Communication Systems:

Sampling Theorem, Time-division Multiplexing,
Pulse-code Modulation, Demodulation
& Eye-diagram observations & measurements

EECS 562

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1 Introduction

Utilize circuit modules to observe how the Sampling Theorem, Time-division Multiplexing, Pulse-code Modulation, De multiplexing, and Eye-diagram change the behavior of an input signal.

2 Theory

2.1 Sampling Theorem

The Sampling Theorem states that if a signal is bandlimited by a range of $[-B, B]$, the signal can only be reconstructed exactly from its samples if the sampling rate is twice the limit frequency B or larger.

$$F_s \geq 2f \tag{1}$$

2.2 Time-division Multiplexing

TDM allows us to transmit several signals through the same medium, by sending each signal as a series of pulses which are interleaved with the other signals being transmitted contemporary.

2.3 Pulse-code Modulation

PCM allows us to convert analog information into a binary sequence, by representing the input signal in discrete form in both time and amplitude. This allows us to multiplex many low bit rate channels on a single hit bit rate channel.

2.4 De multiplexing

The reverse multiplexing process, de multiplexing allows us to reconvert a signal formed by several analog or digital streams back into the original separate unrelated signals.

2.5 Eye-diagram

Graph generated by repetitively sampling a digital signal from a receiver, displaying it in an oscilloscope.

3 Methodology

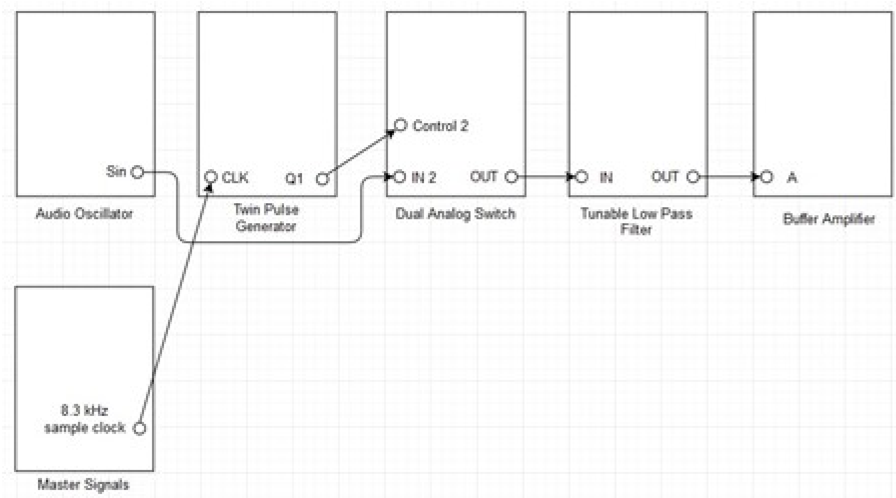

Figure 1: Sampling Theorem Setup.

The experimental setup of the Sampling Theorem experiment is built as shown in Fig. 1. The message signal is used as a 2 kHz sine signal. The Time Pulse Generator (TPG) on board switch is set to single, and the Tunable Low-Pass Filter (TLPF) panel switch is set to normal. The knobs in the buffer amplifier and TLPF are turned to minimum, and the TPF knob is turned to maximum. The modulated signal is acquired via the Pico-Scope, and its trace is captured along with the message signal.

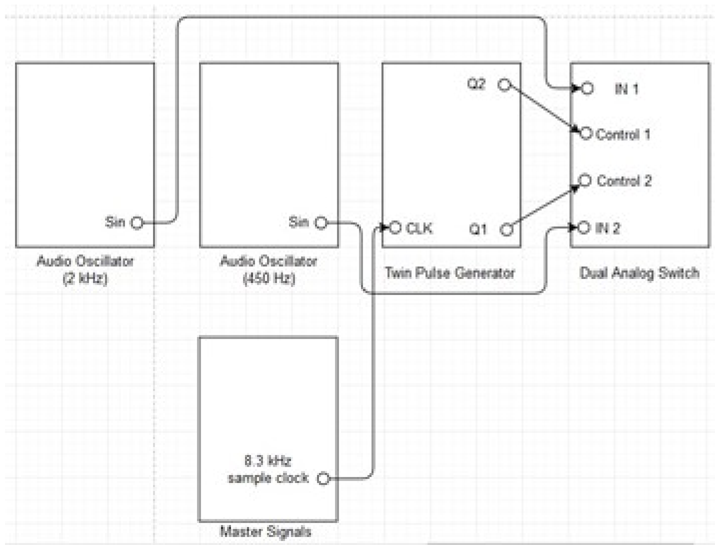

Figure 2: Time-Division Multiplexing Setup

The experimental setup of the Time-division multiplexing experiment is built as shown in Fig. 2. The message signal is used as a 2 kHz sine signal in the first audio oscillator. The second audio oscillator is set to 450 Hz. The output signal is a combination of both input signals, observed via the Pico-Scope.

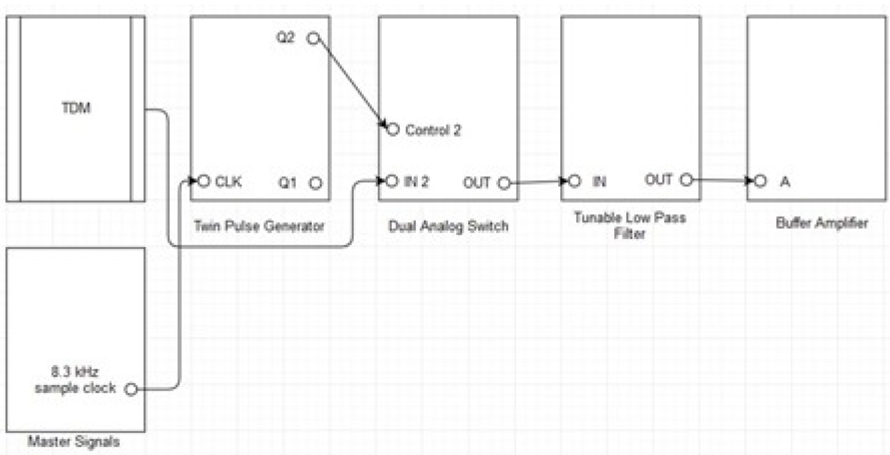

Figure 3: De multiplexer

The experimental setup of the De multiplexer experiment is built as shown in Fig. 3. The message signal is used as the TDM's output signal. The Time Pulse Generator (TPG) on board switch is set to twin, and the Tunable Low-Pass Filter (TLPF) panel switch is set to normal. Both knobs from the TPG and TLPF are set to minimum. The modulated signal is acquired via the Pico-Scope, and its trace is captured along with the message signal.

$$f_{IF} = f_{LO} - f_c \tag{2}$$

$$HUM(dB) = -40dB + 20\log_{10}(\frac{V_{dis}}{3000mV}) \tag{3}$$

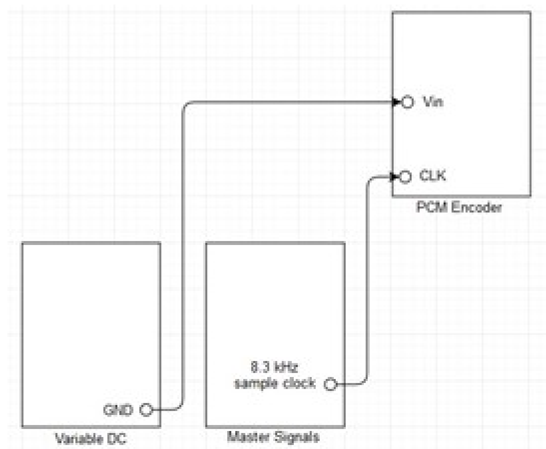

Figure 4: Pulse-code Modulation

The experimental setup of the Pulse-code Modulation experiment is built as shown in Fig. 4. In the PCM encoder, the on boad switch-SW2 has its left pin is turned down and right pin up. Its front panel switch is set to 4 bit linear. The modulated signal is acquired via the Pico-Scope.

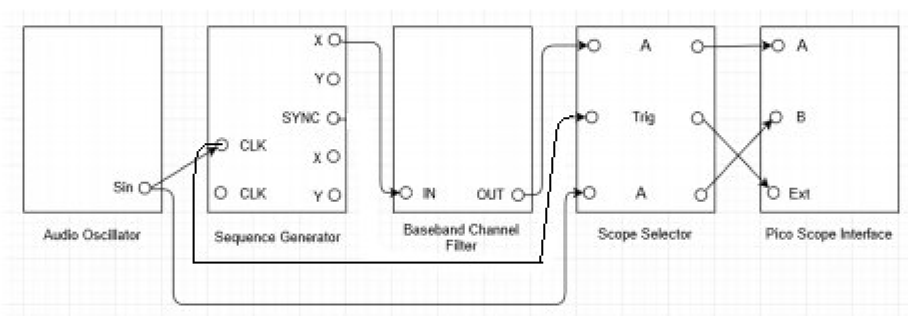

Figure 5: Eye Diagram

The experimental setup of the Eye Diagram experiment is built as shown in Fig. 5. The message signal is used as a 1 kHz sine signal from the audio oscillator. The sequence generator's on-board pins of switch-SW2 are toggled down. The modulated signal is acquired via the Pico-Scope, and its trace is captured in persistence mode.

4 Discussion & Results

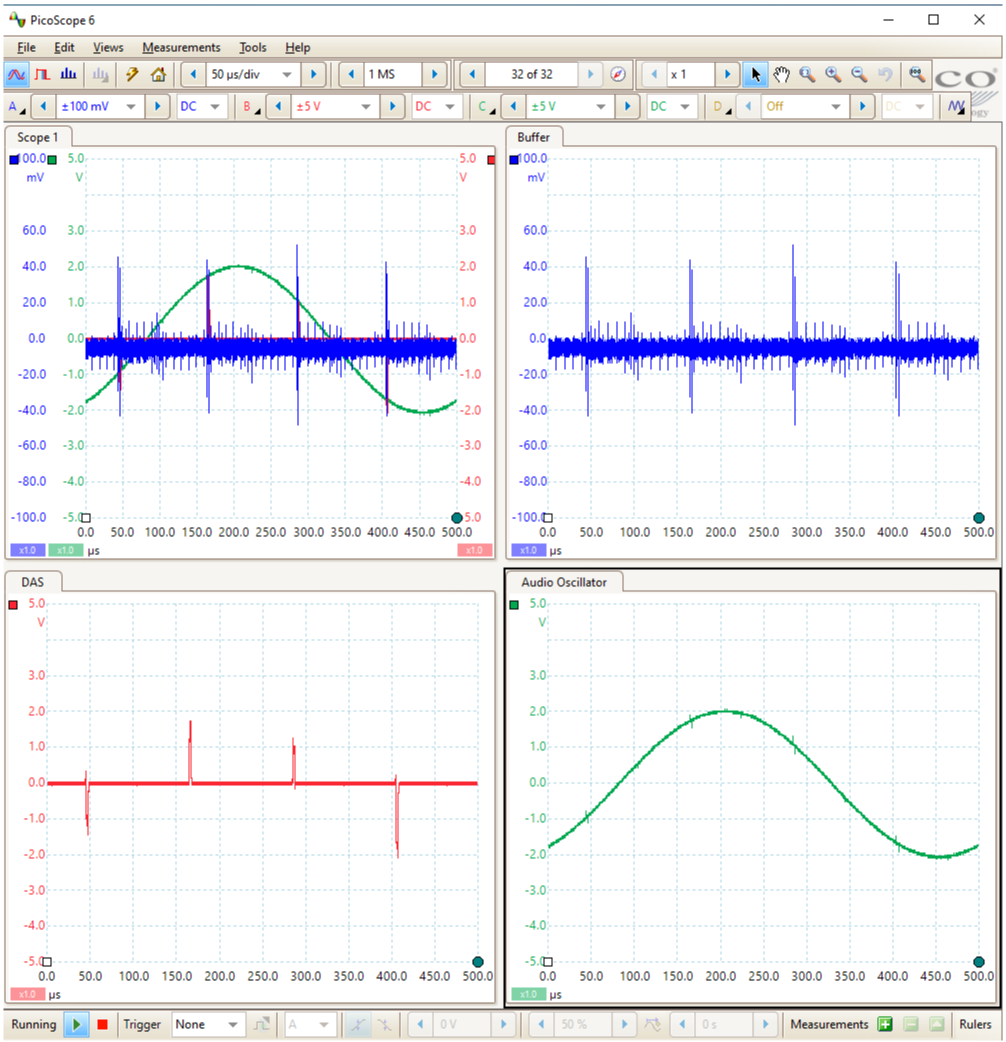

Figure 6: Sampling Theorem DAS, audio oscillator and buffer amplifier signal

Figure 6 shows the Sampling Theorem experiment message signal (audio oscillator, green), its buffer signal (blue), and its DAS signal (red) in the time domain.

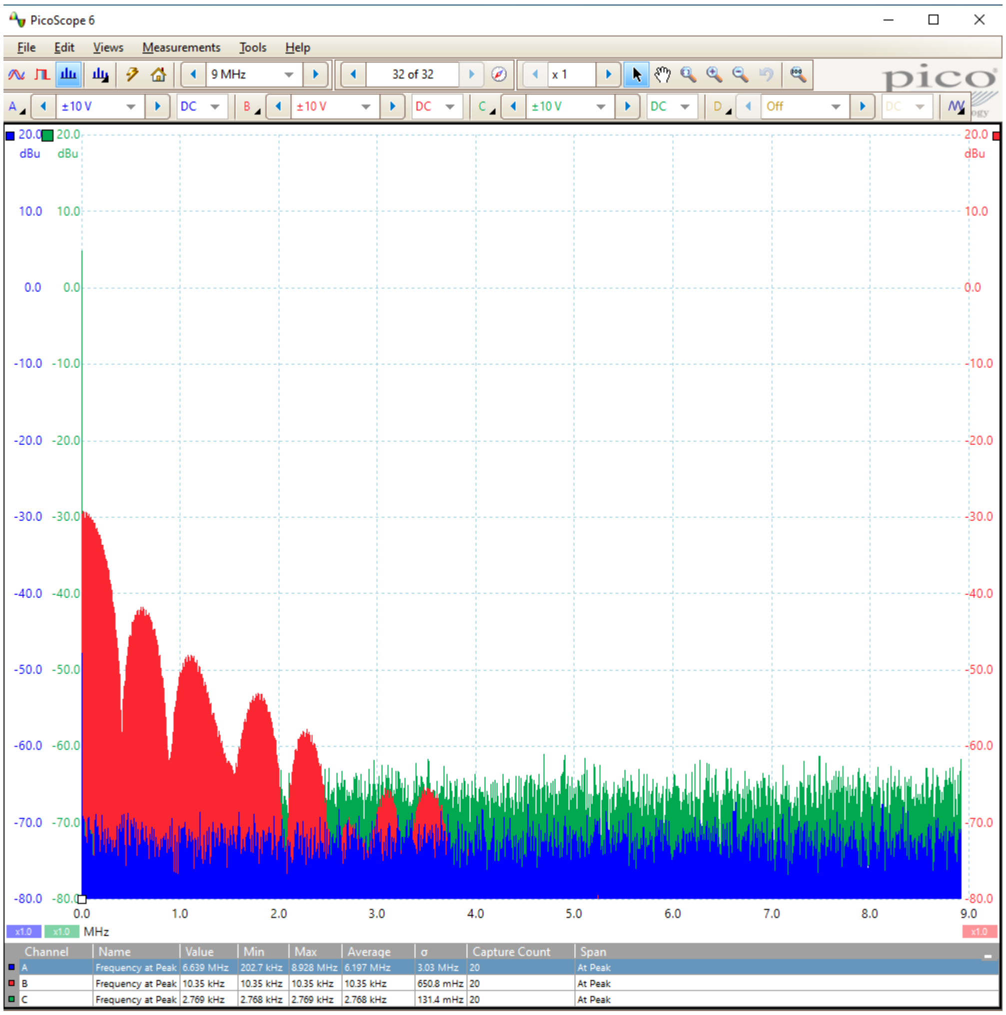

Figure 7: Sampling Theorem DAS, audio oscillator and buffer amplifier frequency response

Figure 7 shows the Sampling Theorem experiment message signal (audio oscillator, green), its buffer signal (blue), and its DAS signal (red) in the frequency domain.

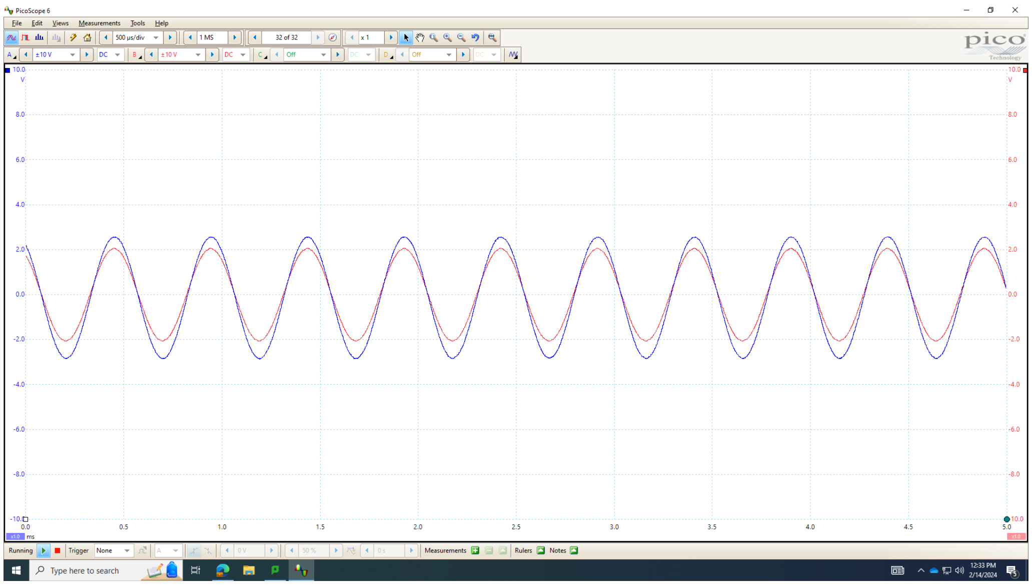

Figure 8: TDM DAS & audio oscillator at 2 kHz

Figure 8 shows the Time Division Multiplexing experiment message signal from the audio oscillator at $2kHz$ (blue) and DAS (red).

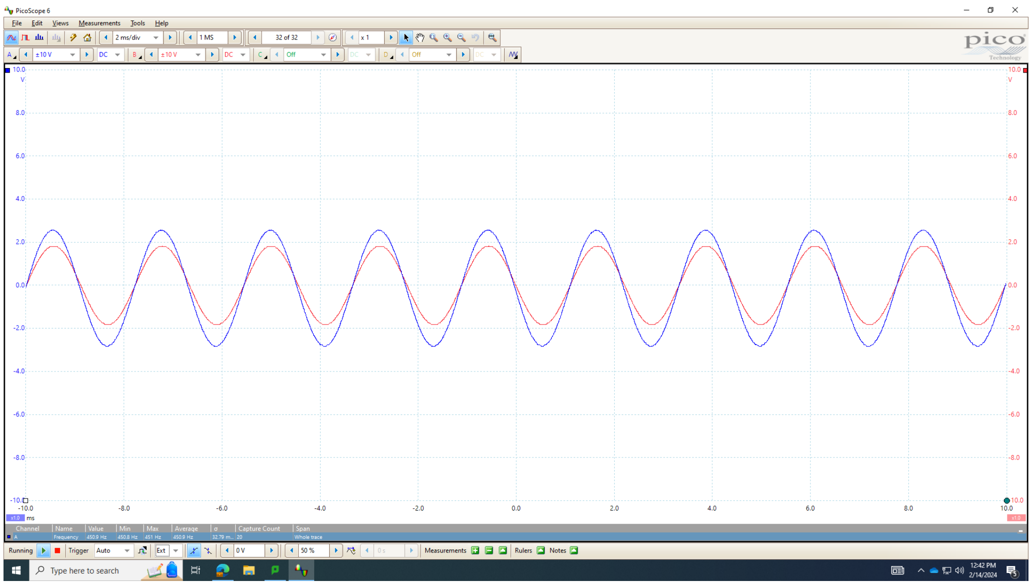

Figure 9: TDM DAS & audio oscillator at 450 Hz

Figure 9 shows the Time Division Multiplexing experiment message signal from the audio oscillator at $450Hz$ (blue) and DAS (red).

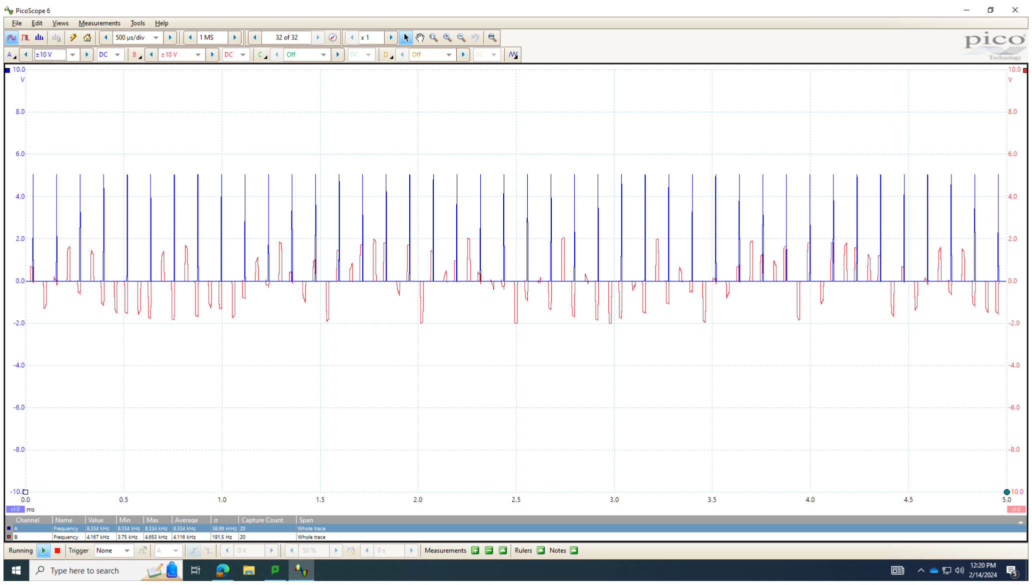

Figure 10: TDM DAS & Twin Pulse Generator

Figure 10 shows the Time Division Multiplexing experiment twin pulse generator signal (blue) and DAS (red).

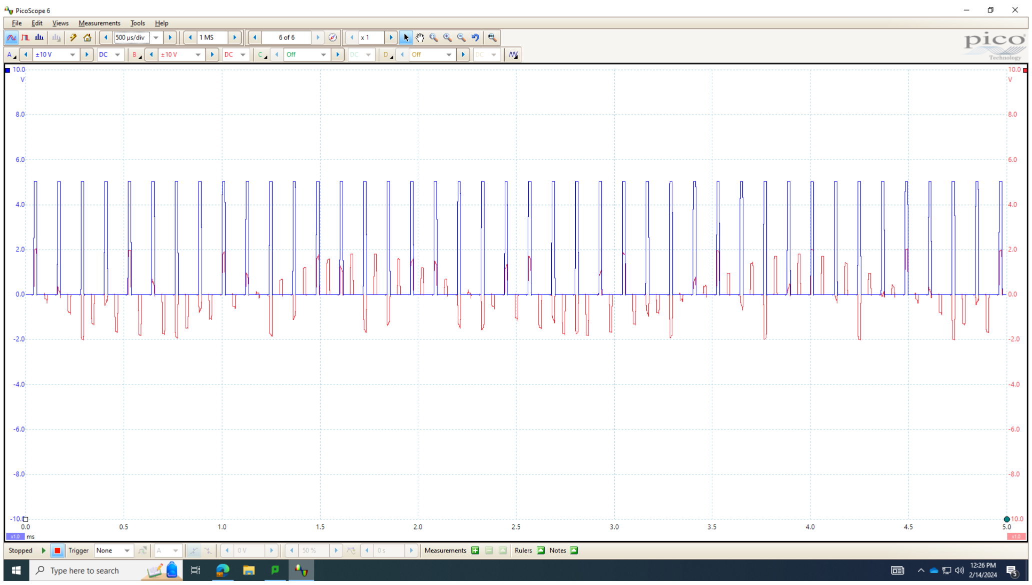

Figure 11: TDM DAS & De multiplexer

Figure 11 shows the Time Division Multiplexing experiment de multiplexer signal (blue) and DAS (red).

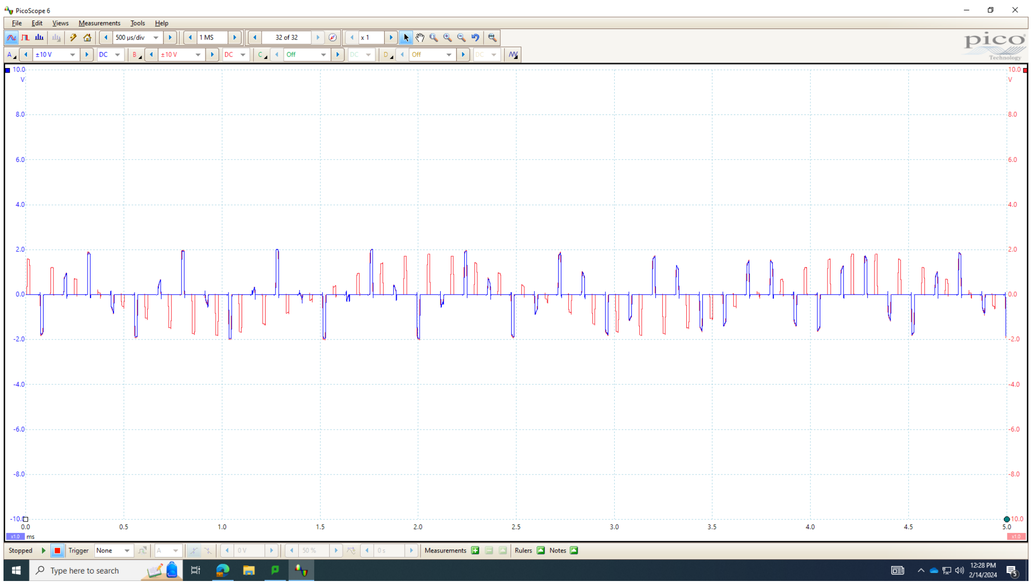

Figure 12: TDM buffer & audio oscillator

Figure 12 shows the Time Division Multiplexing experiment buffer (blue) and audio oscillator (red).

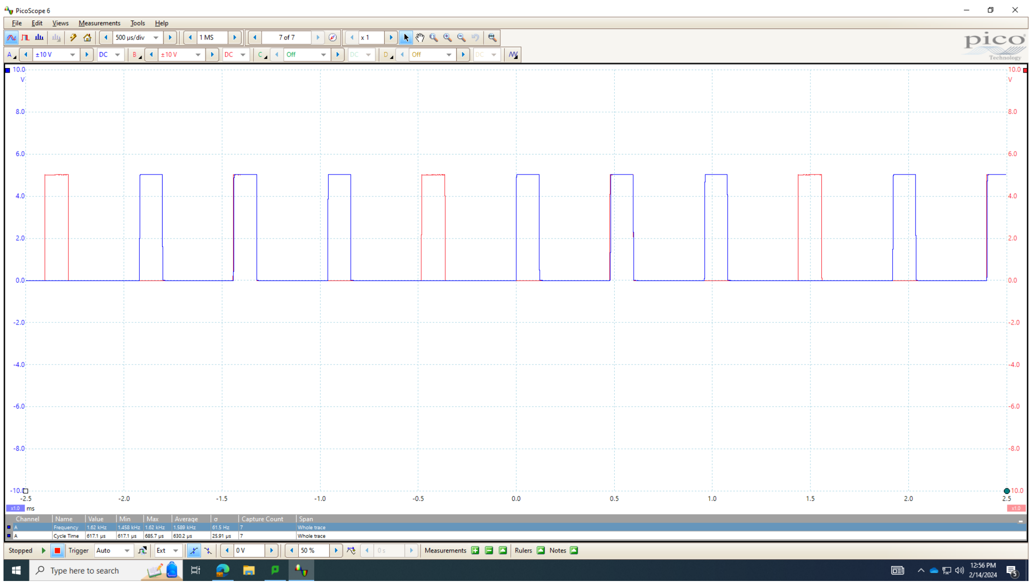

Figure 13: PCM Clock & FS

Figure 13 shows Pulse Code Modulation experiment Clock signal (blue) and FS (red).

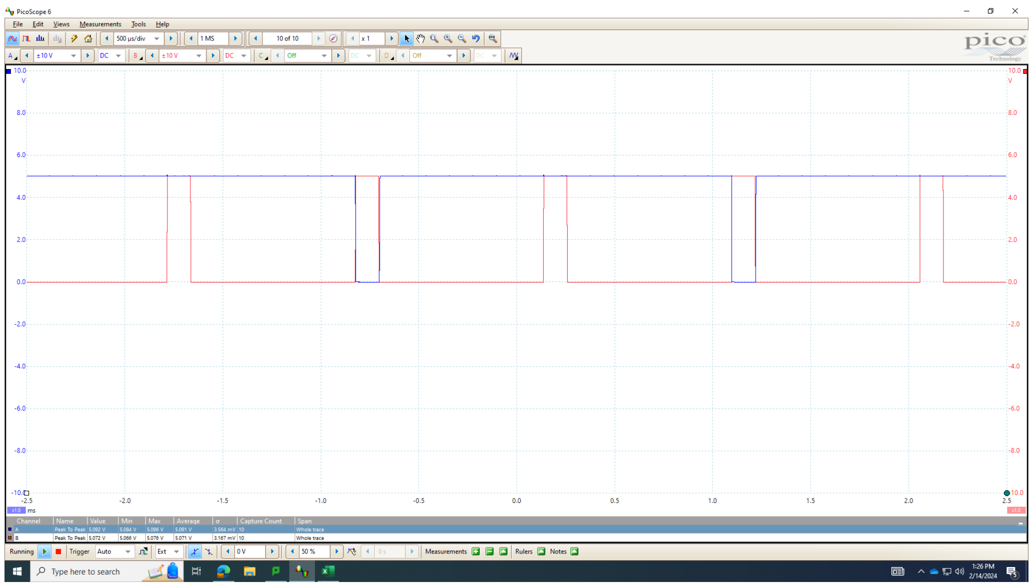

Figure 14: PCM Data & FS

Figure 14 shows Pulse Code Modulation experiment Data signal (blue) and FS (red).

VDC	# Bits	Bits							
-2.558	8	1	0	0	0	0	0	0	0
-1.841	8	1	1	0	0	1	0	0	0
-1.049	6	1	1	0	1	0	0		
0.2302	4	1	1	1	0				
0.7673	8	1	1	1	0	1	1	0	0

Table 1: PCM Binary Words vs VDCs

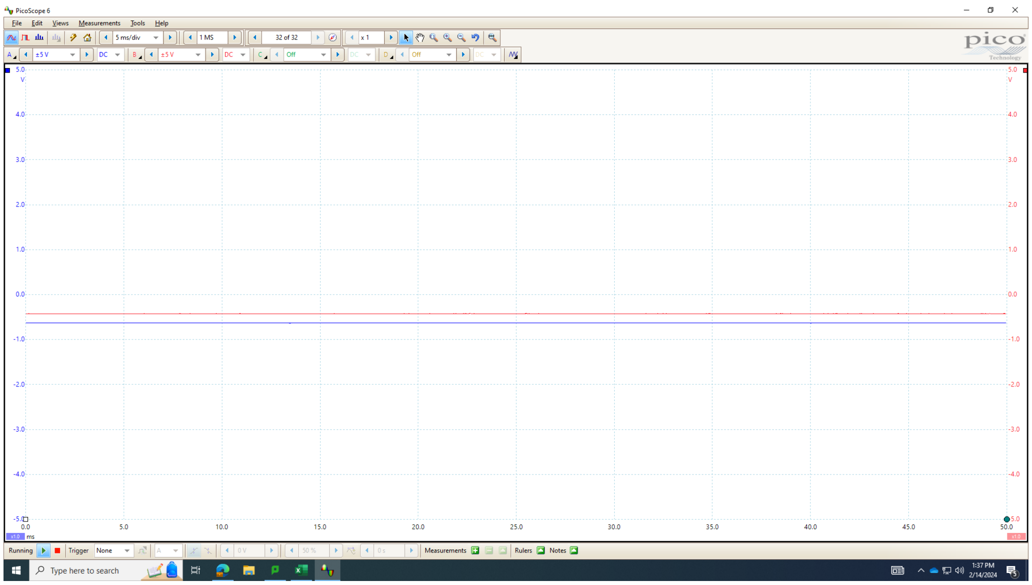

Figure 15: PCM Data & FS 4-bit VDC

Figure 15 shows Pulse Code Modulation experiment Data signal (blue) and FS (red) when we utilize a DC voltage input for 4-bits.

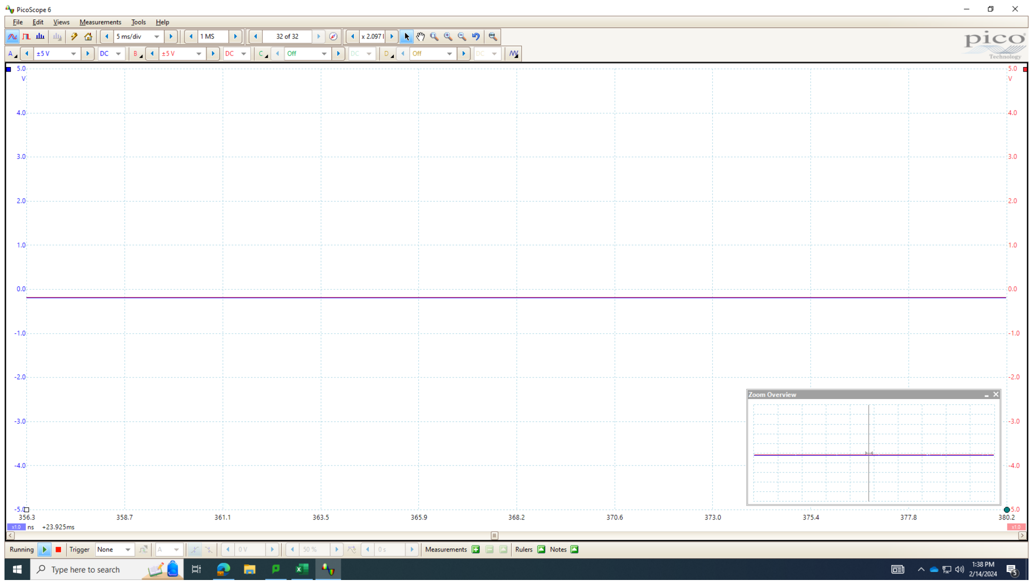

Figure 16: PCM Data & FS 7-bit VDC

Figure 16 shows Pulse Code Modulation experiment Data signal (blue) and FS (red) when we utilize a DC voltage input for 7-bits.

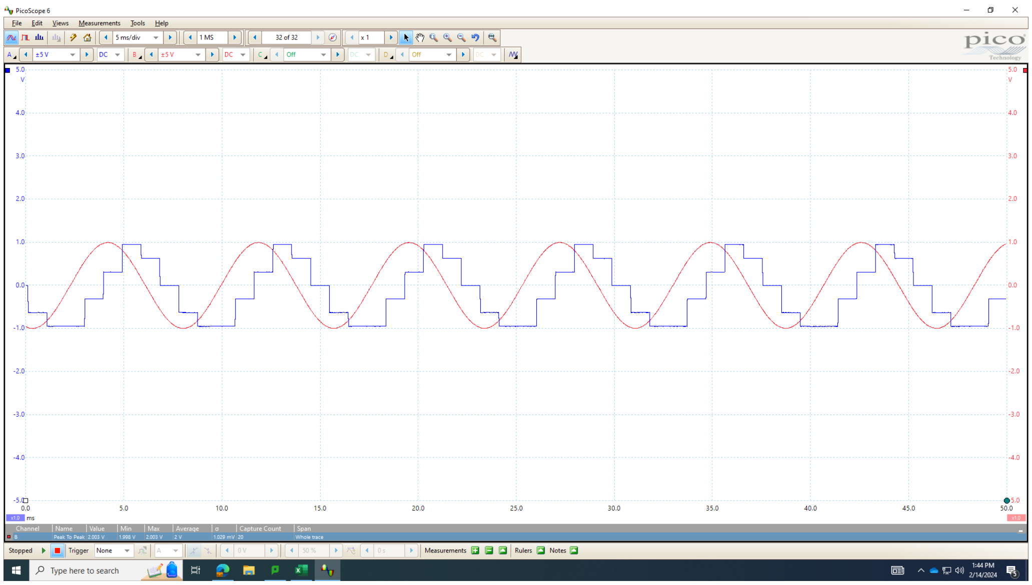

Figure 17: PCM Decoder Output & Encoder Input 4-bit

Figure 17 shows Pulse Code Modulation experiment Decoder Output (blue) and Encoder Input (red) for 4-bits.

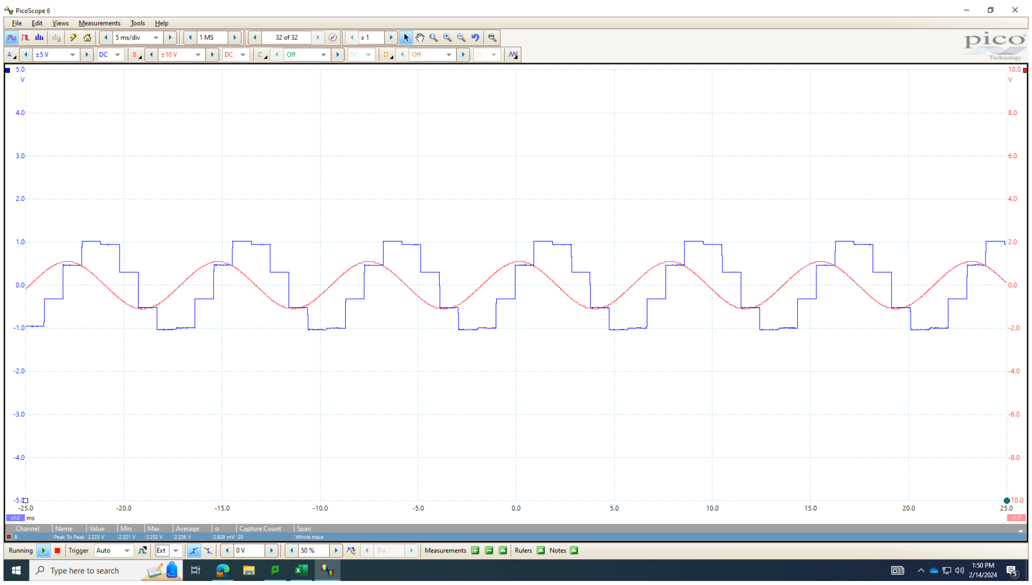

Figure 18: PCM Decoder Output & Encoder Input 7-bit

Figure 18 shows Pulse Code Modulation experiment Decoder Output (blue) and Encoder Input (red) for 7-bits.

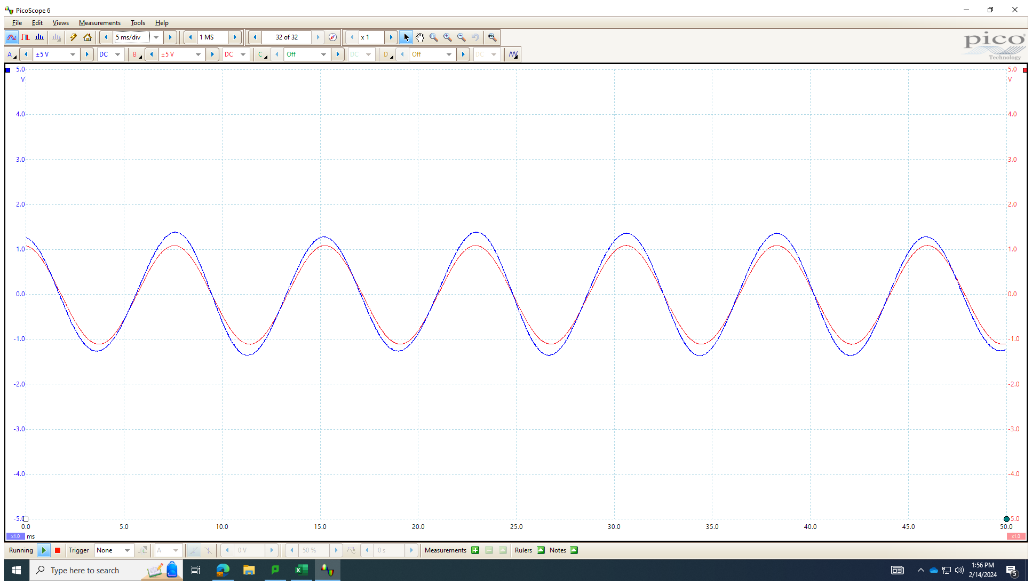

Figure 19: PCM Decoder Output & Demodulated Signal 4-bit

Figure 19 shows Pulse Code Modulation experiment Decoder Output (blue) and Demodulated Signal (red) for 4-bits.

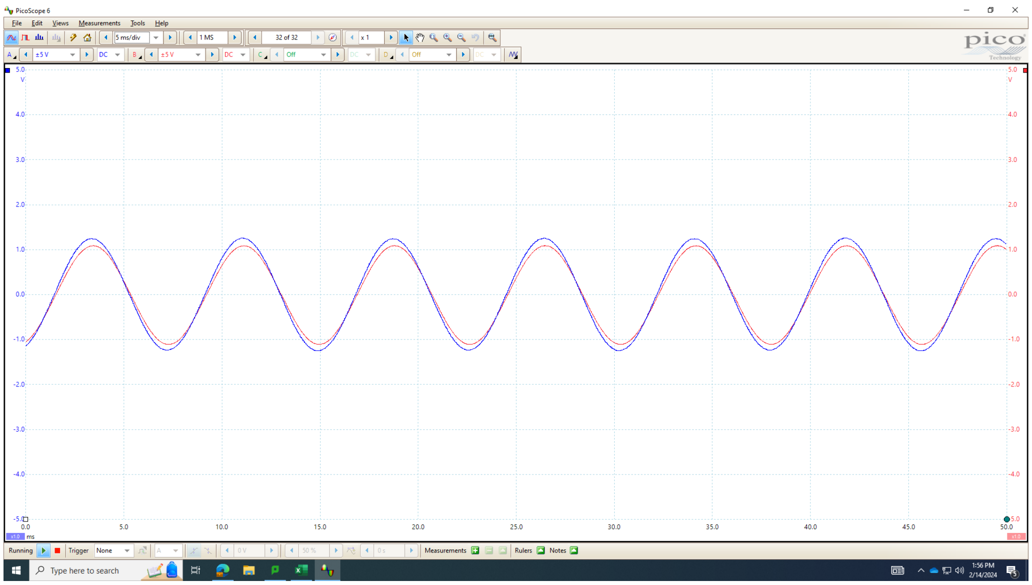

Figure 20: PCM Decoder Output & Demodulated Signal 7-bit

Figure 20 shows Pulse Code Modulation experiment Decoder Output (blue) and Demodulated Signal (red) for 7-bits.

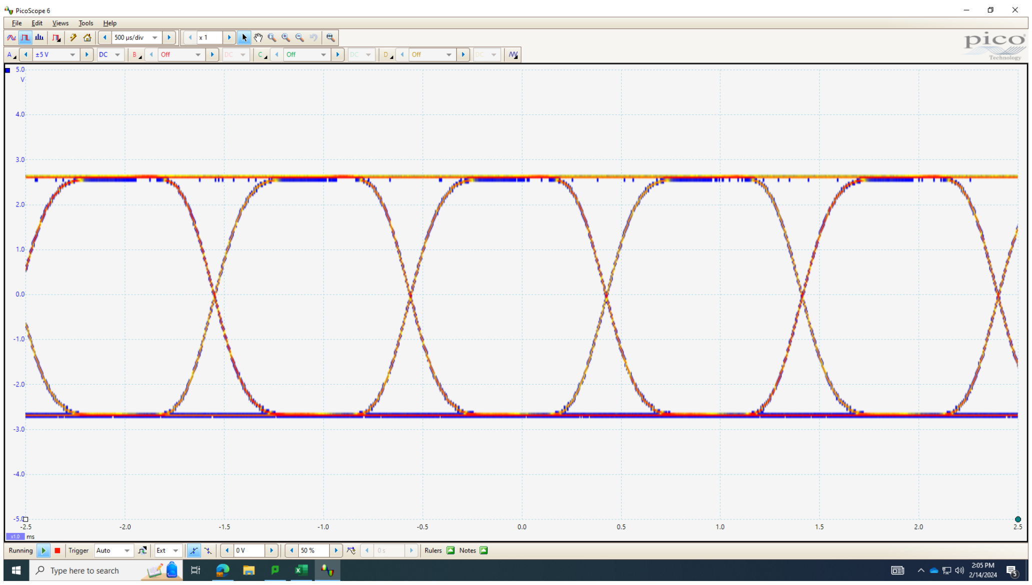

Figure 21: First Eye Diagram

Figure 21 shows the first response to a 1 kHz audio oscillator message signal in persistence mode.

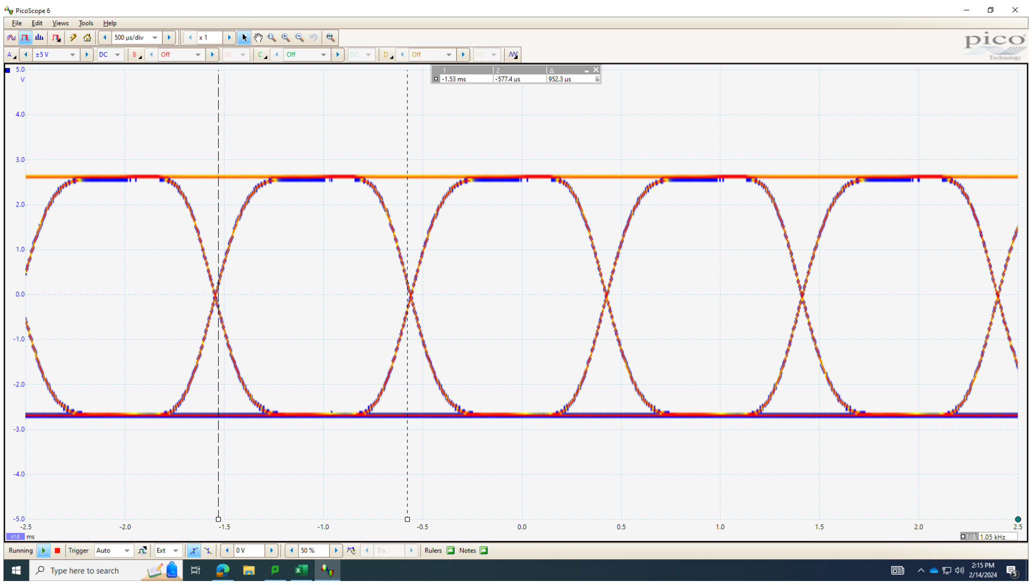

Figure 22: Improved Eye Diagram

Figure 22 shows the improved response to a 1 kHz audio oscillator message signal in persistence mode to achieve the best possible eye-diagram.

5 Conclusion

The goal of the lab was to reproduce the message signal for the Sampling Theorem, combine 2 signals utilizing Time Division Multiplexing, encode and decode a signal utilizing Pulse Code Modulation, and create an Eye Diagram utilizing PicoScope's persistence mode. The Sampling Theorem input signal was recovered without distortion, as well as the Time Division Multiplexing and Pulse Code Modulation signals. The Eye Diagram was improved, achieving a clear vision of the output signal through time.