EEP3010

Communication Systems Lab

Sampling techniques, PCM and demodulation

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By:

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Abstract

The experiment explores the transformation of analog signals, such as speech, into digital form for computer processing through techniques like sampling. Three sampling methods—natural sampling, sample and hold, and flat top sampling—are investigated, analyzing the trade-offs among different sampling frequencies, the impact of the Nyquist rate on signal reconstruction, and the occurrence of aliasing. Following analog-to-digital conversion, the parallel data word is encoded into a serial PCM stream for transmission. Pulse code modulation (PCM) is utilized for converting digital information back to analog signals at the receiver's end, ensuring accurate message reception. Additionally, the experiment delves into encoding and decoding techniques, such as NRZ-L, NRZ-M, NRZ-S, BIO-L, BIO-M, and BIO-S, to assess the integrity of transmitted messages after encoding and subsequent decoding, elucidating the efficacy of various encoding schemes in preserving data integrity during transmission.

Objective

- In the first part of the experiment, the focus is on understanding sampling techniques and their various types, followed by the reconstruction of a sampled signal. An important aspect of this segment involves exploring the tradeoff between sampling frequency and the accuracy of signal reconstruction. By varying the sampling frequency, participants gain insight into how different rates affect the fidelity of the reconstructed signal, providing valuable understanding of the relationship between sampling rate and signal integrity.

- The second part, the experiment involves performing pulse code modulation (PCM) on an analog message signal input. The modulated signal is then transmitted using the direct synchronization technique and subsequently decoded and reconstructed at the receiver's end.
- Lastly, participants explore various data encoding schemes for digital signals, including NRZ- L, NRZM, NRZ-S, BIO-L, BIO-M, and BIO-S. Each encoding scheme is implemented, decoded, and examined for accuracy, providing insights into the efficacy and reliability of different encoding techniques in maintaining the integrity of transmitted data.

Equipment Used

- DCS-B KIT
- Connecting chords
- Power supply
- 20Mhz Dual Scope Oscilloscope

Procedure

Part 1

1. Prepare the experimental setup by gathering the DCS-B kit, connecting cords, powers upply, and a dual trace oscilloscope, ensuring all switch faults are turned off.
2. Select the group 1 (GP1) clock in the clock generation section using switch S1, indicated by the LED signal corresponding to GP1.
3. Adjust the sampling frequency (fs) using switch S2 and observe LED indication, generating a sampling clock signal at the TX CLK post.
4. Generate a sine wave signal with a frequency of 2 kHz (fm = 2 kHz) from the function generator section, adjusting its amplitude via the LEVEL pin corresponding to fm (pot P6).
5. Connect the TX CLK to the CLK1 post in the SAMPLING section to provide the sampling signal to the circuit.
6. Input the message signal to post IN1 using a connecting cord, and set the jumper JP1 to the first position for observing natural sampling (NS) effect.
7. Observe the output signal at the OUT1 post to analyze the sampled signal.
8. Reconstruct the sampled signal by passing it through a filter, connecting the sampled signal output to the IN post in the filter circuit.
9. Use a 2nd or 4th order filter and observe the reconstructed signal at the OUT post in the filter circuit.
10. Analyze the performance of 2nd and 4th order filters and the impact of the Nyquist criterion on signal reconstruction by comparing results obtained at different sampling frequencies (fs = 2 kHz, 4 kHz, and 16 kHz).

11. Repeat the process for studying sample and hold and flat top sampling techniques by shorting the 2nd and 3rd jumper JP1, respectively.

Part 2

1. Choose group 3 (GP3) clock in the clock generation section by using switch S1 and observing the corresponding LED selection.
2. Keep jumper JP3 in fast position mode to obtain a clock frequency of 230 kHz at theTXCLK post.
3. Generate a message signal with a frequency of fm = 2 kHz and an amplitude of Vmax4 V, providing this signal as input at the ADC IN post in the A/D converter circuit.
4. Set switch S12 to the NONE parity mode and observe LED indications corresponding to the digitally converted bits (B0 to B6).
5. Examine the pseudo random bit pattern at the test point marked PRBS OUT.
6. Observe the multiplexed data with PRBS and PCM data at the TX DATA post,connecting it to the RX DATA post to obtain the analog signal back from the PCM data.
7. Transmit TX CLK and TX SYNC to the receiver’s end by connecting TX CLK post to RX CLK post and TX SYNC to RX SYNC post.
8. Convert serial data to parallel data and observe it on the corresponding LED indication at the Data Latch section.
9. View the digitally-to-analog converted data at the DAC OUT post, connecting it to a2nd order LPF at IN33 post.
10. Connect the output OUT30 of this 2nd order LPF to the input IN34 of the 4th order LPF for better decoding of the signal at the receiver’s end.
11. Observe the final recovered signal at the output OUT31 of the 4th order LPF circuit.
12. Use an oscilloscope to observe and capture screenshots of the input message signal, clock, TX SYNC, TX DATA, DAC output, and recovered signal after passing through the 4th order LPF.

Part 3

1. Choose group 4 (GP4) clock in the clock generation section to observe the transmitted clock at the TX CLK post.
2. Set an 8-bit data pattern using switch S4, with the upper side representing OFF or0 and the lower side representing ON or 1. For example, set the data sequence as 01101001.

3. Observe the set data at the S DATA post and capture a screenshot for analysis.
4. View the encoded data at the OUT10 post of the encoded data section.
5. Select different encoding schemes using switch S3 and corresponding LEDs for each scheme.
6. Compare the encoded output for each encoding technique with the original data generated using the dual trace mode of the oscilloscope, capturing screenshots for reference.
7. Connect the OUT10 post to the IN27 post in the data decoder section to observe the decoded signal at post OUT23.
8. Compare the decoded data with the generated 8-bit stream to verify if the decoded data matches the input data.
9. Examine the recovered clock at the REC.CLK2 test point of the Decoded Data section.
10. Through these steps, analyze the performance of different encoding and decoding techniques for the generated digital signal, completing the third part of the experiment.

Test Results

Message Signal and Sampling Signal

Natural Sampling

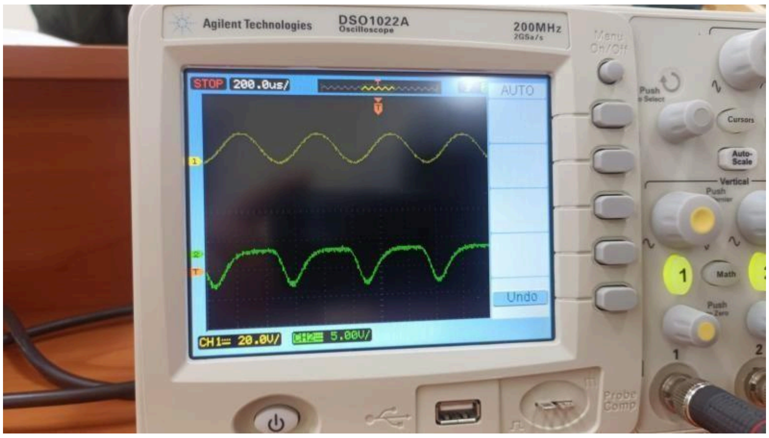

Figure 1: fs=2kHz

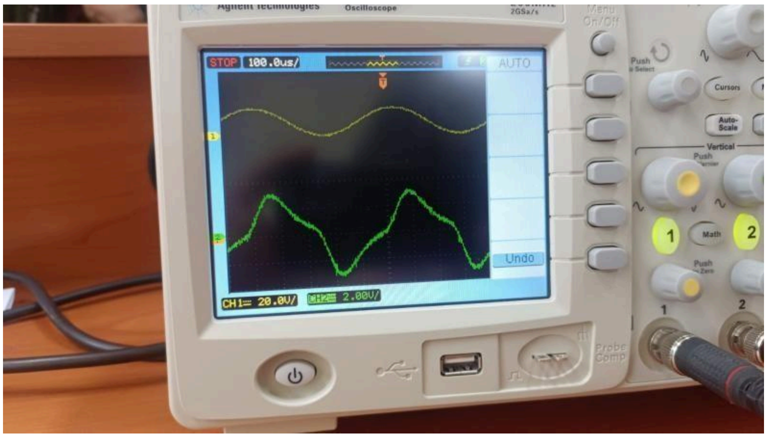

Figure 2: fs=4kHz

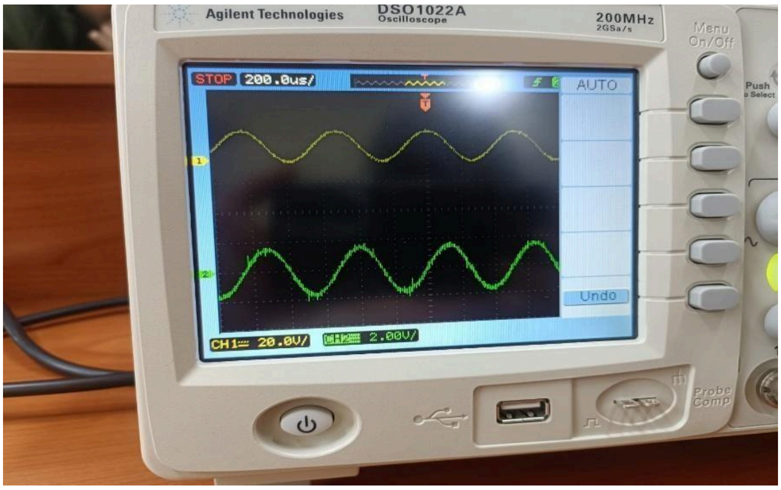

Figure 3: fs= 64kHz

Sample and Hold sampling

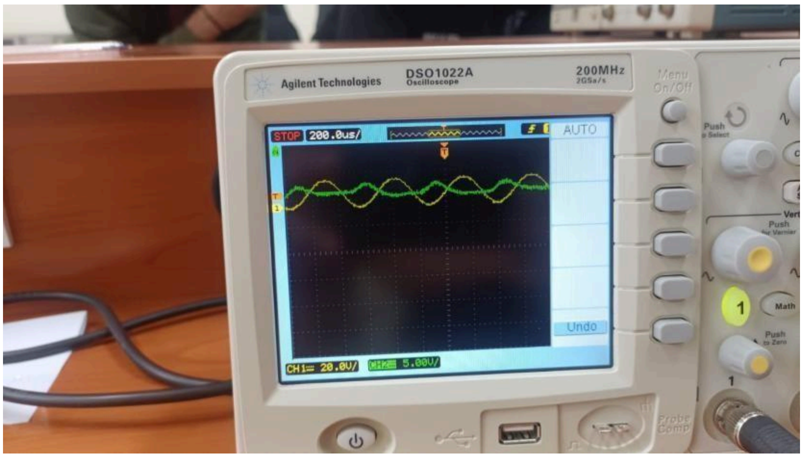

Figure 4: fs=2kHz

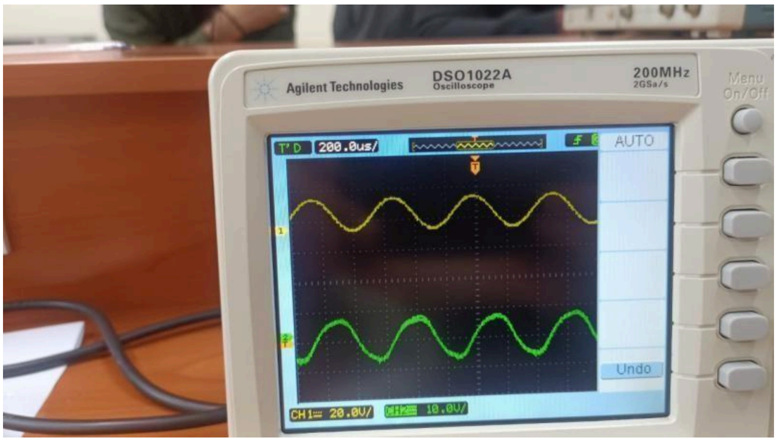

Figure 5: fs=4kHz

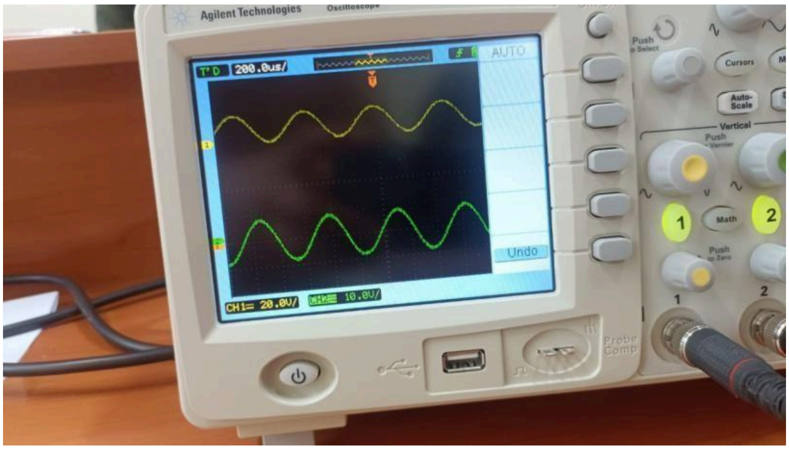

Figure 6: fs=8kHz

Sample and Hold sampling Reconstruction

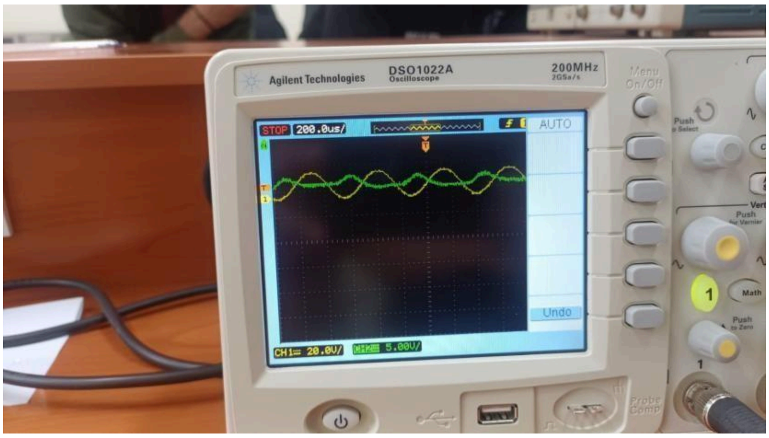

Figure 13: fs=2kHz

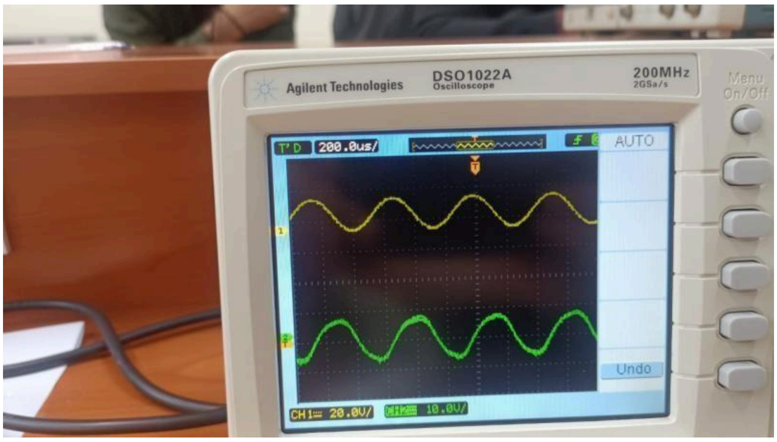

Figure 14: fs=4kHz

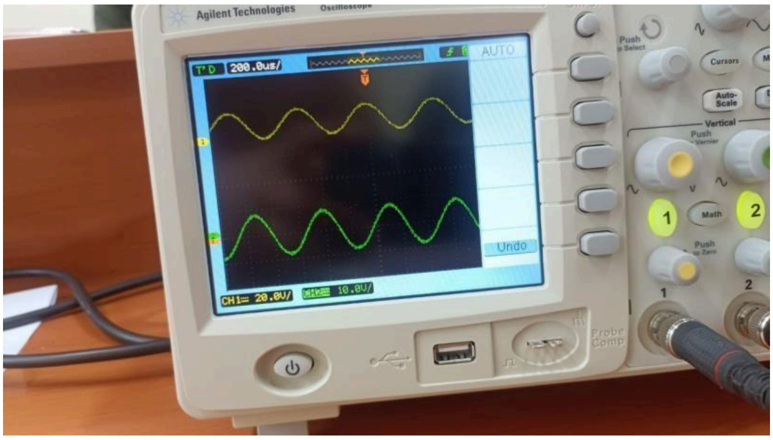

Figure 15: fs=8kHz

Flat Top sampling Reconstruction

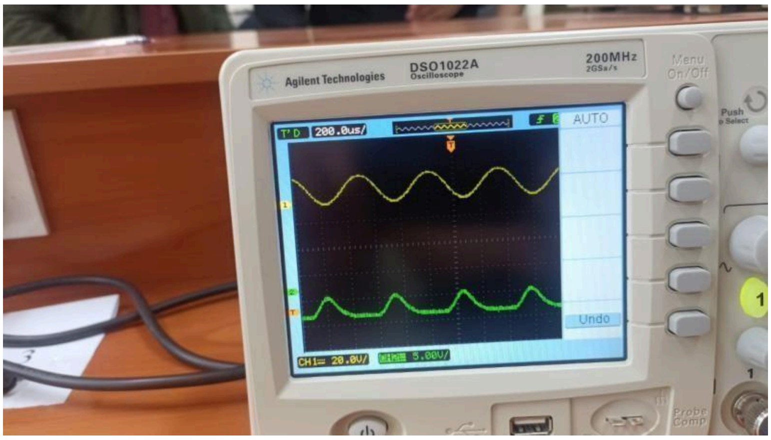

Figure 16: fs=2kHz

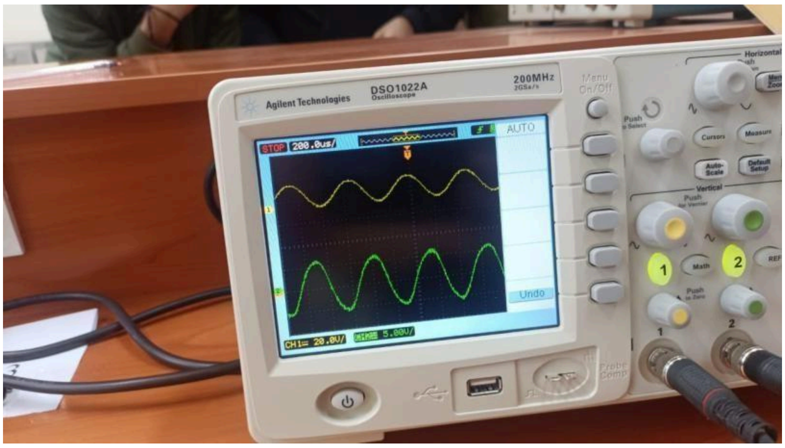

Figure 17: fs=4kHz

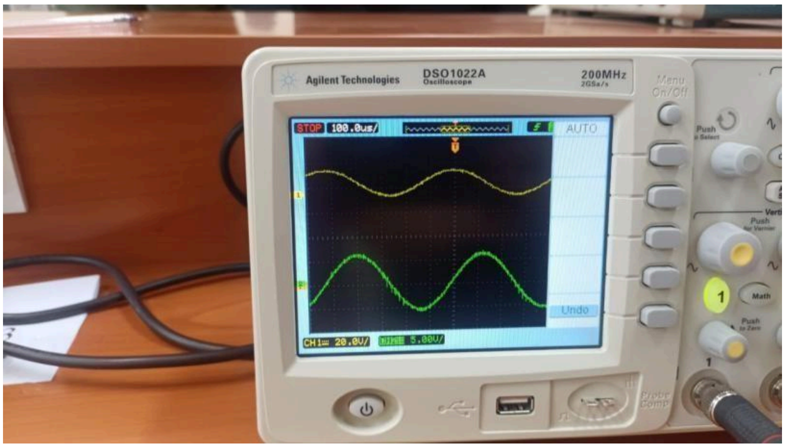

Figure 18: fs=16kHz

Pulse Code Modulation

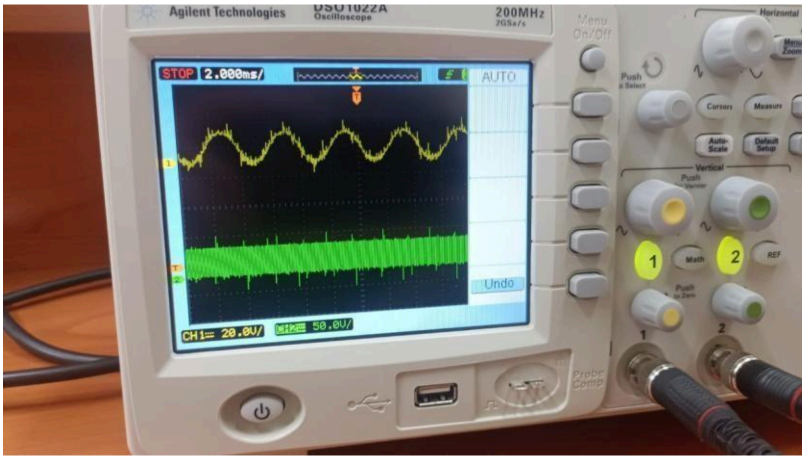

Figure 19: Message signal(yellow), clock(green)

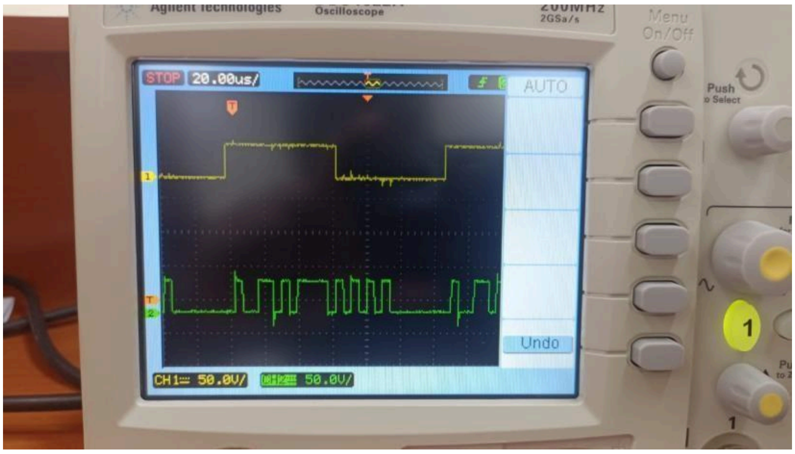

Figure 20: Tx Sync and PCM Data

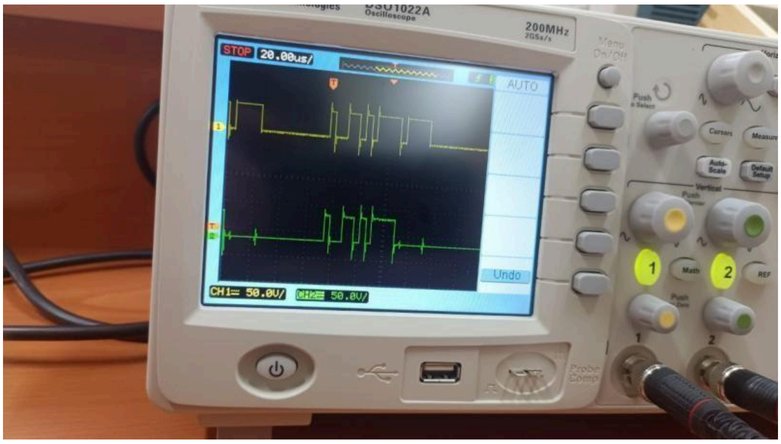

Figure 21: PCM data with PRBS

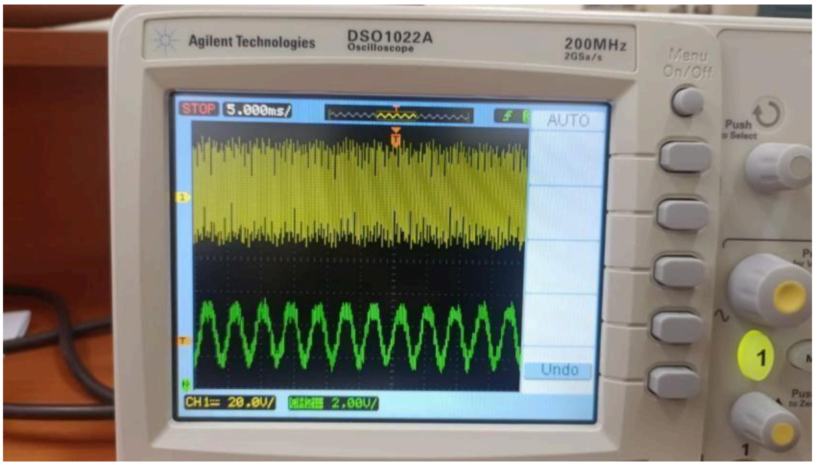

Figure 22: Recovered output(green), DAC output(yellow)

<u>Natural Sampling Reconstruction</u>

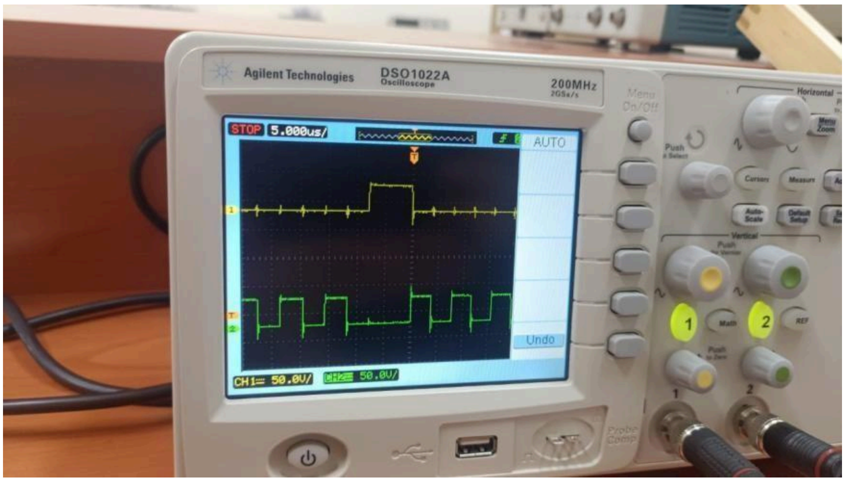

Figure 23: NRZ S

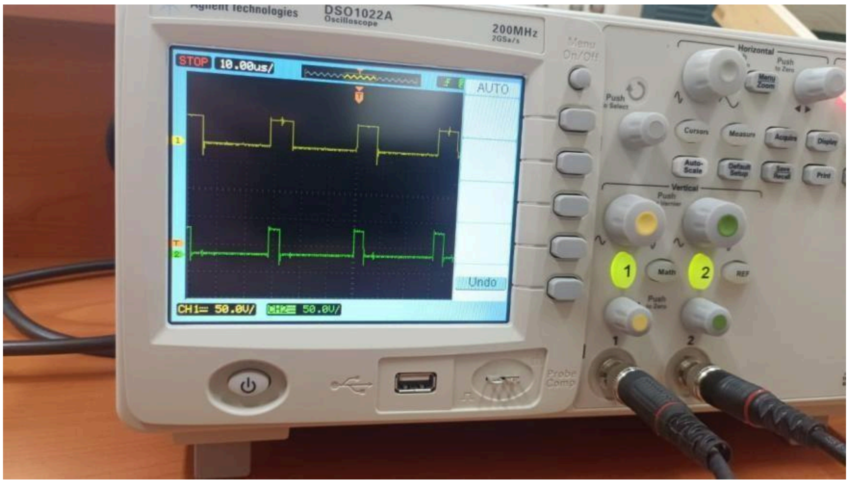

Figure 24: NRZ M

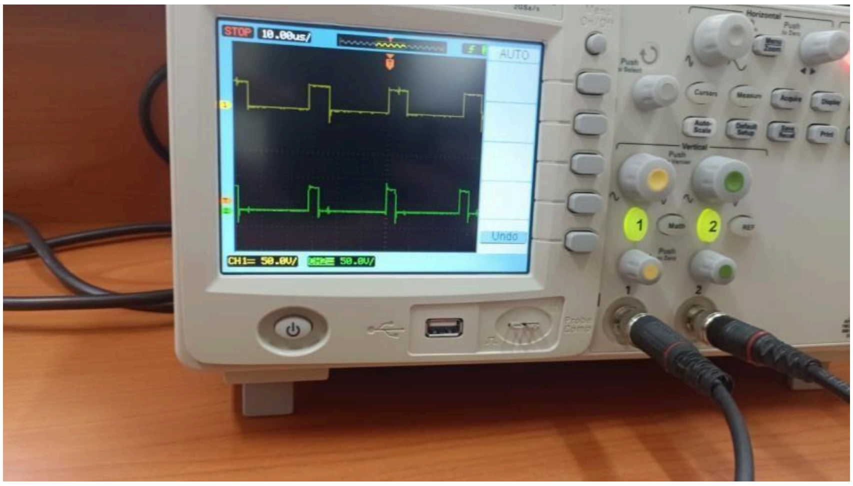

Figure 25: NRZ – L

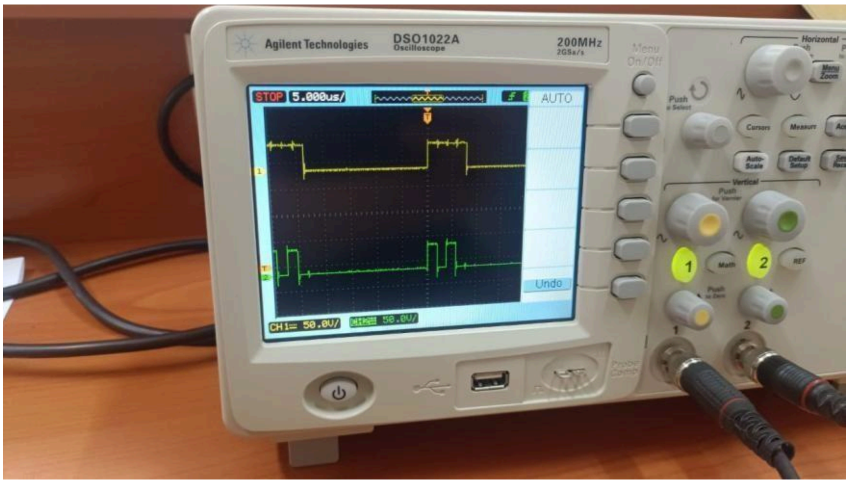

Figure 26: URZ

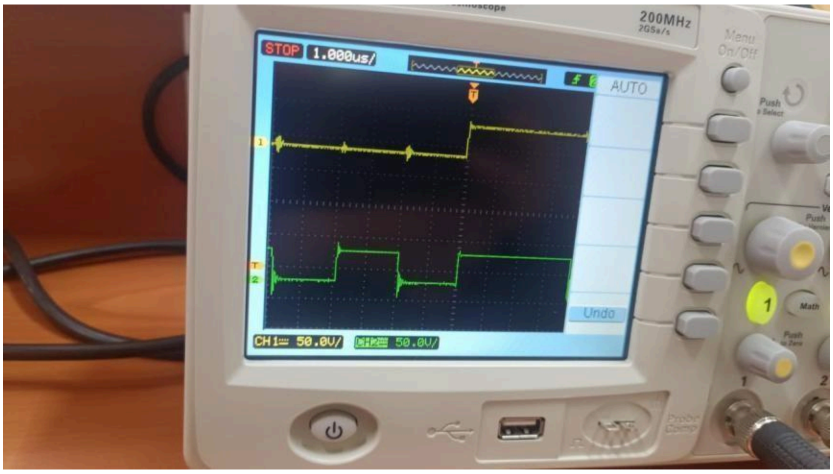

Figure 27: BIO S

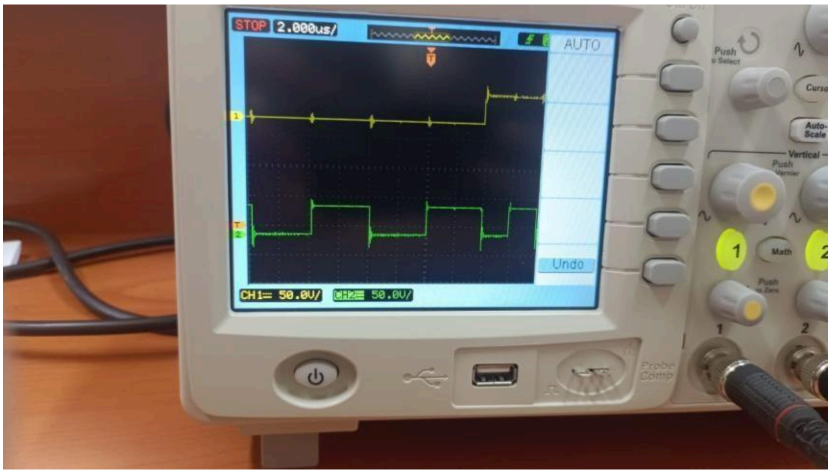

Figure 28: BIO M

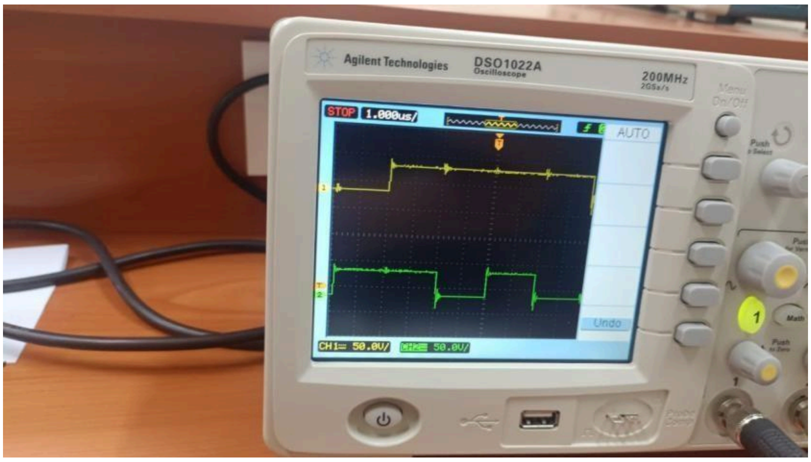

Figure 29: BIO L

Data Encoding and Decoding

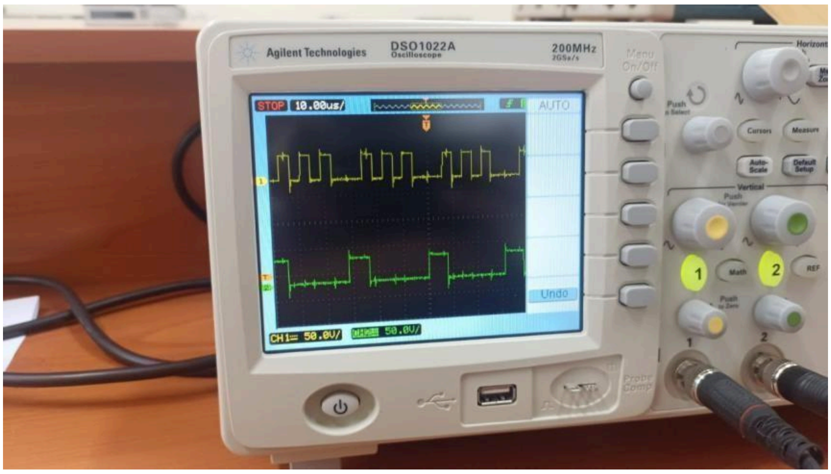

Figure 23: NRZ S ED

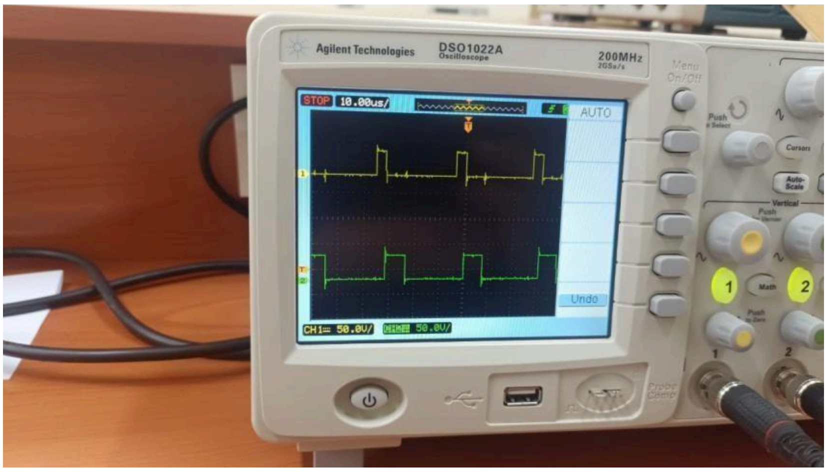

Figure 24: NRZ M ED

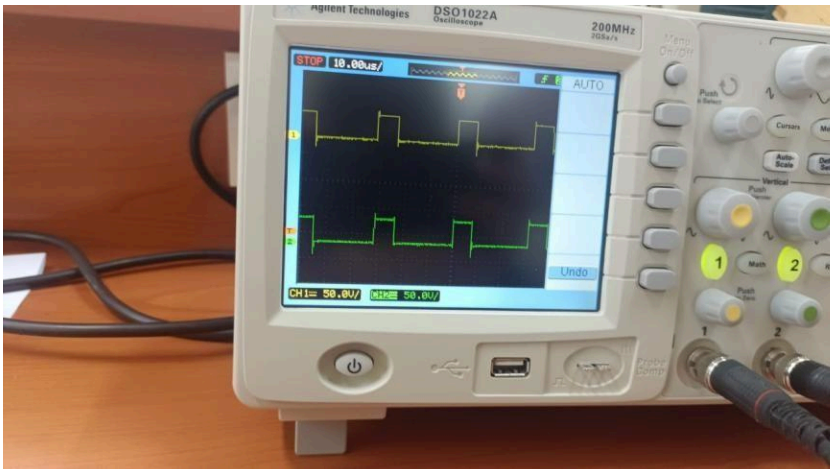

Figure 25: NRZ – L ED

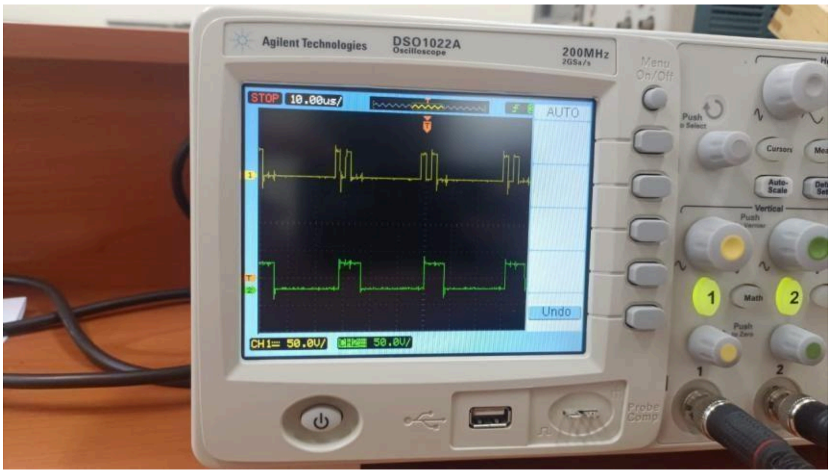

Figure 26: URZ ED

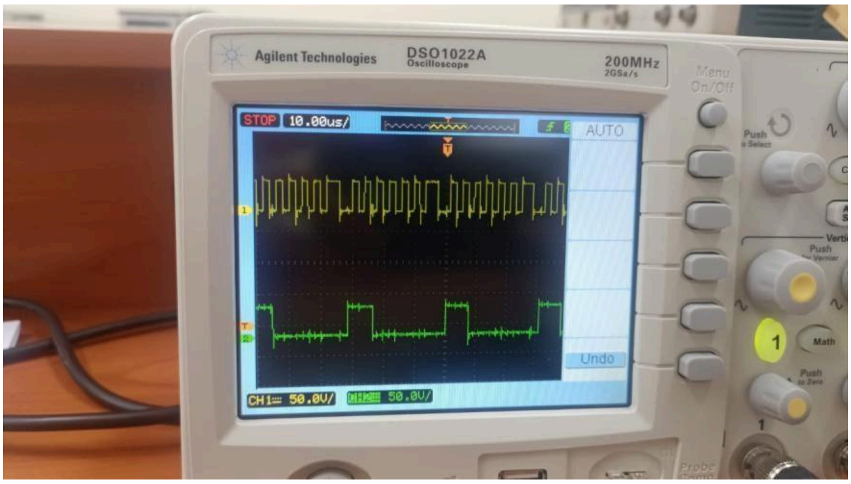

Figure 27: BIO S ED

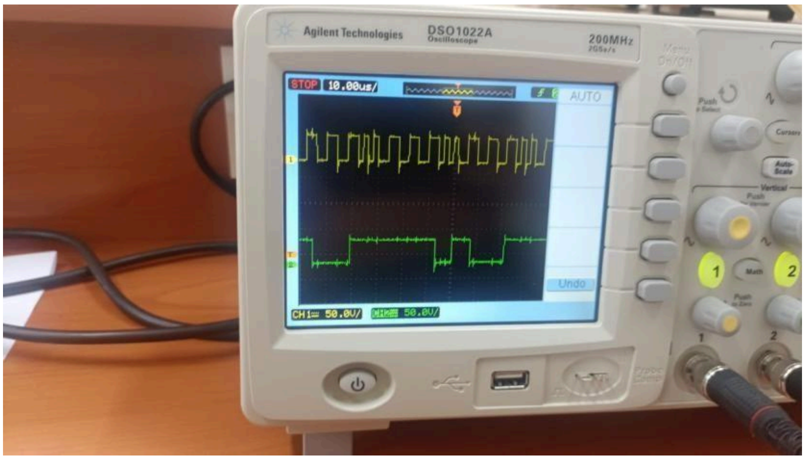

Figure 28: BIO M ED

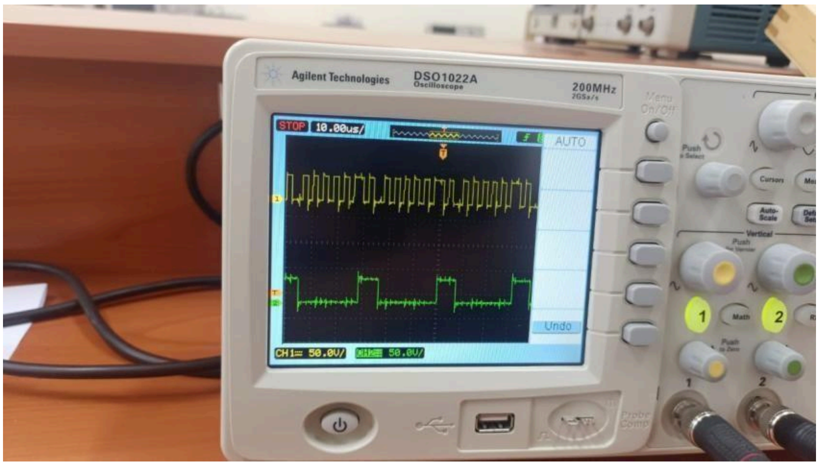

Figure 29: BIO L ED

Discussion

1. Sampling at a faster rate is necessary for signals with high frequency components to ensure that no information is lost.
2. The Nyquist rate dictates that sampling should occur at least twice the message signal frequency to retain all its information.
3. The Sampling Theorem states that a signal can be precisely retrieved if sampled at a frequency (fs) higher than twice the maximum frequency (2fm).
4. Aliasing, the presence of unwanted signals, becomes more apparent in under sampling scenarios.
5. In natural sampling, a resistive load is attached to the circuit; in sample and hold, a capacitor is used; in flat top sampling, an additional capacitor extends the sample and hold circuit.

6. If the signal is not band-limited, spectral overlap or" aliasing" can occur, causing higher frequencies to appear at lower frequencies in the recovered message.
7. Pulse code modulation (PCM) converts analog signal samples into digital words in a serial bit stream.
8. PCM transmission involves generating a PAM signal from an analog signal through sampling, which is then quantized and digitized.
9. A pseudo random binary sequence (PRBS) exhibits periodic, deterministic behavior with white-noise like properties, shifting between two values.
10. Data encoding and decoding schemes find applications in magnetic recording, optical communications, and satellite links functions.

Conclusion

1. Sample and hold sampling provides the best results.
2. Fourth-order filters reconstruct signals better, but cause a slight delay compared to second-order lowpass filters.
3. Proper signal reconstruction requires sampling above or at the Nyquist rate.
4. PCM transmission requires filtering the DAC output to reduce noise and reconstruct the received signal.
5. Different encoding and decoding schemes were tested using waveforms and theoretical definitions, showing accurate signal decoding with a slight delay.

Reference

- Lab Manual
- Principles of communication systems – S. Haykin