ELEC 2120-005
Lab 4 – Special Signals TIMS
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Introduction
The purpose of this experiment was to study the degradation and distortion of digital signals due to inertia of a physical system. This was done by studying the system response to step and impulse input signals. Additionally, the system distortion of a sinusoid input and cutoff was analyzed, ultimately culminating with building a digital detector.

Part A
A.1
The first part of Part A analyzed the digital signal produced by the AUDIO OSCILLATOR module. The TTL output from the AUDIO OSCILLATOR was connected to the FREQUENCY COUNTER which displayed the current frequency of the TTL signal. The TTL signal was also connected to Scope ChA and displayed on the PicoScope. The frequency of the TTL signal was then set to 1kHz. After this, the window settings were adjusted, and single shot triggering was used to get a quality picture of digital signal. Finally, the duration of the pulse width and one clock cycle were measured. These values are listed below in Table 1.

Table 1. Pulse Width and Clock Cycle of 1kHz TTL Signal

Pulse Width(ms)	Clock Cycle(ms)
0.9854	1.0068

A.2
The second part of Part A studied the pseudorandom sequences output by the SEQUENCE GENERATOR. The TTL signal was connected to the clock input for the sequence generator and frequency counter, while the SEQUENCE GENERATOR output, X, was connected to ChB. The window was fixed on the scope and the minimum interval of the digital signal output, X, was measured. This value is shown below along with the scope window in Figure 1.

Minimum Interval = 0.990ms

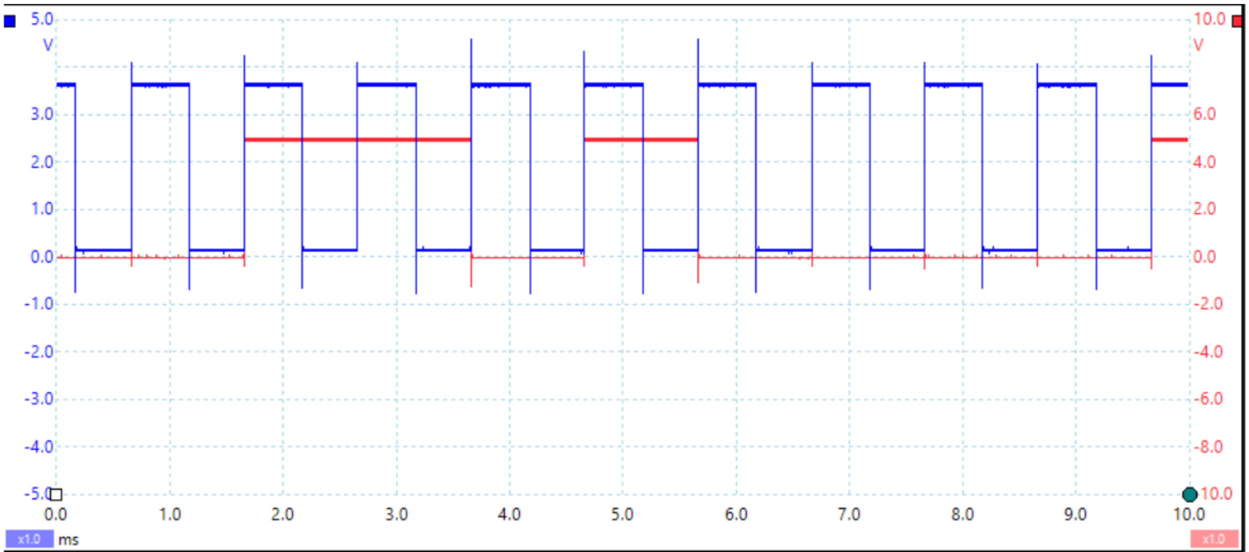

Figure 1. Digital Signals for A.2

As seen in Figure 1, the minimum interval of X is about one full clock cycle. The resulting binary code starting at the first rising clock edge is 0110100001.

A.3

Part A.3 examined time limitations in system response by using Baseband Low Pass filters to simulate delay in the system. The scope channels in this part measure the digital signal just before and just after the signal passes through the filter. The TTL signal was again connected the the SEQUENCE GENERATOR's clock input as well as the frequency counter. The SEQUENCE GENERATOR output was connected to the BASEBAND CHANNEL FILTERS input. Scope ChA was also connected to this signal. Scope ChB was connected to the output. The scope window was set to show the digital signal before and then after passing through the filter. The delay, rise, and fall times for each filter were measured at 1kHz. The results are shown below in Table 2.

Table 2. Delay and Transition Times for Sequence Data

	BBLPF2	BBLPF3	BBLPF4
	1 kHz	1 kHz	1 kHz
Delay(ms)	0.2350	0.2491	0.8310
Rise time (ms)	0.2410	0.3599	0.2130
Fall time(ms)	0.2385	0.3440	0.2010

After finding all transition times, BBLPF 4 was selected, and the frequency was increased to 2kHz. With the frequency increase, it became more difficult to discern which responses was due to which clock impulse. The frequency was increased until it was no longer discernable which output was due to a certain input. This occurred at 5.93 kHz and the scope window of this signal is shown below in Figure 2.

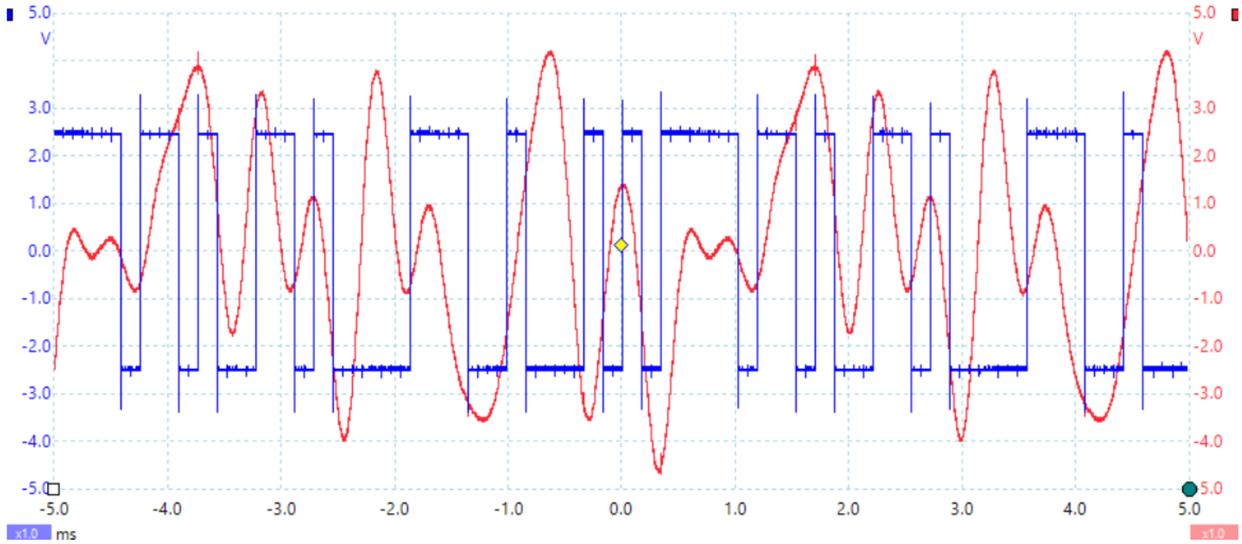

Figure 2. Scope Output at 5.93kHz

Part B

Part B analyzed the system response to a step function input to study system delay. The step function was simulated using a long duration pulse. To setup, the TTL signal was connected to the BASEBAND CHANNEL FILTERS input and frequency counter. Scope ChA was also connected to the channel input. Scope ChB was connected to the channel output. BBLPF2 was selected, and the frequency was lowered to 0.30kHz. The scope window was fixed and zoomed to capture a single pulse which mimicked a step function, allowing the initial part of the step response to be analyzed. The delay and rise times for the step response were measured and are shown in Table 3.

Table 3. Step Response for Various Filter Systems (low f setting)

	BBLPF2	BBLPF3	BBLPF4
Delay time (ms)	0.859	0.241	0.828
Rise time (ms)	0.233	0.308	0.172

Part C

Part C looked at system response to the impulse function. In lab, the impulse response was modeled with a short duration rectangular pulse. However, while the ideal impulse function has an infinite height at time zero, the actual height of impulse used in lab is system limited. This means that the impulse response observed will have the same shape, but the voltage of the response will be compressed. To start, the TTL signal was connected to the SEQUENCE GENERATOR clock and the frequency counter. Next, the SEQUENCE GENERATOR SYNC output was connected to Scope ChA. The SYNC output served as the rectangular pulse. The scope window was set, and the frequency was set to 0.5kHz. The pulse width at 0.5kHz was then measured. This process was repeated up 10kHz, the results of which are shown in Table 4. A plot of Table 4 is shown in Figure 3.

Table 4. Pulse Width at Varying Frequency

Frequency (Hz)	Pulse Width (us)
500	2013
1000	997
1500	665
2000	501.6
3000	332
4000	248.2
6000	164
8000	126.1
10000	102.6

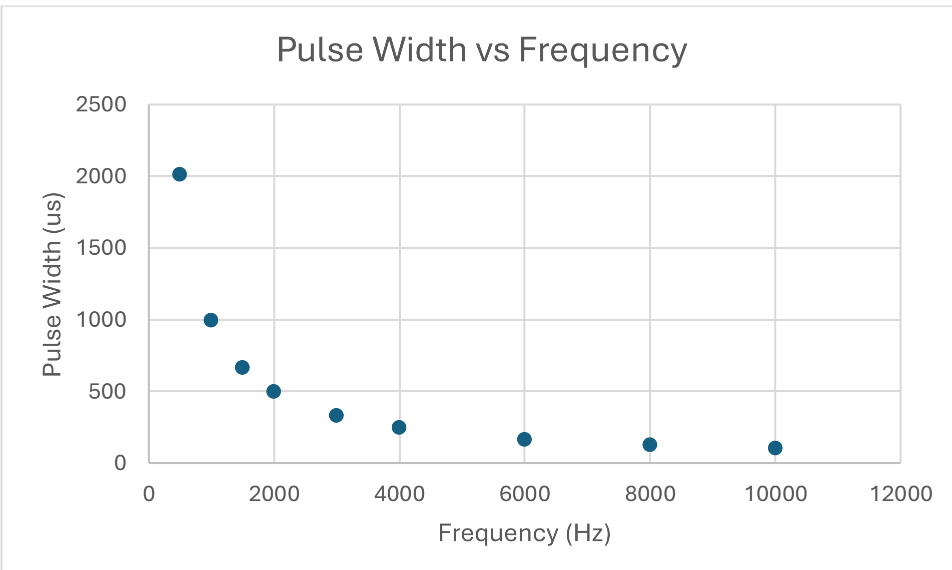

Figure 3. Pulse Width vs Frequency

Next, the SEQUENCE GENERATOR Sync output was connected to BASEBAND CHANNEL FILTERS input with the output connected to Scope ChB. The frequency was slowly increased from 300 to 1000 Hz. At around 1000 Hz, the flat top in the pulse response disappeared and the response resembled the peak of a sinusoid. Next, frequency was slowly increased from 2000 to 10,000 Hz. At a certain frequency, the response stays constant. This is the impulse response. Also, as frequency increased, amplitude decreased. This is because the height of the pulse is limited and not continuing to increase as pulse width decreases, which is what would happen with an ideal impulse. Instead, the upper limit voltage is being applied over a shorter pulse width. This results in less total voltage supplied to system and therefore a smaller amplitude on the output signal.

Part D

D.1

Part D focused on sinusoidal signals. To get the sinusoid input, the AUDIO OSCILLATOR sin(ωt) output was connected to the BUFFER AMPLIFIER input A. The amplifier is used to control the sinusoid amplitude. The amplifier output was connected to the BASEBAND CHANNEL FILTERS input, frequency counter, and scope ChA. Frequency was set to 300 Hz. BASEBAND CHANNEL FILTERS output was connected to scope ChB. The amplifier gain was adjusted so the input signal has a 6 V peak-to-peak voltage. The peak-to-peak voltage for the output signal was recorded at various frequencies and across all filters. The results are shown in Table 5.

Table 5. Vpp of BBLPF2-4 vs Frequency

Frequency (Hz)	BBLPF2 Vpp	BBLPF3 Vpp	BBLPF4 Vpp
300	6.314	5.65	7.022
1000	6.088	5.13	6.174
2000	4.362	4.59	5.806
3000	4.21	4.29	4.954
4000	3.846	4.06	4.042
5000	2.728	3.2	3.556

As frequency increased, the signal quality deteriorated significantly, with the signal getting very noisy.

D.2

Next, the CLIPPER BIPOLAR OUTPUT on the UTILITIES module was used to convert a sine wave to a square wave. The AUDIO OSCILLATOR sin(ωt) output was connected to the amplifier input. The amplifier's analog output was connected to the frequency counter, UTILITIES module ANALOG SIGNAL INPUT, and Scope ChA. The CLIPPER output was connected to Scope ChB. Initially, the input signal Vpp was set to 6 V. At this point, the output appeared square like. After lowering the Vpp to 350mV, the output looked like a sine wave. After increasing the input Vpp to 20 V, the output appeared as a square wave.

Part E

Part E looks at signal degradation and recovery of the original signal using a digital detector. The sin(ωt) signal was input to the SEQUENCE GENERATOR and frequency counter. The SEQUENCE GENERATOR audio output was connected to the BASEBAND CHANNELS FILTER input and scope ChA. The filter output was connected to the UTILITIES module ANALOG SIGNAL INPUT. Scope ChB was connected to CLIPPER. Table 6 shows comparisons between the input and output digital signals at various frequencies.

Table 6. Comparing Recovered Digital Signal to Original Digital Signal

f (kHz)	Input Digital Signal	Output Digital Signal
4	Inverted, Delayed	Inverted, Delayed
5	Delayed	Delayed
7	Delayed	Delayed

Conclusion

This lab was enjoyable by giving an opportunity to examine different manipulations of signals. It was difficult to determine what part of the clock cycle corresponded to what part of the response, making Part E difficult. No major improvements to the procedure.