Faculty of Engineering & Technology

Electrical & Computer Engineering Department

COMMUNICATIONS LAB

ENEE4113

Experiment #8

Pulse Code Modulation (Part 2)

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1.Abstract:

This experiment aims to obtain complete knowledge in the digital system when it combines two types of modification, namely PAM and PCM. As well as exploring the noise that arises through triangle and sine signals. The experiment will also include DPCM, which is similar to PCM but is considered a newer type, which makes it better by considering the differences between successive sample

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2.Theory:

2.1.Part One: PCM Transmission with TDM

2.1.1.Pulse-Code Modulation (PCM)

is a digital method used to transmit analog data. Its function involves the conversion of an analog signal into a digital format. PCM allows the digitization of various types of analog data, encompassing full-motion video, voice, music, telemetry, and more.in the process of obtaining a PCM signal from an analog signal at the source (transmitter) of a communications circuit, the analog signal undergoes sampling at regular time intervals.[1]

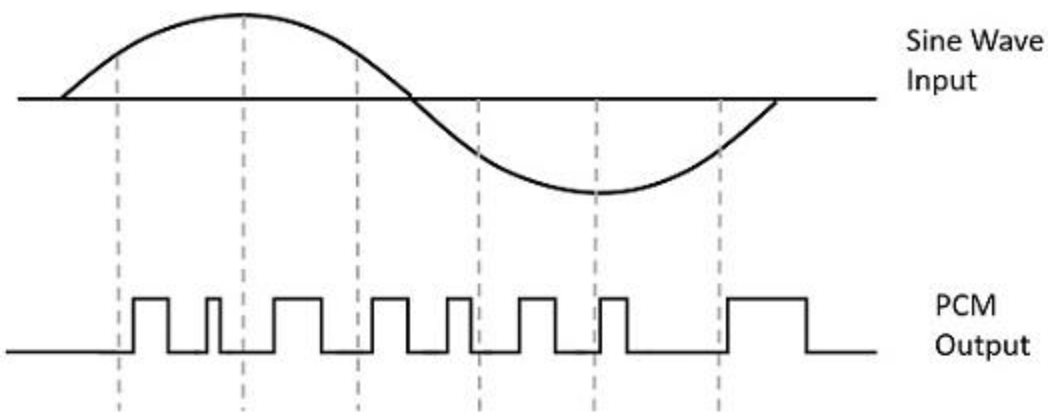


Figure 1.Pulse-Code Modulation. [1]

2.1.2.Time-division multiplexing (TDM):

Time division multiplexing (TDM) is a technology commonly used in communications and networks to increase the efficiency of data transfer, as its working principle is to send several signals at the same time in one communication channel divided into a number of time slots, and each signal is sent during the time period allocated to it. As a result, multiple signals share the channel without interfering with each other.[2]

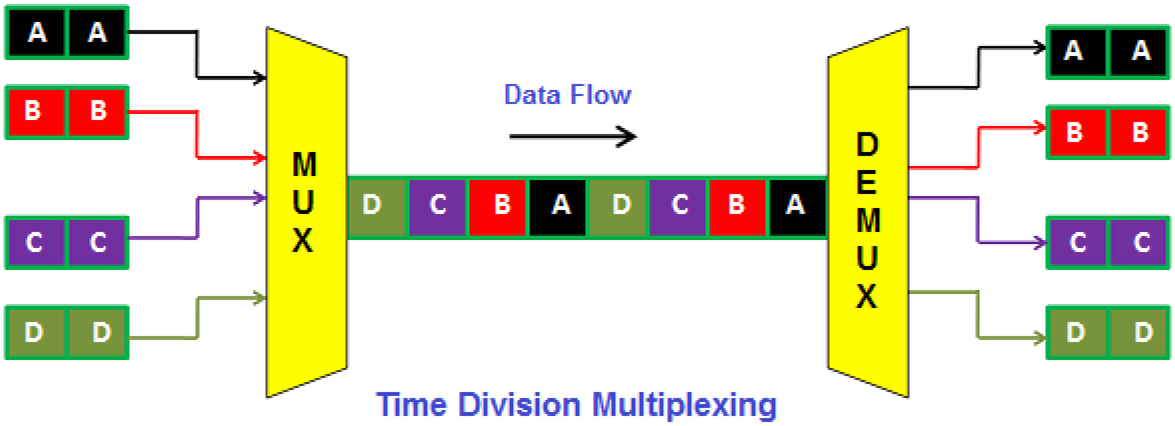


Figure 2.Time-division multiplexing. .[2]

2.2. Part Two: Quantization Noise:

Quantization noise is the inconsistencies and errors that result from the process of converting information from a smooth and continuous form to a more limited and discrete form, especially in image processing. The number of levels used for quantization determines the accuracy of the digital representation, as this noise arises due to the presence of a discrepancy between the original continuous values and their digital equivalents. The quantity in the images, and this noise in the images is slight differences in pixel density, and this appears in the image resolution through colors and clarity.[3]

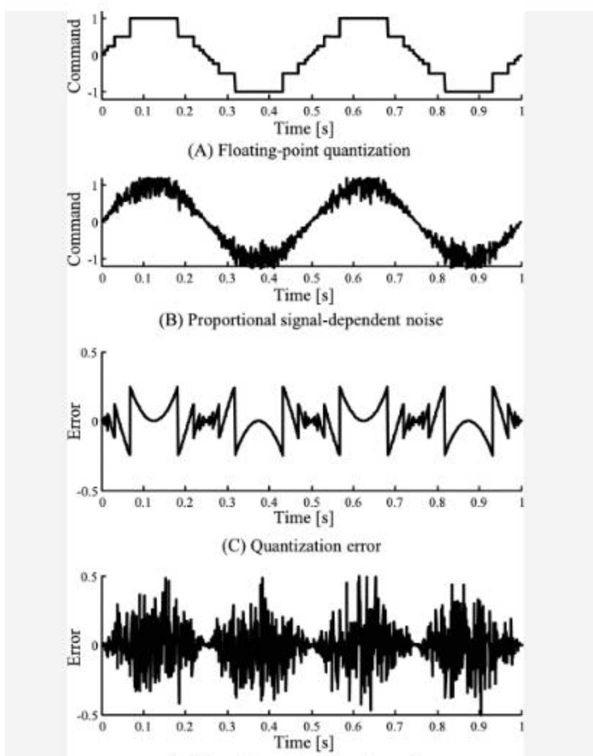


Figure 3.Quantization Noise. [3]

2.3. Part Three: Difference Pulse Code Modulation (DPCM)

Differential pulse code modulation (DPCM) is a technology similar to pulse code modulation (PCM), as it is used to convert analog signals into digital signals in the same way as (PCM). However, it is distinguished from (PCM) in its working method. Where the PCM works to measure the difference between a particular sample and its expected or predicted value, while the PCM works to measure each sample of the analog signal. This key distinction gives rise to the term "differential" in DPCM.

DPCM also focuses on encoding differences or differences between successive samples. This approach allows for more efficient representation of the signal, especially when successive samples show correlation or similarity. It has an effect on the signal-to-noise ratio (SNR), which is usually moderate.[4]

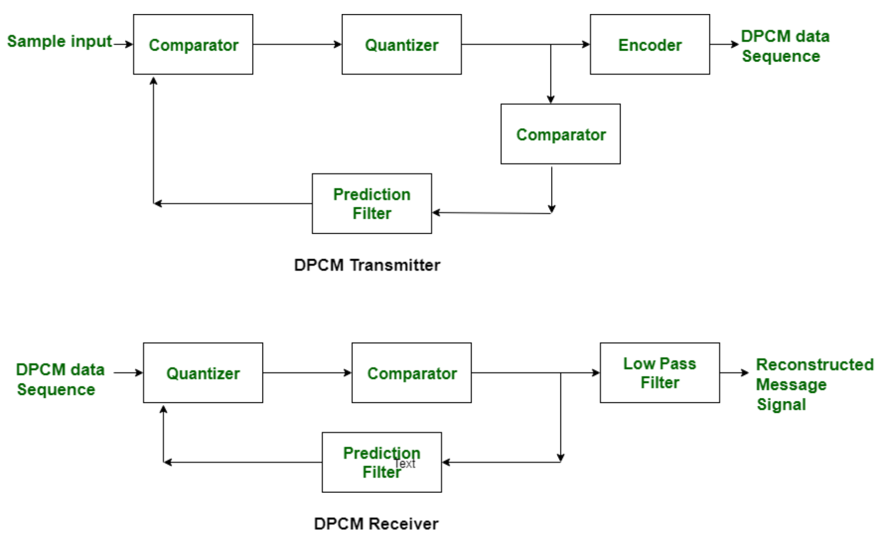


Figure 4.DPCM transmitter and DPCM receiver. [4]

3.prosedure

3.1. Part One: PCM Transmission with TDM:

In this part of the experiment, sampled, quantized and binary coded data of two analog signals were sent over a single communication channel using the concept of time division multiplexing.

Here in figure (1) the assembly of the components required to conduct this part of the experiment is shown.

the CASSY UA1 was connected to Input PAM Modulator CH1, while the CASSY UB1 was connected to Output PAM Demodulator CH1. The PCM modulator and demodulator panels were set to linear quantization, and all coded bits were activated.

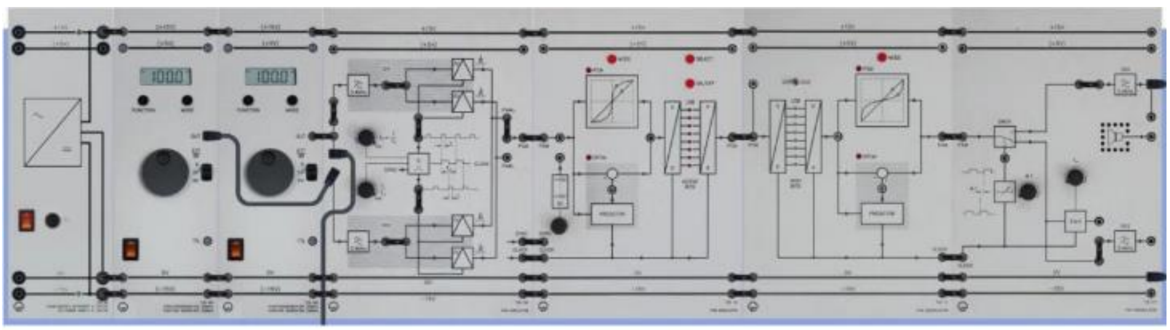


Figure 5.PCM Transmission with TDM.[5]

After assembling the components, the settings for the PAM Modulator were set: the duty cycle of the clock generator (Sampler) was set to the maximum, and the sampling frequency of the clock generator was set to the minimum. Additionally, Function Generator 1 was configured with a sine waveform, a frequency of 300 Hz, and an amplitude of 10 V. and the Function Generator 2 was set to generate a triangle waveform with a frequency of 200 Hz and an amplitude of 5 V.

for the PAM Demodulator, the time shift knob (Δt) was set to the min (Anticlockwise).

Here the result for 5 cycle:

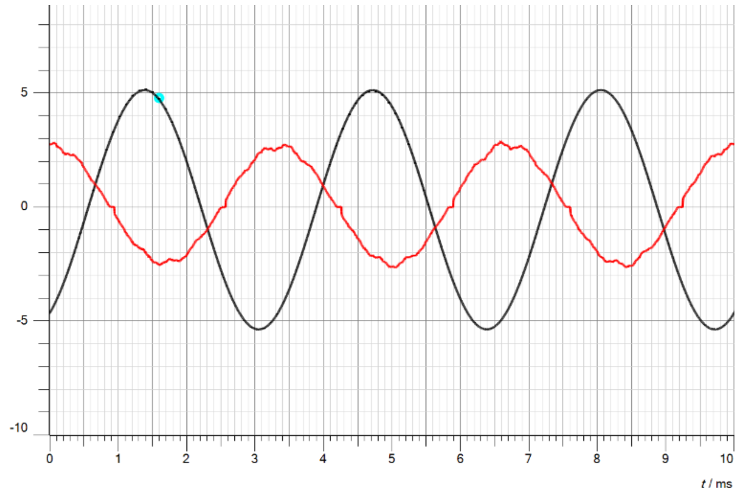
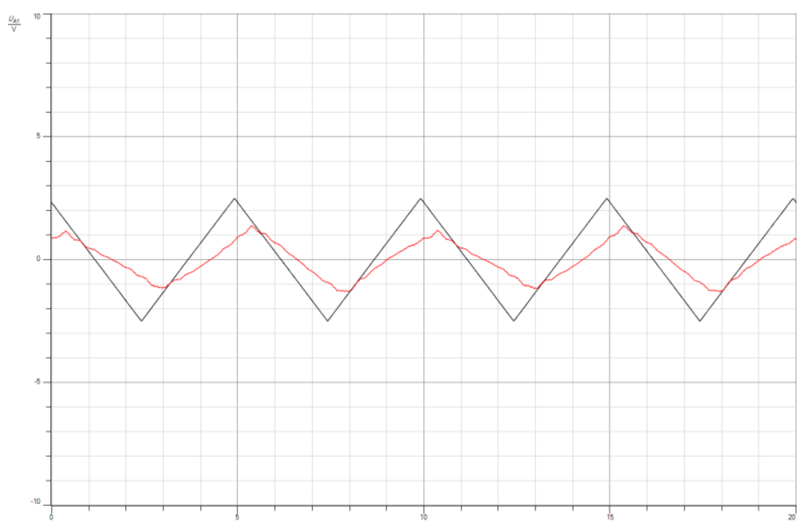


Figure 6.PAM1 result Natural Sampling

In the next step, CASSY UA1 is connected to Input PAM Modulator CH2, and CASSY UB1 is connected to Output PAM Demodulator CH2.

Here the result for 5 cycle:



PAM2 flat-top sampling:

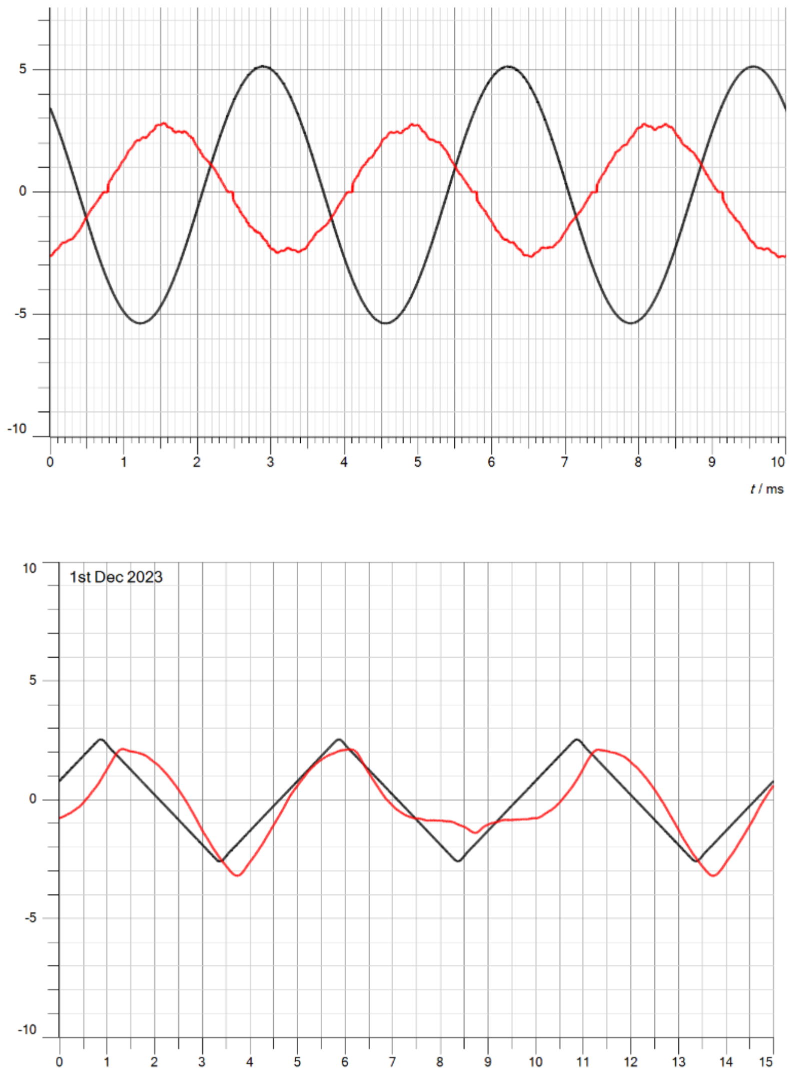


Figure 7.PAM2 flat-top sampling result

From the above images we can see the output of the PAM Modulator operation, where there were differences and inconsistencies between the shape of the quantized signal and the original signal. Likewise, the output of the PAM Demodulator showed aberrations and distortions, particularly affected by quantization noise. However, despite this the communication system allowed multiple signals to be sent and retrieved via Shared channel using time division multiplexing. Adjusting settings such as linear quantization and coded bit activation are intended to improve signal accuracy, but accuracy can be affected by factors such as noise and distortion.

3.2.Part Two: Quantization Noise

3.2.1. Triangle Signal:

Here in figure (4) the assembly of the components required to conduct this part of the experiment is shown.

both channels (CH1 and CH2) of the PAM Modulator were connected to one function generator. The function generator was configured to generate a triangle waveform with a frequency (fm) of 30 Hz and an amplitude (VSS) of 12 V. The purpose of this connection was to avoid the time gaps at the output of the PCM demodulator. the PCM modulator and demodulator were set to linear quantization, and all bits were activated . Additionally, CASSY UA1 was connected to Input PAM Modulator CH2, while CASSY UB1 was connected to Output PCM Demodulator CH2. and, the CASSYLab 2 example QNoise.labx was loaded.

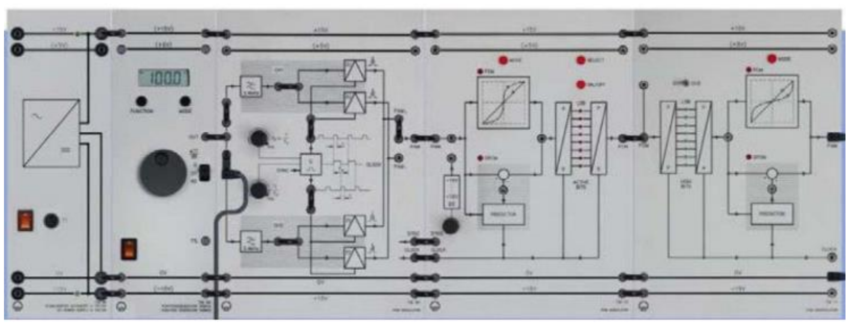


Figure 8.Triangle Signal connection

And here the result :

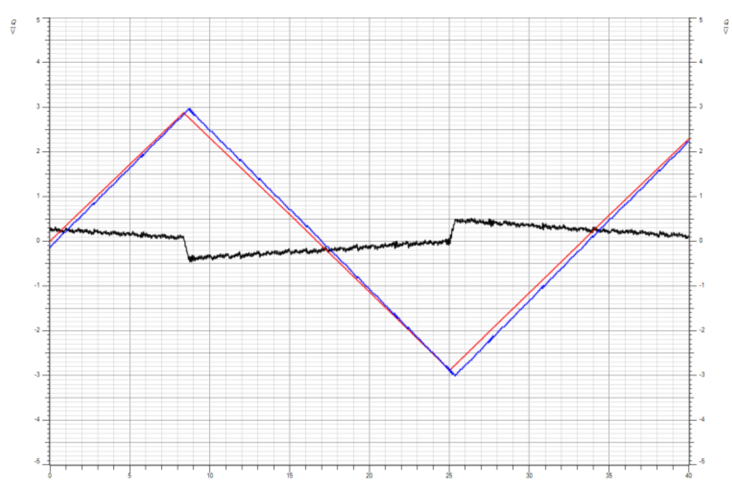


Figure 9. the error between modulated and demodulated for the sinusoidal

From the previous image we see that there is a difference in the two triangles. We find that the error is due to the encoding and decoding stages of the PCM system, and this error is what is known as distortion. The size of this error also shows us how well the PCM system works. The smaller the amount of error, the better the quality. Higher, meaning that the signal that we obtained is very similar to the original analog signal, but if the amount of error is large, this indicates that there is an error and loss of parts in the signal that we obtained and that it differs from the original analog signal.

The measurement was Repeated for a resolution of 5 bits and this the result:

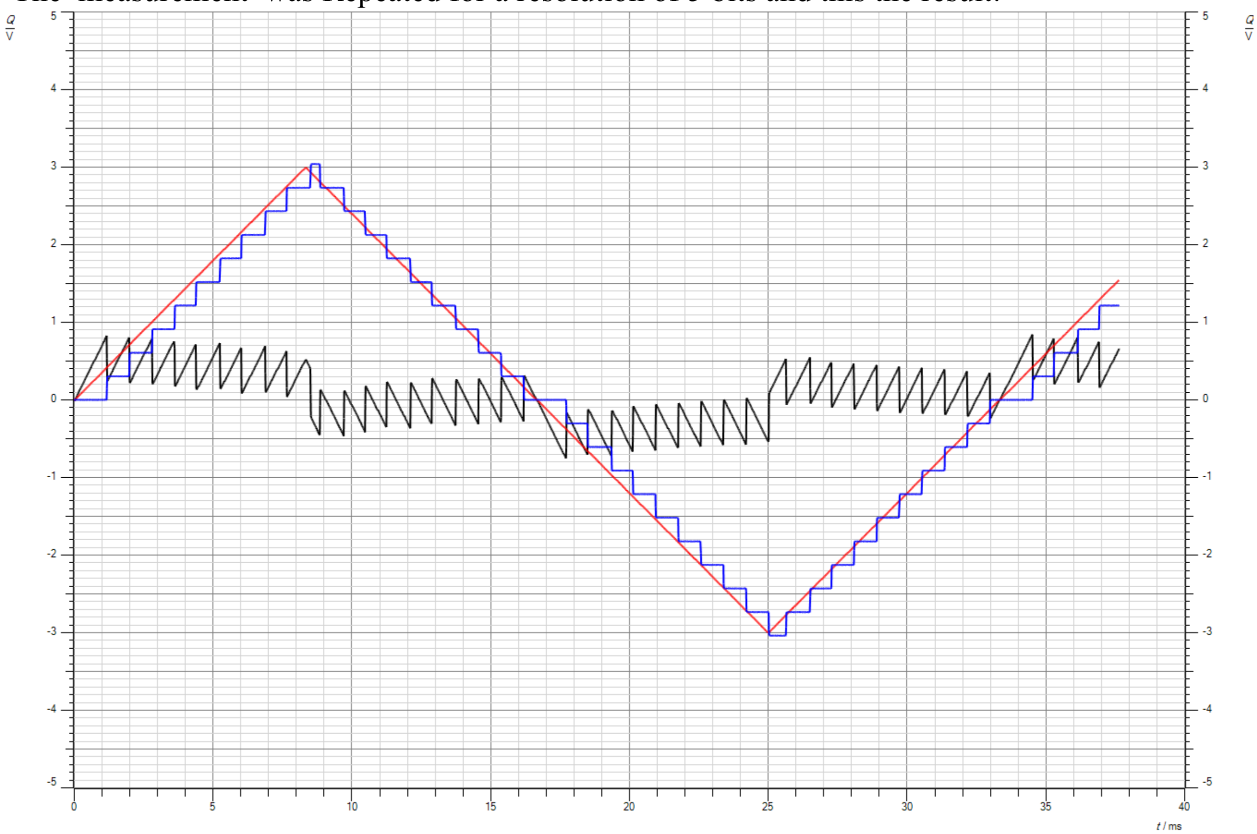


Figure 10. the error between modulated and demodulated for the sinusoidal 5 bit

There is a direct relationship between the number of bits and the accuracy of the signal. When the number of bits is reduced, we find that the accuracy of the recovered signal decreases and distortions increase because the number of bits used to encode the signal is small. This is what we observed in the previous image.

The measurement was Repeated for a resolution of 5 bits for Triangle, fm = 300 Hz, VSS = 12 V. and this the result

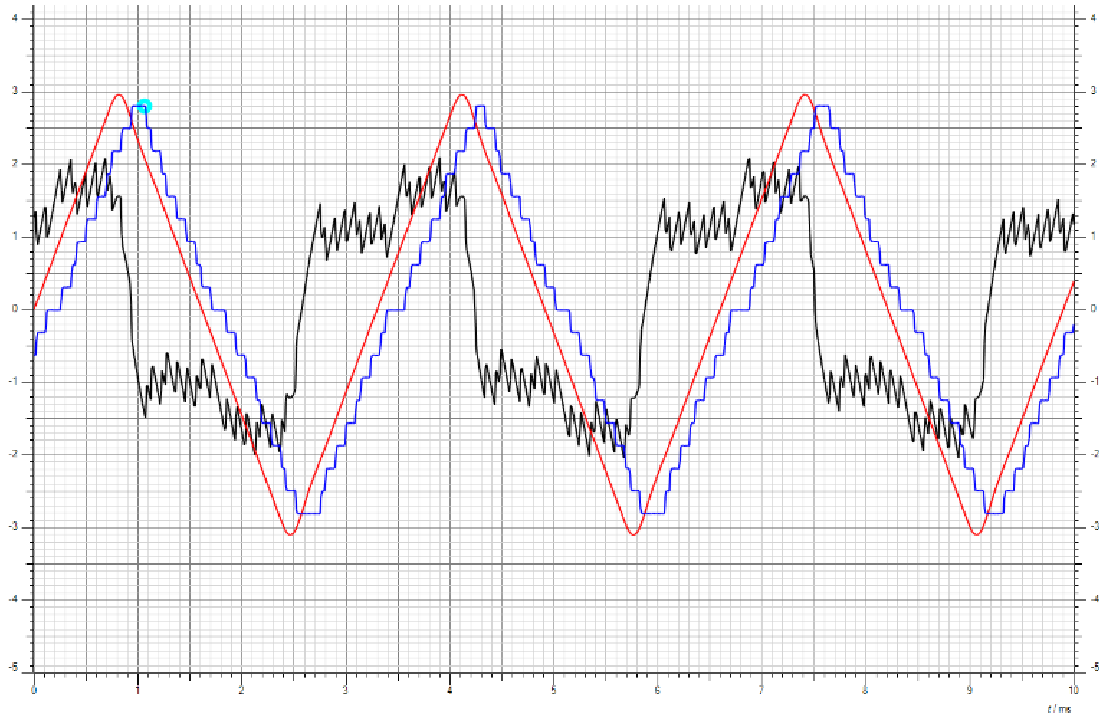


Figure 11. the error between modulated and demodulated for the sinusoidal with 5 bit &fm=300Hz

Adjusting both the resolution and message frequency during the quantization process has an effect on the quality of the demodulated signal. The higher the resolution, the more accurate the representation of the primary signal during demodulation, and vice versa. If the resolution is low, there are errors and a reduction in the accuracy of the signal. There is also an effect of the frequency of the messages. Higher frequencies lead to distortions and inaccuracies if the quantization process is not possible. Of continuing. Striking a balance between accuracy and message frequency is crucial to getting the best results. Mismatches can lead to distortions and quantization errors, which compromise the overall quality of the demodulated signal.

3.2.2. Sinusoidal Signal:

Here we have done the same steps as the previous part, but using the sinusoidal signal instead of the triangle signal. This results in a more complicated structure of the quantization noise.

The both channels (CH1 and CH2) of the PAM Modulator were connect to a single function generator. The function generator settings were specified as a sine wave with a frequency (fm) of 30 Hz and a (VSS) of 12 V. after that , the PCM modulator and demodulator were set to operate with non-linear quantization, and all bits were activated.then the CASSY UA1 was connected to the Input PAM Modulator CH2, while CASSY UB1 was connected to the Output PCM Demodulator CH2. Finally, the CASSY Lab 2 example QNoise.labx was loaded to complete the procedure.

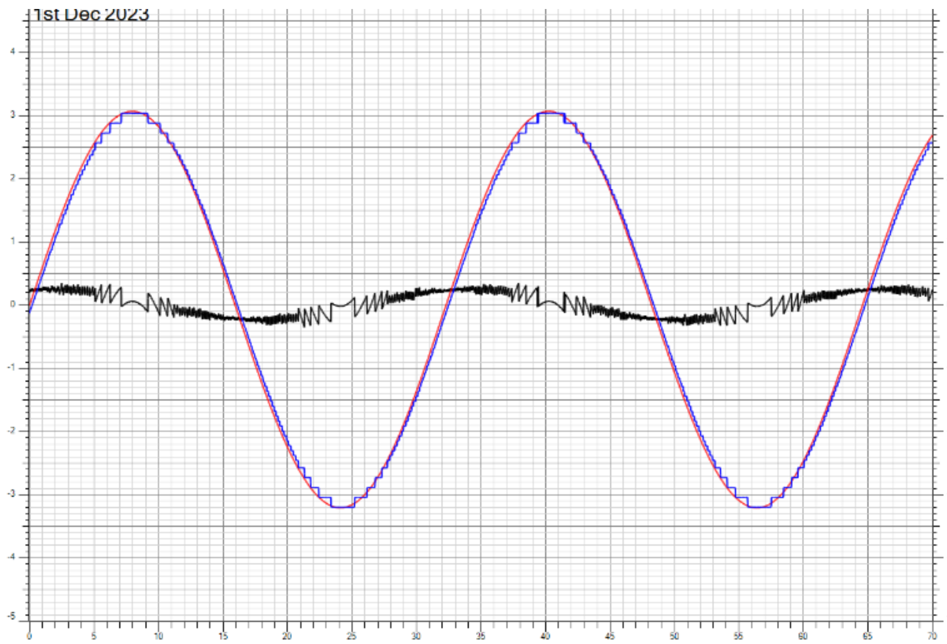


Figure 12.the error between modulated and demodulated for the sinusoidal

We notice from the previous image that when we used a sinusoidal modulation signal, a new form of noise appeared that differed from what we obtained when we used a triangle wave. There is an effect on noise by the amplitude and frequency of the sine signal, as well as the chosen resolution of the quantization. This is because the sine signal contains different frequency components. When we measure it, these components interact with the quantization levels, which increases distortions.

After repeated the measurement for a resolution of 5 bits we get this result.

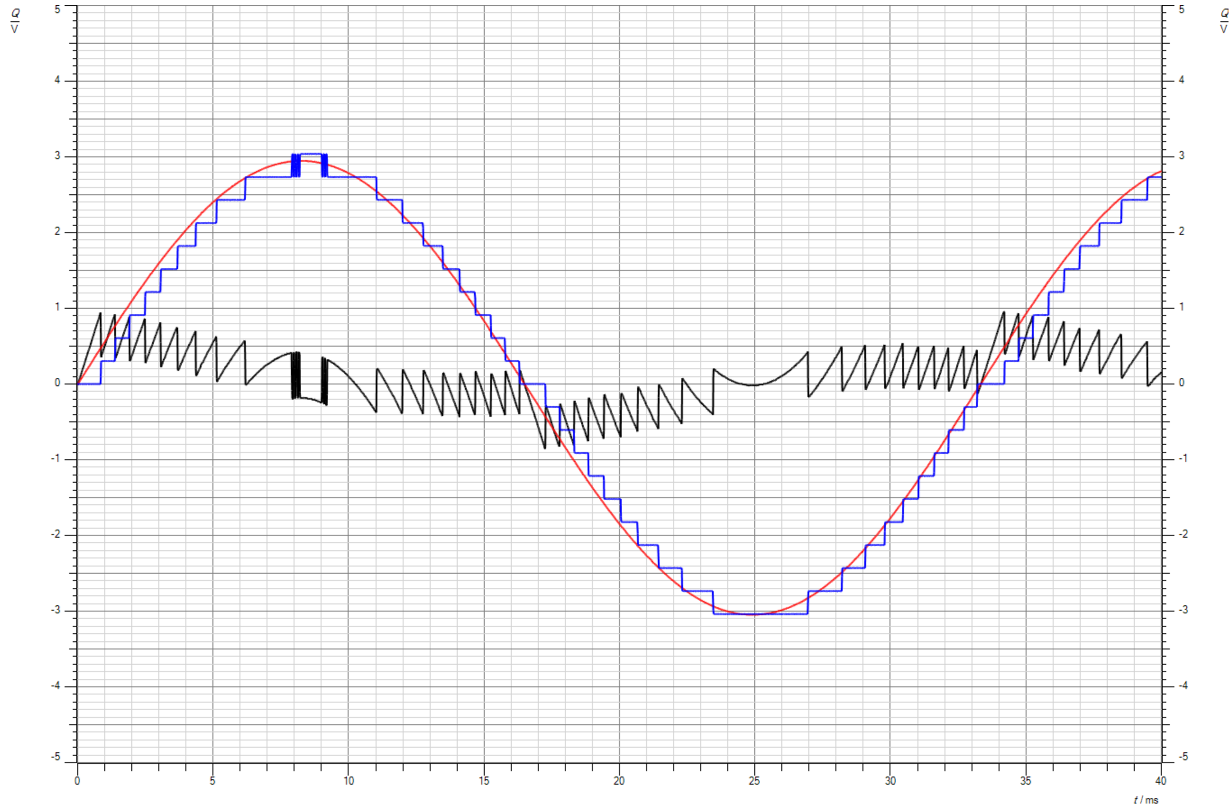


Figure 13.the error between modulated and demodulated for the sinusoidal 5 bit

The quantity of noise is influenced by the number of bits, meaning that a smaller number of bits results in greater noise. and this what we notice from previous figure.

The measurement was repeated for a resolution of 5 bits with the following settings:Sine wave: frequency (fm) = 300 Hz, voltage supply (VSS) = 12 V.

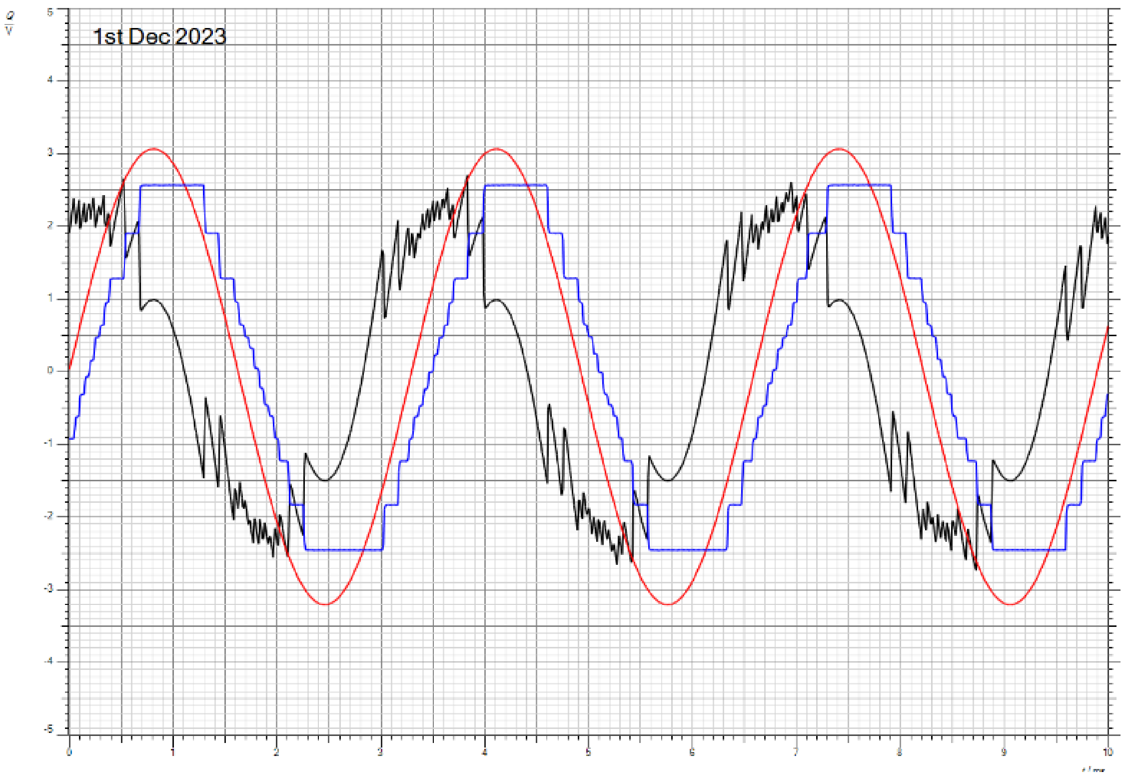


Figure 14.the error between modulated and demodulated for the sinusoidal with 5 bit and fm =300Hz

Adjusting both the resolution and message frequency during the quantization process has an effect on the quality of the demodulated signal. The higher the resolution, the more accurate the representation of the primary signal during demodulation, and vice versa. If the resolution is low, there are errors and a reduction in the accuracy of the signal. There is also an effect of the frequency of the messages. Higher frequencies lead to distortions and inaccuracies if the quantization process is not possible. Of continuing. Striking a balance between accuracy and message frequency is crucial to getting the best results. Mismatches can lead to distortions and quantization errors, which compromise the overall quality of the demodulated signal.

3.3. Part Three: Difference Pulse Code Modulation (DPCM):

The components were connected as shown in figure below:

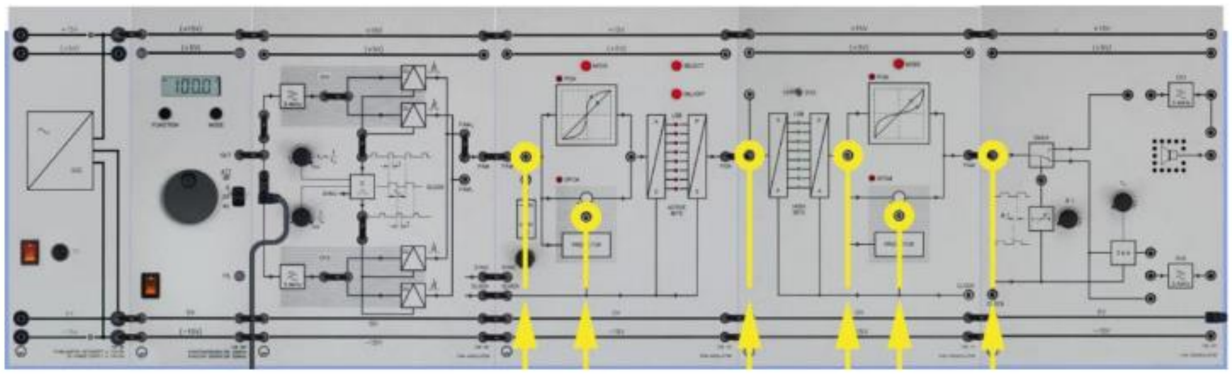


Figure 15.Difference Pulse Code Modulation (DPCM)

Connected both channels (CH1 and CH2) of the PAM Modulator with one function generator. The function generator was set to a Triangle wave with a frequency (fm) of 30 Hz and a voltage supply (VSS) of 12 V. The PCM modulator and demodulator were configured for DPCM, with all bits activated. The measurement was initiated by pressing F9. Due to the systems' inability to be turned on simultaneously, a specific switch-on sequence was followed. The PAM input of the PCM modulator was connected to 0 V, and then the PCM modulator and demodulator were switched to DPCM mode, with the subsequent steps synchronized. After disconnecting the PAM input from 0 V, the modulation signal's amplitude was dropped to 0 V on the function generator. The sampled signal was then fed into the PCM modulator, resetting it to the desired amplitude (i.e., VSS = 12). The CASSY channel UA1 was connected to the input signal of the PAM modulator. For channel UB1, successive records of different signals were taken as separate measurements.

1.Predictor of the DPCM modulator

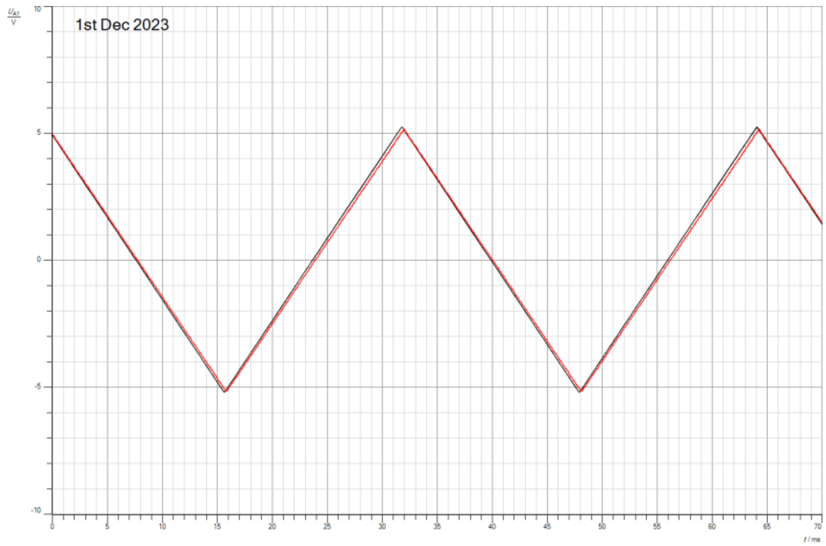


Figure 16.Predictor of the DPCM modulator

The predictor in the DPCM detects how different one part of a sample is from the next. The principle of his work is to predict what the next information should be by looking at what came before it. The strength of the forecaster's work lies in the extent to which he accurately understands and predicts how the information will change over time.

2.Output of the DPCM modulator

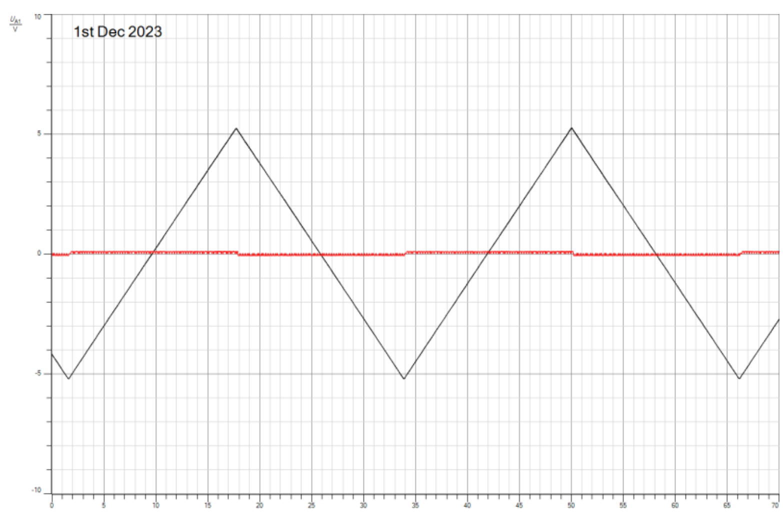


Figure 17.Output of the DPCM modulator

We notice from the previous image that the output of the DPCM modulator showed that the amplitude was reduced compared to the input signal.

3. **Input of the DPCM demodulator**

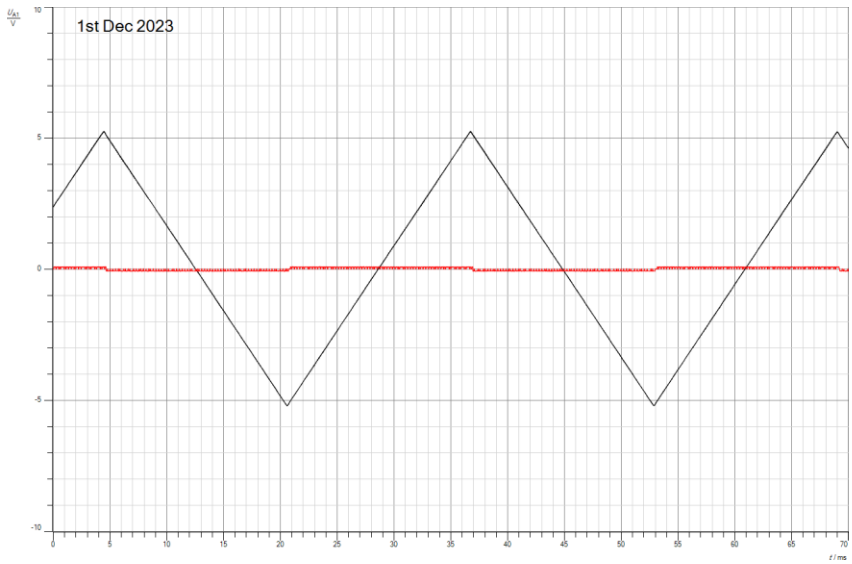


Figure 18.Input of the DPCM demodulator

We find that the input signal of the DPCM demodulator was similar to the signal we obtained from the output of the DPCM modulator. It should also closely resemble the signal we get from the DPCM because it shows us how the samples are changing. It shows if any noise occurred during transmission, to maintain how well the demodulation is working.

4.Predictor of the DPCM demodulator:

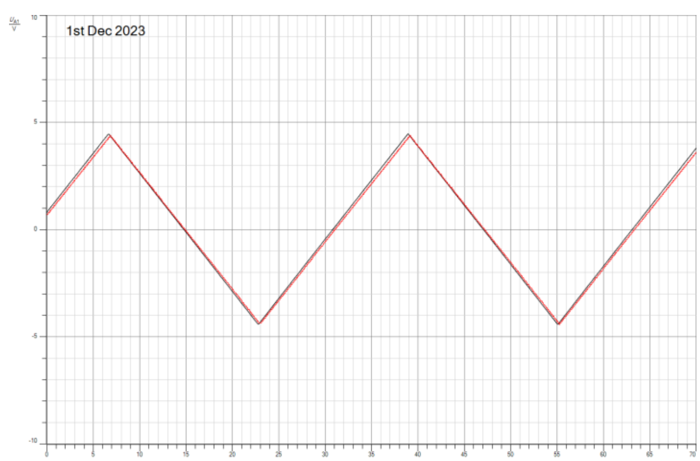


Figure 19.Predictor of the DPCM demodulator

5. **PAM output of the DPCM demodulator:**

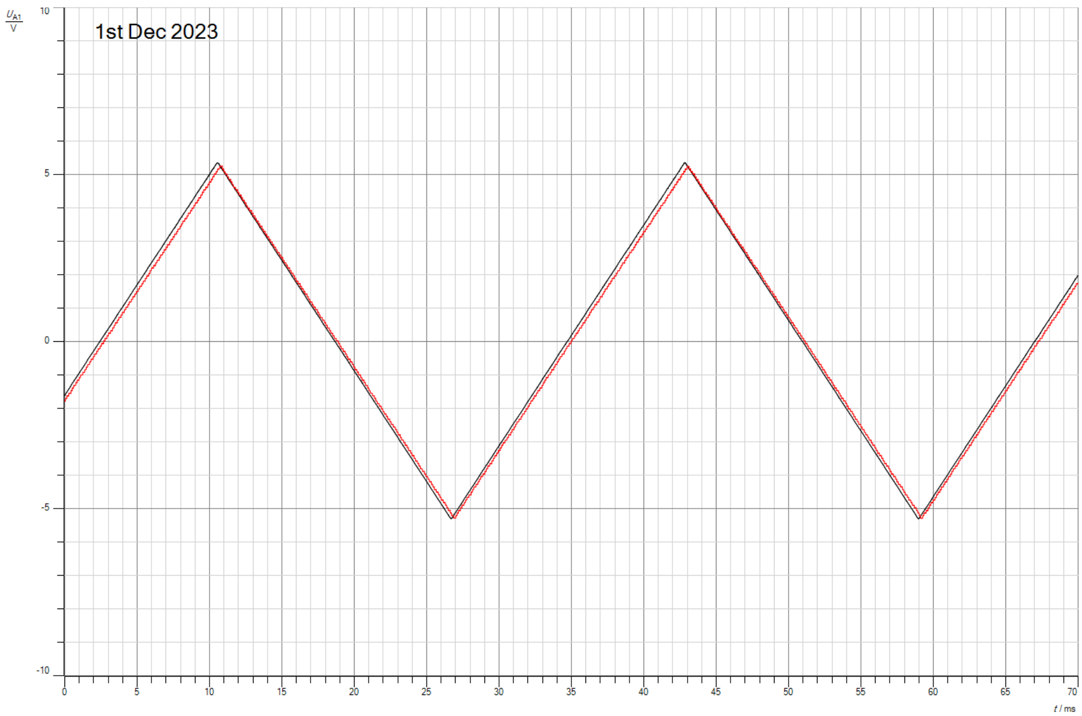


Figure 20.PAM output of the DPCM demodulator

Repeated Part IV for a resolution of 4 bits by deactivating the indicated bits "--."

LSB							MSB
ON	ON	ON	--	--	--	--	ON

1.**Predictor of the DPCM modulator**

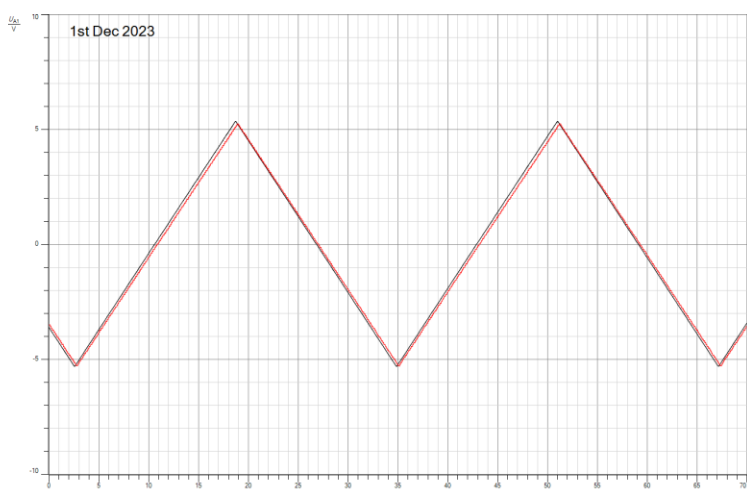


Figure 21.Predictor of the DPCM modulator

Here the number of bits was reduced and only 4 were used, and this makes the predictor in the DPCM modulator recognize a limited set of patterns compared to using a higher resolution. With fewer bits, it only evaluates a small range of changes between samples. This results in less accurate predictions, especially for signals with small changes or fast transitions. Having fewer options may lead to more incorrect predictions.

2. Output of the DPCM modulator:

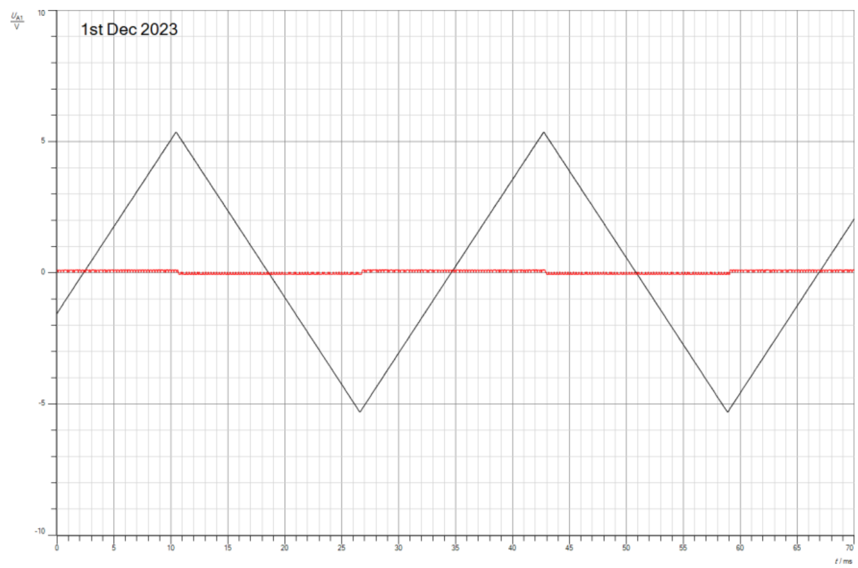


Figure 22.Output of the DPCM modulator

The picture shows us that the capacity has become less and the representation is greater compared to the case with a higher number of bits and a higher resolution

3. Input of the DPCM demodulator:

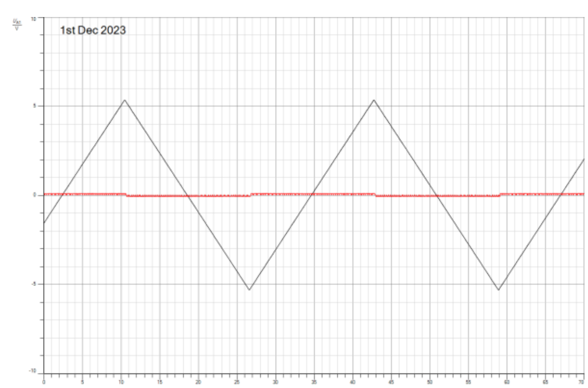


Figure 23.Input of the DPCM demodulator

4. Predictor of the DPCM demodulator:

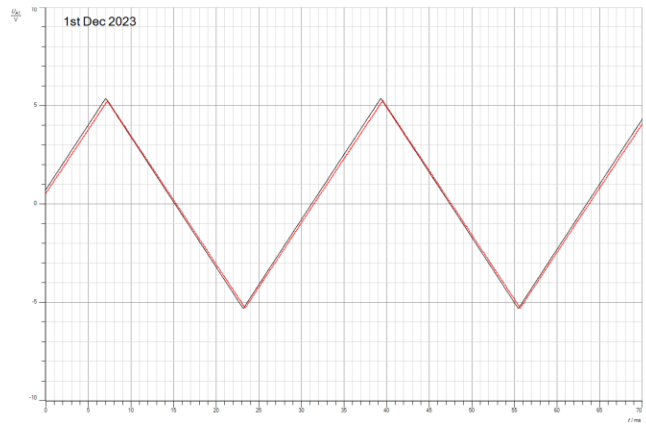


Figure 24.Predictor of the DPCM demodulator

When we reduce number of bit to 4 ,the predictor in the DPCM demodulator has a constrained set of patterns, similar to the one in the DPCM modulator, but it's not as accurate. It means that the demodulator's predictor can identify only a limited range of changes between samples, and its predictions are not as precise as those of the modulator. so, the signal might not come back as clear

5. PAM output of the DPCM demodulator:

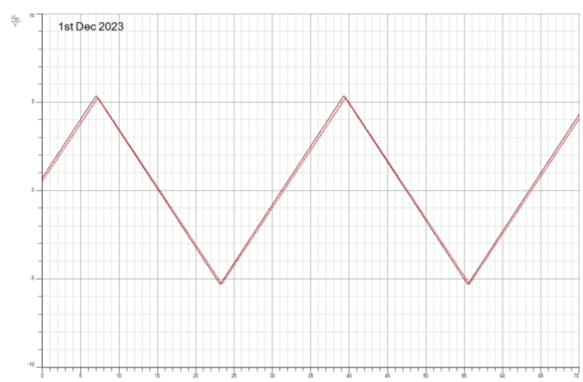


Figure 25. PAM output of the DPCM demodulator

Discussion: Therefore, after obtaining the previous cases, we find that there is an effect when reducing the number of bits used significantly on accuracy. The smaller the number of bits, the more limited the available range of representable values is, making the signal representation coarser. Reducing the number of bits also leads to the loss of fine details, as the system becomes less sensitive to small changes in the signal. These results indicate that the theoretical and practical aspects of this experiment match, as the number of bits and frequency greatly affect the accuracy of the signal.

4.concluosion:

In this experiment, we came up with a similar concept of pulse code modulation (PCM), including time division multiplexing (TDM), noise quantization, and pulse code modulation (DPCM). Valid results were obtained that support studies in all the topics I discussed. Theoretical. We noted the factors affecting the signal, including reducing the number of bits and the frequency of the signal, as it was a successful experiment that led to an increase in the level of knowledge of the previous topic.

5.References:

[1] Pulse code modulation. Pulse Code Modulation - an overview | ScienceDirect Topics. (n.d.). https://www.sciencedirect.com/topics/engineering/pulse-code-modulation

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[4] GeeksforGeeks. (2022, October 12).5 DEC 2023, *Difference between PCM and DPCM*. GeeksforGeeks. https://www.geeksforgeeks.org/difference-between-pcm-and-dpcm/

[5] Lab Manual.