number of \{0,1\} sequence. After this step, the signal is called as PCM wave.

If the max and min amplitude values of information signal $x(t)$ are $A_{\text{max}}$ and $A_{\text{min}}$, respectively, and if n-digit code words will be used, then the quantizing interval/pace “$a$” becomes:

$$a = \frac{A_{\text{max}} - A_{\text{min}}}{2^n}$$

In quantizing process, “which quanta region does the sample belong to” is an important question. The sample value is rounded to the closest quanta level. Later the quantized signal is encoded and the signal is matched with code words. In two-word number system,
+V volt pulse can be sent for ‘1’s, and space/no volt is sent for ‘0’s to transmit the code. As another method, +V volt pulse is sent for ‘1’s, and –V volt pulse is sent for ‘0’s. A guide gap \( (t_g) \) is kept between two pulses. An example to the PCM steps explained up to here is given in Figure 2.

In Figure 2, the signal is divided into 16 amplitude levels (0-1.5) between its max and min values. Therefore, \( n=4 \) and the quantizing pace \( a = 0.1 \).

If the quantizing levels are selected equally, then this is called as “linear quantizing”. Figure 3 shows an example to the linear quantizing.
The coding process can be realized by the following circuitry; by means of coding, discrete sample values can be expressed in terms of ones and zeros.

In the converter shown in Figure-4, $V_A$ is compared to $V_B$ voltage during the sampling period $T_s$ as the output of the D/A converter. If $V_A > V_B$, then the comparator output is logic 1 and the gate is open. In this case, the coming clock pulse reaches the counter and the counting continues. Output of D/A increases by 1 step, as each step comes. Sometime later $V_B$ voltage catches the $V_A$ and starts to become larger. At that time, output of the comparator reduces to '0' and the gate is closed. Counting process has stopped. At that time, Q outputs give the code corresponding to the input voltage. When the sampling period ends, the counter resets and the same process starts for the second sample. The
converter given in Figure 4 is only used for positive voltages. If both negative and positive
voltages are required to be converted, then the circuitry given in Figure 5 is used.

![Figure 5. Coding of an analog signal after rectifying it.](image)

3. Experiment Set
   - PC & LabView Software

4. Experimental Procedure
   - In this experiment an analog signal will be sampled and according to the specified
     word length it will be digitized.
   - Generate a sinusoidal analog signal so that the display duration $T$ and the duration
     between each sample $dT$ can be changed externally by the user.
   - Sample this analog signal with a sample frequency that can be changed by the user
     while the program is running.
   - Display both the analog signal and the samples in a single waveform graph screen.
   - Define a “word-length” control in the front panel of the “*.vi” program you
     design, to specify the quantizing levels. The word length should be selectable
     externally by the user.
   - Try to recover the analog signal from the quantized digital signal and display it in
     a waveform graph screen.