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BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Department of Electrical and Computer Engineering

COMMUNICATIONS LAB (ENEE4113)

Report of Experiment 8

“Pulse Code Modulation (Part 2)”

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Table of contents

Table of Figures

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1. Abstract

This report examines a comprehensive digital multiplexing system that uses both PCM and PAM, or pulse amplitude modulation. The experiment's main goal is to examine how Quantization Noise affects the system's triangular and sinusoidal signals. A brand-new modulation method called Difference Pulse Code Modulation (DPCM) is also presented, and its improved performance is evaluated. The evaluation includes determining the DPCM modulation technique's effectiveness and efficiency within the digital multiplexing system. Overall, this experiment offers insightful information about the functionality and potential development of digital multiplexing systems.

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2. Theory

A Pulse Code Modulator circuit's transmitter section is made up of the analog-to-digital converter section's functions of sampling, quantizing, and encoding. The message signal's aliasing is prevented by the low pass filter used before sampling.

Regeneration of compromised signals, decoding, and reconstruction of the quantized pulse train are the receiver section's fundamental operations. The PCM block diagram that shows the fundamental components of both the transmitter and receiver sections is shown below.

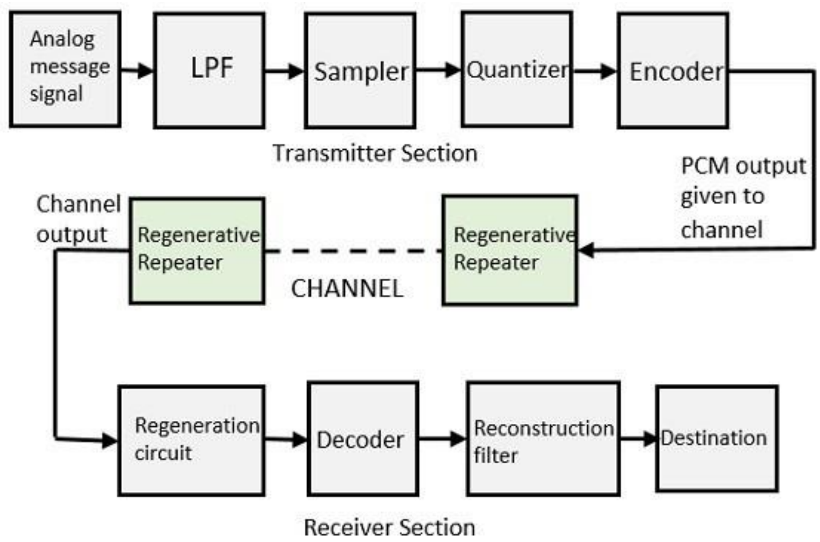

Figure 1:PCM

Digital encoding of analog signals is done using PAM (Pulse Amplitude Modulation) and PCM (Pulse Code Modulation) techniques. Despite their similarities, PAM and PCM differ significantly in the following ways:

- Encoding Method:

PAM: PAM modulates the digital signal's pulse amplitude in accordance with the amplitude of the analog signal being encoded.

PCM, on the other hand, quantizes the signal's amplitude at regular intervals to encode analog signals, and after that, each sample is represented by a binary code.

dont just copy

- Signal Representation: PAM: In PAM, the digital pulses' amplitudes exactly match those of the original analog signal. Discrete levels are frequently used to represent the amplitude values.

PCM: In PCM, each sample is represented by a fixed number of bits, and the amplitude of the analog signal is quantized into a finite number of levels. The amplitude levels, but not the precise amplitude values, are represented by the resulting digital samples.

- Quantization:

PAM: PAM frequently excludes quantization. Using digital pulses, it directly samples and represents the analog signal's amplitude.

PCM: Quantization, or the discretization of an analog signal's continuous amplitude into a finite number of levels, is a component of PCM. The resolution and fidelity of the encoded signal are determined by the quantization levels. While PCM quantizes the amplitude levels and represents them using binary codes, PAM directly represents the amplitude of the analog signal with digital pulses. PCM is appropriate for applications requiring higher fidelity because it uses quantization and more intricate reconstruction. Contrarily, PAM is less complicated and frequently used in some analog signal transmission scenarios.

The quantization procedure, which is a crucial step in digitizing analog signals, uses both linear and non-linear approaches. After dividing the input range into equal levels or intervals, the linear quantization process entails mapping each input value to the nearest level. If we have a linear quantization with 8 levels, for example, the input range is divided into 8 equal intervals, and each input value is quantized to the nearest level. The uniform representation of the signal is ensured by linear quantization, but it may result in higher quantization error for minute signal variations. Contrarily, a non-uniform distribution of quantization levels is used in non-linear quantization. It distributes more levels to the input signal's perceptually significant regions and fewer levels to the less significant regions. This makes it possible to represent the signal more effectively, especially in regions where human perception is more sensitive. Non-linear quantization may increase the complexity of the encoding and decoding processes but can reduce quantization error for important signal components. The specific needs of the application and the properties of the signal being processed determine whether linear or non-linear quantization should be used. Although linear quantization is easier to use and more straightforward to implement, it may not always perform at its best. While more difficult, non-linear quantization can increase signal fidelity by allocating quantization levels in accordance with perceptual importance. (Stack OverFlow , 2017)

each part must have

DPCM:

A technique for reducing redundant signal transmission is called DPCM (Differential Pulse Code Modulation). It entails sending the difference between the signal and the signal's predicted value, which is supplied by the predictor element. It is essential that the predictors in the PCM modulator and PCM demodulator start from the same prediction value in order to guarantee accurate transmission. The prediction value starts out at 0 when the switch is turned on.

The quantizers that we have so far studied work independently on each sample without taking the correlation between subsequent samples into account. Differential pulse-code modulation (DPCM), a particular kind of quantizer, makes use of this correlation.

In DPCM, the difference between a sample and its predicted value is quantized rather than directly quantizing each individual sample. The signal's previous m samples are typically used to base the prediction. This method takes advantage of the correlation between successive samples to more effectively compress and encode the signal. (University, n.d.)

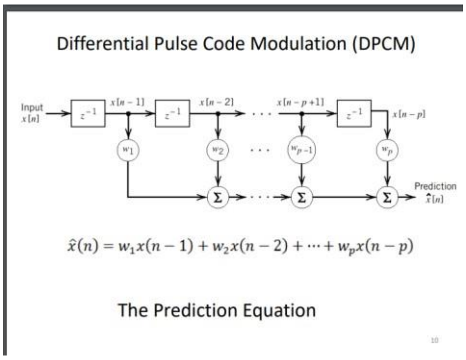

Figure 2:DPCM

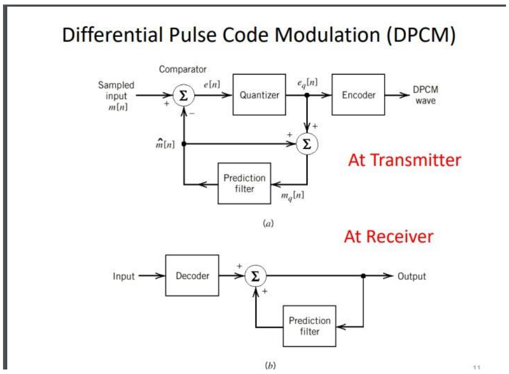

Figure 3:Transmitter & Reciver of DPCM

Quantization Error

The difference between the quantizer's input and output in absolute terms is known as the quantization error per sample.

$e = |x - \check{x}|$

Quantizer resolution (maximum error per sample)=$\frac{\Delta}{2}$ We can assume that this error is a uniform random variable over the interval.$-\frac{\Delta}{2} < e < \frac{\Delta}{2}$

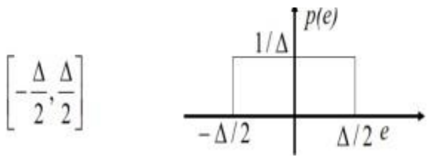

Figure 4:Quantization Error

Over all signal samples, the average quantization error (distortion) is

$$D = (x - \check{x})^2 = E(e)^2$$

$$D = \frac{1}{\Delta} \int_{-\frac{\Delta}{2}}^{\frac{\Delta}{2}} (e)^2 . de = \frac{\Delta^2}{12}$$

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3. Procedure

Part Ones: PCM Transmission with TDM

In this experiment, the utilization of time division multiplexing facilitated the transmission of sampled, quantized, and binary-encoded data from two analog signals over a single communication channel, resulting in a significant improvement in the transmission process.

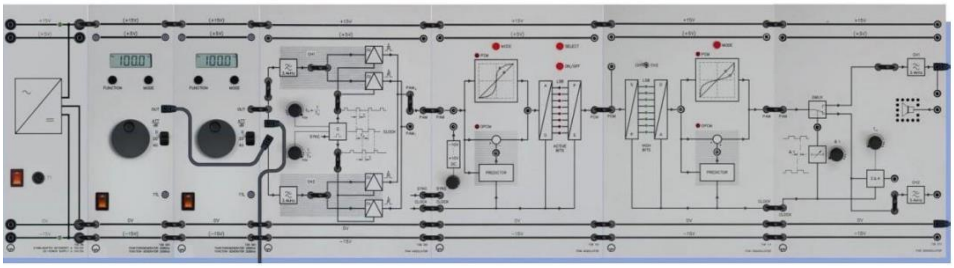
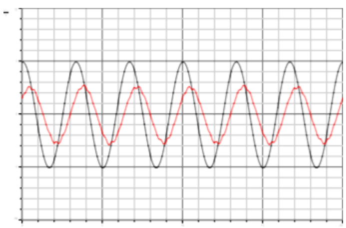


Figure 5: Quantization Noise Triangle Signal

The circuit was flawlessly connected, establishing a seamless connection between channel UA1 and the Input PAM Modulator CH1. Subsequently, UB1 was connected with the Output PAM Demodulator CH1, effectively activating all the bits. The PCM modulator and demodulator panels were accurately set to employ linear quantization, ensuring optimal performance. The duty cycle of the clock generator was set to its maximum value, and the sampling frequency was minimized. Function generator 1 was configured with Vss=10 volts and a frequency of 300 Hz, while function generator 2 was adjusted to Vss=5 volts and a frequency of 200 Hz. The minimum value for the time shift knob delta t was set to achieve precise synchronization. Subsequently, UA1 was connected to the PAM modulator CH2 in order to modulate the input signal. Additionally, UB1 was connected to the output PAM demodulator for the purpose of the demodulation process.

Channel 1:

Figure 6:Output Channel 1



-Input PAM Modulator

-Output PAM Demodulator

Pulse amplitude modulation, also known as PAM, is a type of modulation used in communication systems to transmit analog signals over digital communication channels. PAM uses baseband modulation and varies the pulse's amplitude to simulate an analog signal.

The analog signal is first periodically sampled in PAM modulation. The analog signal's current amplitude is represented by each sample. The amplitude is then transformed into a digital value by quantizing it to a finite number of levels. ADC, or Analog-to-digital conversion, is the name of this procedure. (htt)

We successfully implemented the modulator and verified the effective performance of Pulse Amplitude Modulation (PAM) in sampling and quantizing the signal. By employing the encoding techniques demonstrated in Experiment 7, we were able to achieve reliable signal modulation. The utilization of a linear quantized played a crucial role in quantizing the message signal intervals during transmission, resulting in a modulated signal that closely approximates the original signal. This technique offers substantial advantages, notably in terms of efficient encoding and decoding processes, as the evenly spaced quantization intervals ensure an accurate representation of the message signal. Furthermore, the uniform distribution of quantization intervals facilitates robust and reliable signal recovery at the receiving end. These findings highlight the effectiveness and practicality of the implemented modulation technique, paving the way for improved communication systems in various applications.

Chanel2:

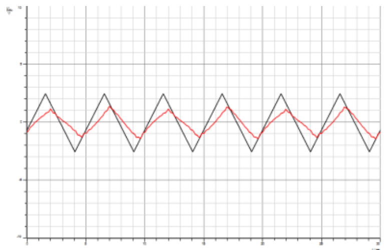


Figure 7:PAM Modulator CH2

-Input PAM Modulator

-Output PAM Demodulator

For dependable and effective signal recovery, Time Division Multiplexing (TDM) communication schemes and digital data transmission are crucial. Quantization transforms analog signals into digital ones, allowing them to be transmitted over digital channels. By giving each signal a specific time slot, TDM enables the simultaneous transmission of multiple signals. However, elements like the signal-to-noise ratio, timing synchronization, and channel capacity are necessary for effective communication and accurate message signal recovery. The successful transmission and recovery of message signals in TDM are ensured by consideration of these factors, along with methods like error correction coding and noise-resilient modulation schemes, making it an essential component of contemporary communication systems. (Morris, 2021)

Part Two: Quantization Noise

Section 2.1: Triangle Signal

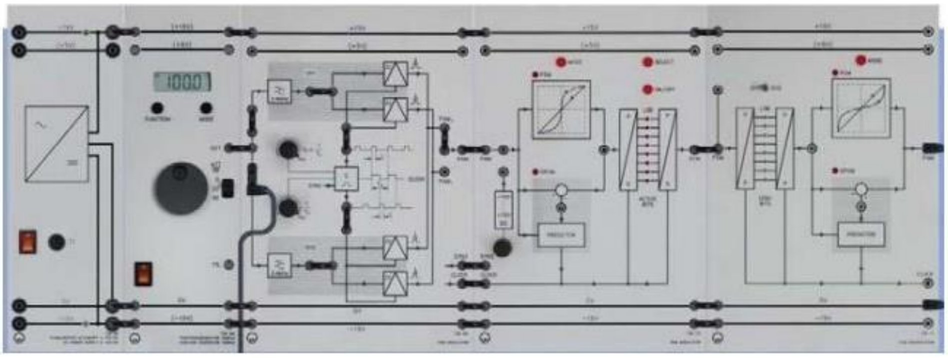


Figure 8: Quantization Noise Sinusoidal Signal

The circuit of figure was connected with the setting shown in figure. In order to guarantee a continuous signal without pauses at the output of the PCM demodulator, the CH1 and CH2 channels of the PAM Modulator are connected to a single function generator. The function generator produces a triangular waveform with a frequency of 30 Hz and a peak-to-peak voltage of 12 V. The PCM modulator and demodulator are subjected to linear quantization with all bits active. The CASSY UA1 serves as the input of the PAM Modulator CH2, and the CASSY UB1 serves as the output of the PCM Demodulator. The CASSY Lab 2 example QNoise labs are used for measurement, and the results are sketched and interpreted. The least significant 3 bits are disabled as the measurement is repeated with a resolution of 5 bits. Additionally, a 5-bit resolution measurement is carried out using a triangular waveform with a 300 Hz frequency. In these experiments, the effects of resolution and message frequency on the quantization procedure and the caliber of the demodulated signal are examined.

8bit & 30Hz:

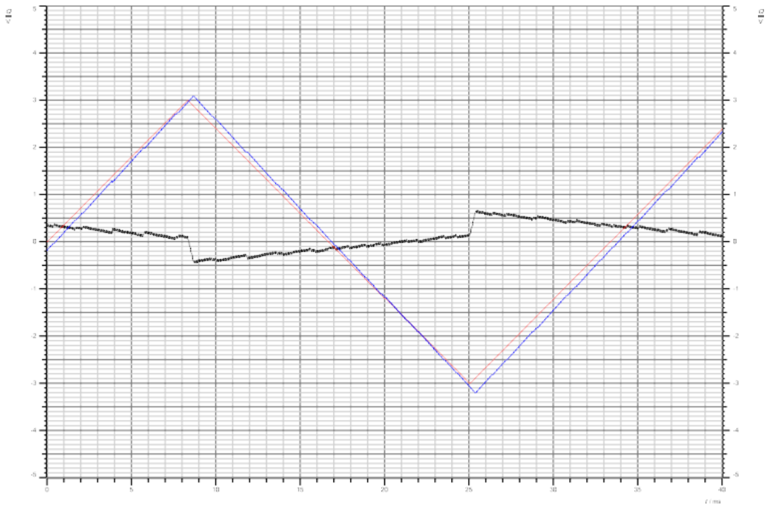


Figure 9:Output for 8 bit & 30Hz

5bit & 30Hz

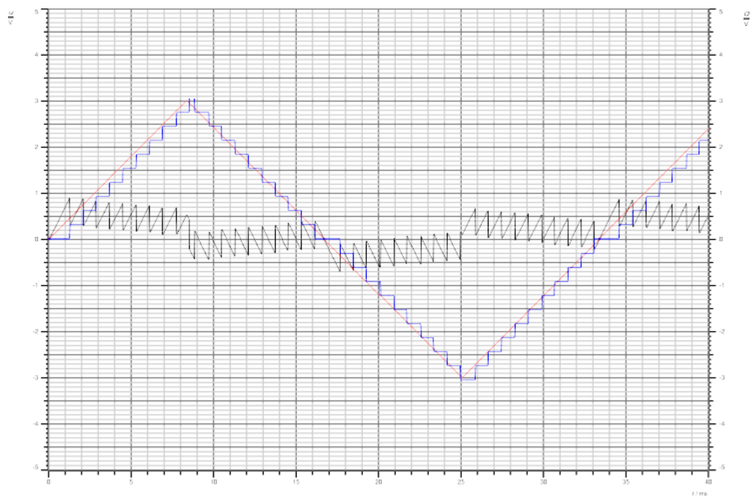


Figure 10:Output for 5 bit &30Hz

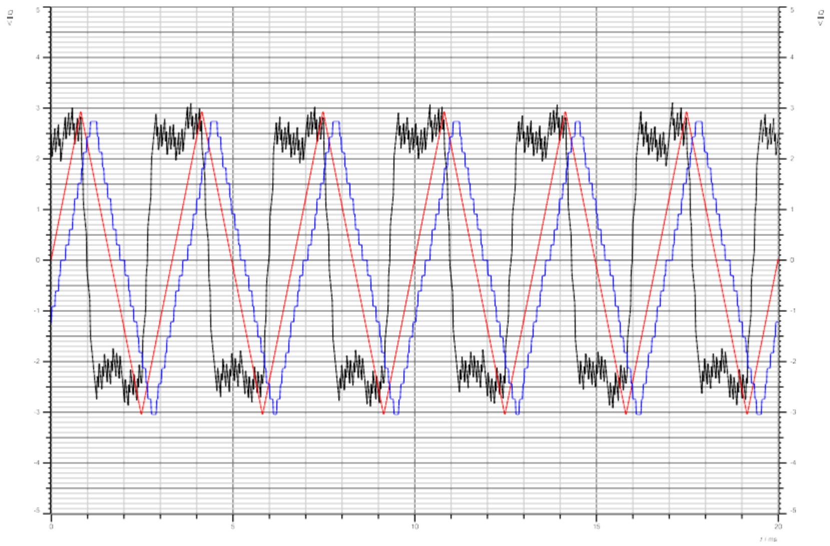


Figure 11:Output for 5 bits & 300Hz

In part 2.1, the effect of changing the bit and the frequency for example: from 8-bit and turning off the 5-bit was investigated. The effect of bit alteration on modulation, as well as the process of message sampling, quantization, and encoding in Pulse Amplitude Modulation (PAM), was studied. When the message was transmitted at 300 Hz with 5 bits, an increase in error was observed. The error is the result of subtracting the modulated signal from the original signal and depends on the number of quantization levels (L). As L decreases, the error is increased.

Section 2.2 Sinusoidal Signal

5bit & 300Hz:

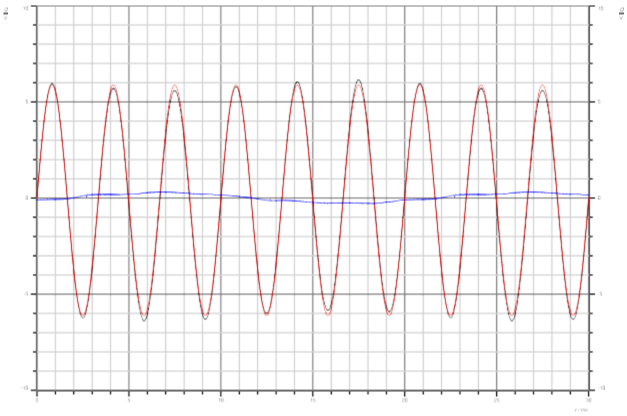


Figure 12: Output for 5bit & 300Hz

5bit & 30Hz:

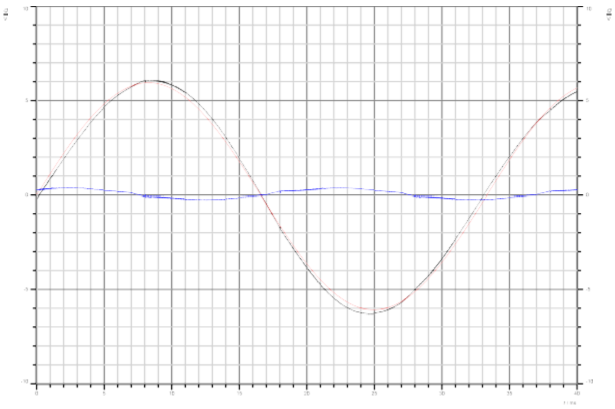


Figure 13: 5 for bit & 30Hz

8bits & 30Hz:

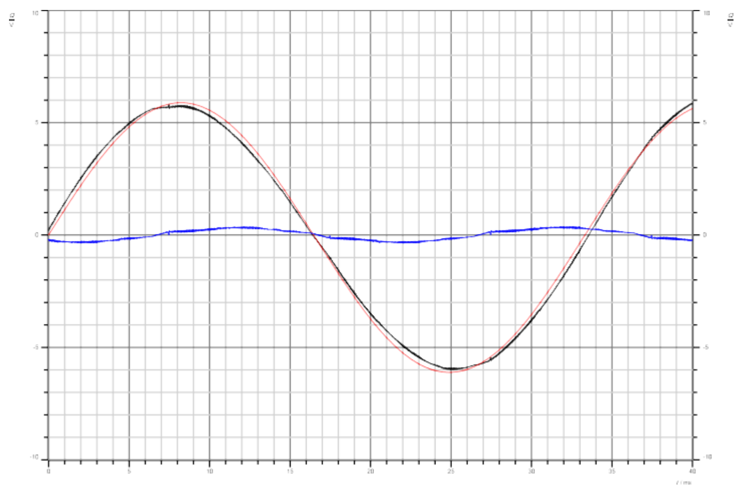


Figure 14: 8bits & 30Hz

In section 2.1, the study was repeated by introducing a sinusoidal signal and employing nonlinear quantization. The bit was initially changed to examine the effect of bit alteration on error quantization. Subsequently, the frequency was modified to investigate the resulting error. It was observed that when nonlinear quantization was used, the output closely approximated the input. Therefore, it is recommended to employ nonlinear quantization as it effectively reduces the error by dividing the interval in a manner consistent with the shape of the signal.

Part Three: Difference Pulse Code Modulation (DPCM)

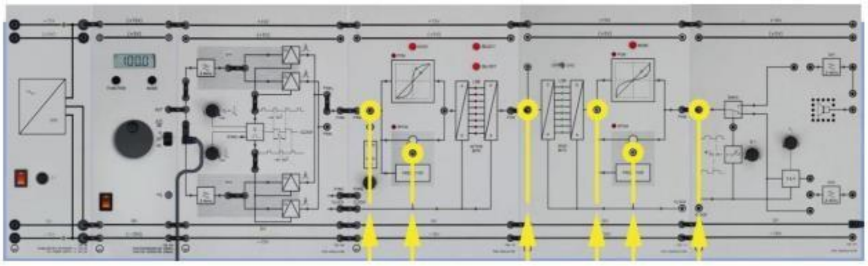


Figure 15:Connection of Part 3

In this part of the experiment involved connecting both channels (CH1 and CH2) of the PAM Modulator using a function generator. The function generator was set to Triangle waveform with a frequency of 30 Hz and a voltage of 12 V. The PCM modulator and demodulator were configured for DPCM mode with all bits activated. A specific switch-on sequence was followed, including connecting the PAM input of the PCM modulator to 0 V, switching the PCM modulator to DPCM mode, simultaneously switching the PCM demodulator to DPCM mode, disconnecting the PAM input from 0 V, reducing the modulation signal's amplitude to 0 V, feeding the sampled signal into the PCM modulator, and resetting the amplitude to the desired value. Measurements were taken for different signals using channel UB1, including the predictor and output of the DPCM modulator, input and predictor of the DPCM demodulator, and PAM output of the DPCM demodulator. Sketches were made, and the measurements were interpreted.

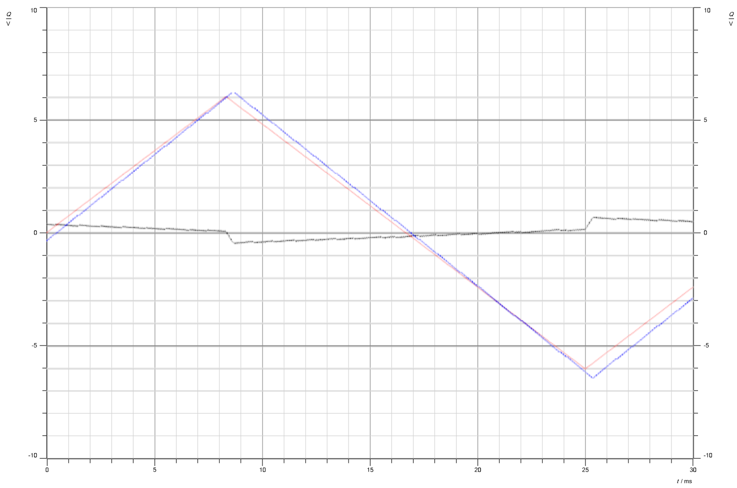


Figure 16:Predictor of the DPCM modulator

-predicted signal

-message signal

-error (and we was skipped no need for it in this section)

Predictor of the DPCM modulator

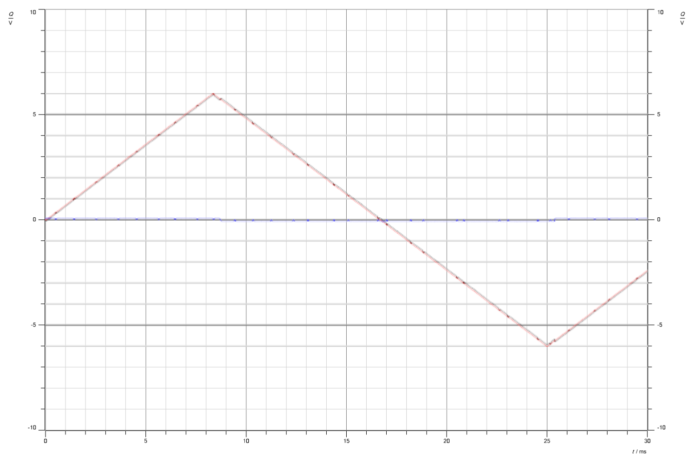


Figure 17:Output of the DPCM Modulator

Output of the DPCM Modulator

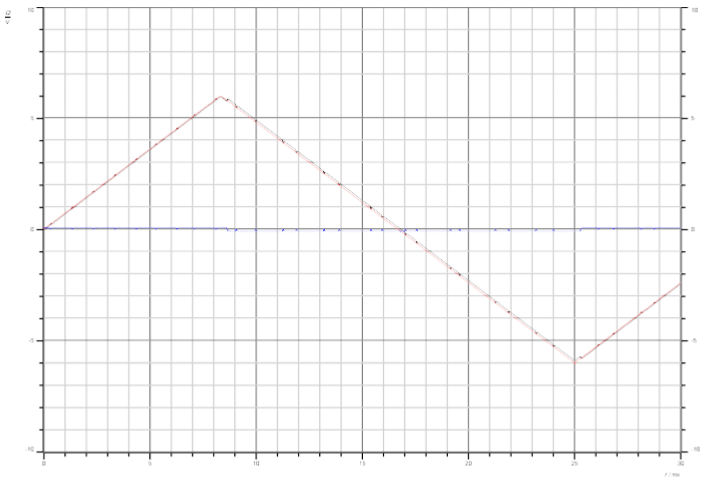


Figure 18:Input of the DPCM demodulator

Input of the DPCM demodulator

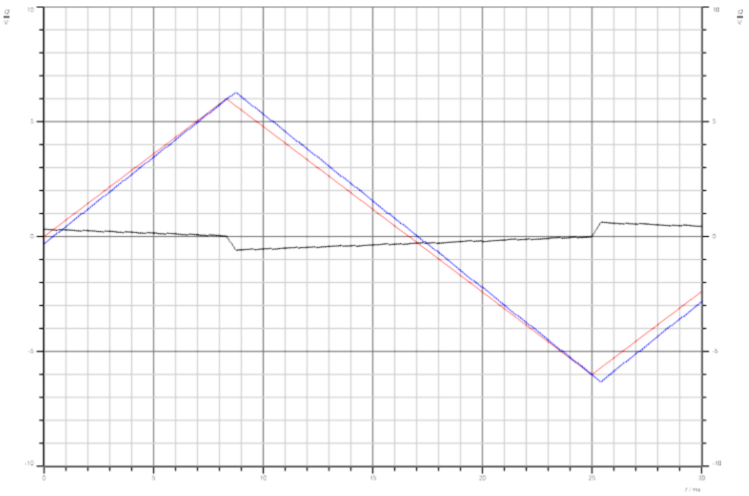


Figure 19:Predictor of the DPCM demodulator

Predictor of the DPCM demodulator

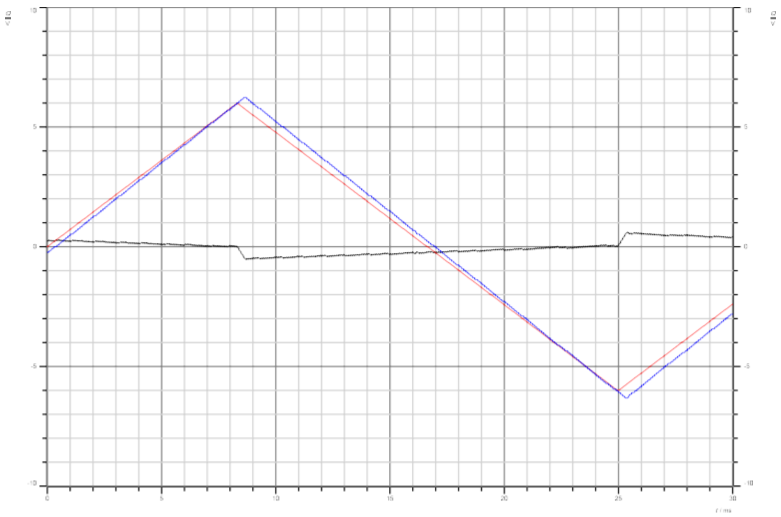


Figure 20;PAM output of the DPCM demodulator

PAM output of the DPCM demodulator

The quantity of bits transmitted in DPCM has a direct impact on the quantization procedure and the accuracy of the encoded signal. The quantization becomes more accurate as the bit count rises, producing a more accurate representation of the original signal. On the other hand, fewer bits result in a lower fidelity representation and coarser quantization. The quantization levels are more precisely spaced with a higher bit count, enabling DPCM to capture smaller signal variations. As a result, there is less quantization error and the reproduction of the original signal is more accurate. In contrast, increasing the bit count results in smaller quantization intervals, which reduces signal detail and increases quantization error.

In conclusion, the number of bits transmitted in DPCM directly affects the degree of fidelity and quantization error in the encoded signal. While decreasing the number of bits reduces accuracy and increases quantization error, increasing the number of bits improves accuracy.

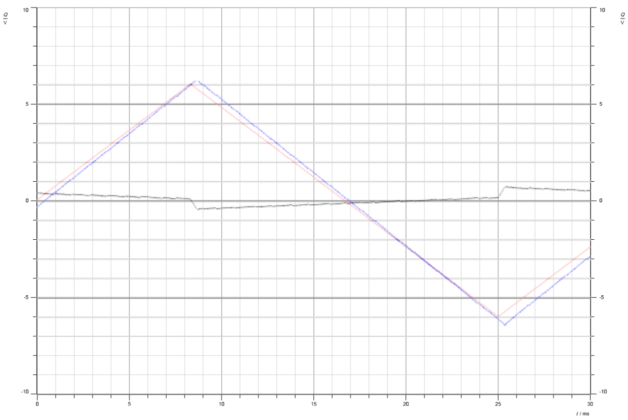


Figure 21:Predictor of the DPCM modulator

Predictor of the DPCM modulator

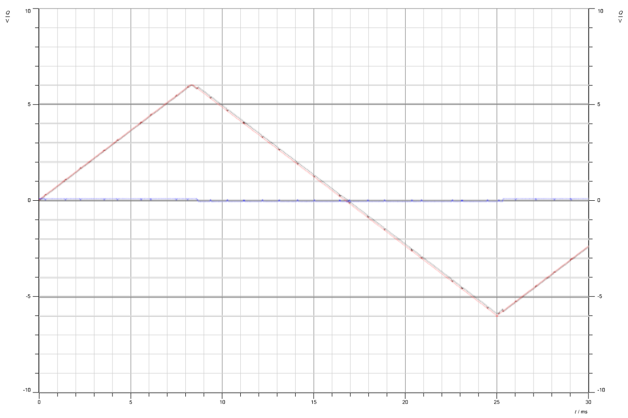


Figure 22:Output of the DPCM modulator

Output of the DPCM modulator

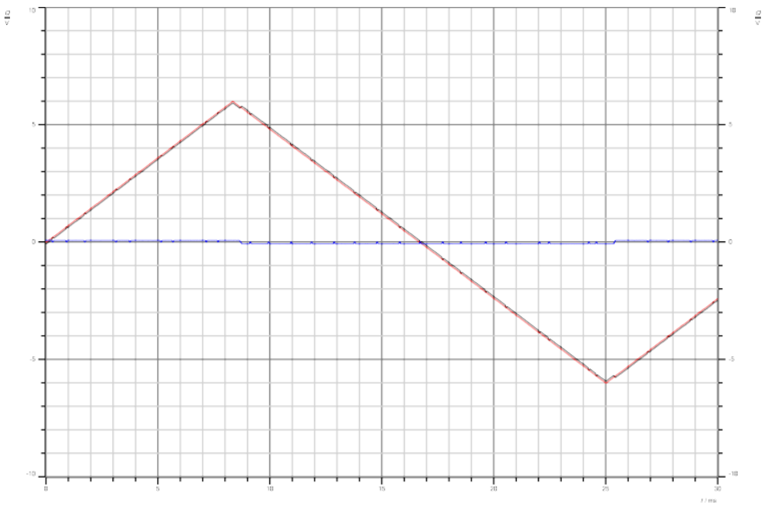


Figure 23:Input of the DPCM demodulator

Input of the DPCM demodulator

The detection resolution is significantly impacted by the reduction in bit usage. The ability to distinguish and precisely detect minute variations or changes in a signal is referred to as detection resolution. The quantization levels are spaced farther apart as the number of bits decreases. This indicates that each quantization level can represent a wider range of values. As a result, it becomes harder to tell apart smaller variations in signal amplitudes. With fewer bits, the encoded signal loses fine-grained detail, compromising the detection resolution. The precision with which slight variations in the signal can be captured and represented is constrained by the decreased number of quantization levels. As a result, it is more difficult to identify minute alterations or features in the signal. In real life, a lower detection resolution can result in the reconstructed signal losing crucial information and obscuring fine details. When working with signals that need high precision or have subtle variations, like audio or image data, it can introduce distortion and inaccuracies. The trade-off between the number of bits used and the desired detection resolution must therefore be carefully taken into account. While reducing the number of bits can help save bandwidth or storage space, it should be done carefully to ensure that the fidelity and quality of the signal for the intended application is not compromised by the resulting loss of detection resolution.

missing data and

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4. Conclusion

In conclusion, methods of using measurements devices in the lab were learned and applied practically. The experiment ran smoothly and gave reasonable results. As a result, we discovered that perfect signal modulation and demodulation can be achieved with fewer bits. In our experiment, we found that decreasing the dynamic range from (-24-24) to (-12-12) led to a smaller bandwidth while keeping the signal quality the same. This has implications for communication strategies.

Our study also looked at how modulation and demodulation were affected by linear and non-linear quantization. We learned more about how well DPCM performs and how useful it is for signal processing. Overall, our team finished the experiment successfully and gained important teamwork skills.

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5. References

1-(n.d.). Retrieved from https://www.tutorialspoint.com/principles_of_communication/principles_of_communication_analog_pulse_modulation.htm

2- Morris, A. S. (2021). *Science Direct* . Retrieved from https://www.sciencedirect.com/topics/engineering/digital-signal-transmission

Stack OverFlow . (2017). Retrieved from https://stackoverflow.com/questions/5321929/what-is-the-difference-between-linear-quantization-and-non-linear-quantization

3- University, B. (n.d.). *Birzeit University Faculty of Engineering & Technology* . Retrieved from Faculty of Engineering & Technology : https://ritaj.birzeit.edu/bzu-msgs/attach/2261647/0.+Communication+Lab+Manual+Version-29-3-23.pdf

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