Precise onset Vibration Detection Testing & Analysis Report

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Activity Report

1 Verification Testing

For our verification testing, we used a vibrating cellphone set to vibrate every 5 seconds. We then observed the digital high pulse generated by our systems at the onset of vibration and quantitatively determined whether this pulse was instantaneous. Each of our systems could seemingly transition from low to high instantaneously upon the onset of vibration (less than 5-millisecond).

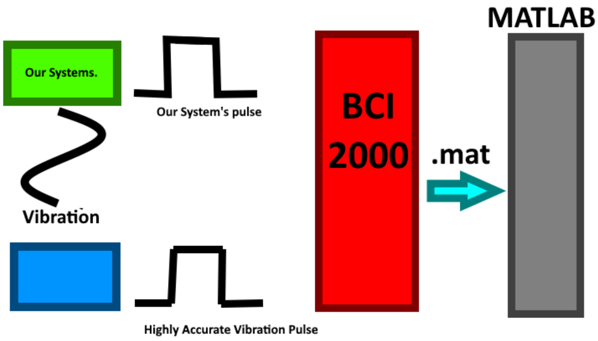

Figure 1. Experiment Design

2 Validation Testing

The procedures for our validation testing involved measuring the latency and jitter across various designs. We conducted these experiments using a high-accuracy vibration device (TTL input) capable of vibrating and sending a digital pulse with one-millisecond precision. We then compared this pulse to those generated by each of our designs upon detecting a vibration. Both pulses were fed into a computer, where they were recorded using BCI2000.
BCI2000 is a general-purpose software system that we are utilizing in our project to simultaneously capture signals generated from our systems and the vibration unit. This allows us to both visualize the data and precisely calculate latency and jitter.
Subsequently, we export the data into MATLAB to conduct signal processing and compute the latency and jitter. (Figure 1)

In this experiment, the changes are our system itself, our system inputs and outputs remain constant, which ensures we only have one independent variable.

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3 Data Analysis

We conducted a comparative analysis of two distinct signal types: analog and digital. Through our experimentation, it was noted that both signal types have similar characteristics, but analog signals need a more elaborate processing methodology than digital signals.

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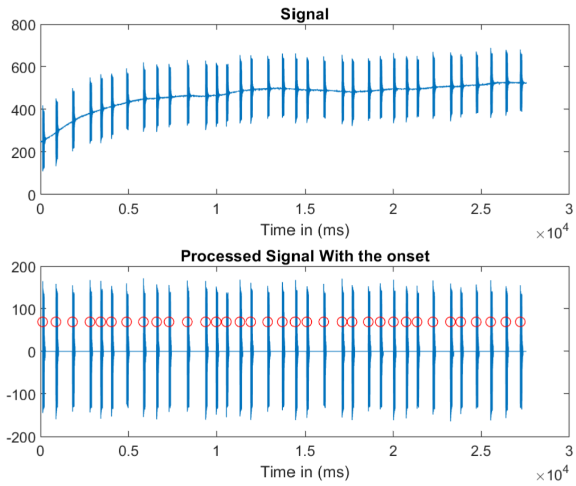

Figure 2. Before and after the signal processing

For the analog signal data analysis, we imported both the data we calculated from our system and the TTL input into Matlab. Then we processed the signal by applying a high pass filter, detrend, and baseline mean removal. This processing approach effectively yielded a binary signal representation, where periods of vibration were denoted by ones and non-vibrating periods by zeros, with a zero slope. After processing the signal, we used the threshold method to determine the signal latency and the jitter. The threshold method proved to be both reusable and robust, offering consistent results across different sensors, and accurately outputting the latency and jitter within the analog signal framework. (Figure 2)

For the digital signal data analysis, we adapted the Arduino programming to facilitate the output of a digital signal. This modification allowed us to precisely identify the onset of signals by comparing the amplitude of the TTL input with our detected signal. then we calculate the latency and the jitter. What distinguishes digital signals is that they are pulse signals, unlike analog signals, they do not require extensive signal processing.

4 Results & Discussion

The tables show the results of multiple experiments with the piezo sensor using an analog and digital signal:

Piezo Sensor Results (Analog Signal)		
Position of the sensor	Latency (ms)	Jitter (ms)
Piezo on top	4.11	0.93
Piezo under	4.43	1.34
Piezo on the side	4.34	1.83
Piezo taped	4.67	1.87

Piezo Sensor Results (Digital Signal)		
Position of the sensor	Latency (ms)	Jitter (ms)
Piezo on top	4.44	1.57
Piezo under	4.47	1.49
Piezo on the side	4.42	1.82

From the results, digital signals are more consistent than analog signals primarily due to their fundamental nature and how they represent information. Digital signals represent data in binary form (0s and 1s), making them less susceptible to noise and distortion compared to analog signals, which vary continuously. Furthermore, in digital signals, we set a threshold in the microcontroller; a signal is transmitted only when vibrations surpass this predetermined threshold. Which makes them a preferred choice for precise and accurate data representation.

5 Future Work

Our future work would be to try more systems. Examples include;
-Using lidar
-A laser
-A more sophisticated audio solution.
- Using more accurate driver board
- Future work could also include investigating the role that pressure has on vibration sensors. This includes a load cell and a display device to give feedback on how much weight is being seen by the load cell.

6 Conclusions

In conclusion, our systems show the ability to instantaneously detect vibrations with less than a 5-millisecond response. Validation testing shows the precision of our system, by using high-accuracy devices and data analysis. Also, highlights the advantages of digital signals over analog in terms of consistency and noise resistance. For future work, we aim to explore more sensor technologies, including radar and advanced audio solutions.