



SHADOWSENSE PERFORMANCE
REPORT: LATENCY

1.0 Objective

The purpose of this experiment is to measure and evaluate the latency between a touch event and the USB output of the ShadowSense frame. Various positions inside the active touch area will be tested to further understand the distribution of latency across the frame as well as to calculate an average latency for the entire frame.

1.1 Equipment

The equipment used during the entire test:

- Baanto ShadowSense touch frame with firmware version 7.41
- Baanto Dashboard software
- Piezo Buzzer Element (35 mm diameter)
- Four Channel Tektronix Oscilloscope
- E550 Lenovo ThinkPad laptop

1.2 Setup

The Baanto ShadowSense frame was assembled and connected to the PC through a USB connection and powered with a 12V power supply. Dashboard was launched to ensure that the frame being tested was operating properly. The configuration parameters in Dashboard were first reset to the default settings. The LED views were examined next to confirm there was no abnormal behavior with the system. This was followed by some basic drawing tests to confirm the system performance.

Channel 1 of the oscilloscope was then connected to the piezo buzzer element, channel 2 was connected to a debug pin on the frame to capture USB interrupts sent to the PC, and channel 3 was connected to a debug pin on the frame to capture the start of each LED polling cycle. This setup is shown in *Figure 1*.

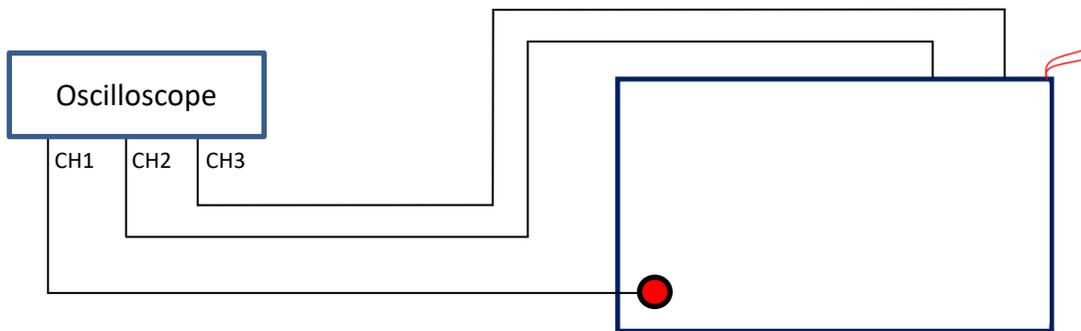


Figure 1: Test setup

The piezo buzzer element was then placed in the active touch area with its leads running underneath the frame to ensure the wires did not trigger a touch event while the test was being performed. To further ensure no unexpected touches occurred due to the wires from the buzzer, the frame was propped up using small cut outs so there was no chance of interference with the optical plane.

2.0 Method

Once the frame was connected and the performance was validated the latency testing could begin. The time between when a touch event occurs and when the ShadowSense frame sends the USB packet to the host PC is the latency being investigated. A piezo buzzer element was used to sense when the touch event had occurred because with piezoelectric materials, when a force is applied to them, the charge that can be stored in the material varies proportionally to the force being applied. The force being applied in this scenario is the touch down of a finger or other touch object. This change can easily be observed and measured using the oscilloscope. The resulting touch information is sent to the PC through the USB HID interface connection which can also be seen and measured with the oscilloscope. The desired latency value under investigation is the time difference between these two signals.

The piezo buzzer element was placed in eight separate locations during testing. The test points included some that were very close to the edge of the frame and others that were closer to the center of the touch frame. The test locations were the four corners of the frame, starting with the corner where the USB and power connections are made (see *Figure 2*) and points about 8 inches towards the center of the frame. In each of the test locations, 5 tests were ran, with the latency between the touch event and the USB packet being sent, measured and recorded each time. This allowed for investigation regarding the distribution of latency across the entire frame.

It was expected that the latency would be the worst in test location 1 and would improve at the succeeding test locations. This is mainly due to the architecture of the ShadowSense frame as well as how it operates. The frame utilizes IR LEDs and sensors to detect touch. There are LEDs located along both sides as well as the bottom and are positioned to face inward. The ShadowSense frame strobes each LED individually in sequence starting in the corner where the first test position is located. Since test location 1 is at the beginning of the strobing sequence, it must wait a minimum of an entire cycle before the data is processed.



Figure 2: ShadowSense frame with the eight test positions labeled

When the latency testing started it was discovered that if the touch probe, which was initially a finger, moved too slowly it resulted in much more error and latency being introduced into the systems because the IR plane would be interrupted and the touch event would be detected before the piezo buzzer was touched. Once this was discovered the method of applying a touch for the testing had to be modified to accommodate for this added latency. The solution that was decided on was to use a ball of butyl and drop it from a height of approximately 1 m in an effort to eliminate this error. Dropping the ball of butyl from this height resulted in the butyl having a velocity when breaking the optical plane of about 9.81 m/s. This velocity was quick enough that the time difference between when the butyl broke the optical plane and when it hit the piezoelectric sensor was negligible.

2.1 Results

The results of the testing can be seen in *Table 1* at the end of this document. It is evident from the data that the latency can vary even when touch events occur in the same location. The latency also varies as the touch location moves to different sections around the touch area. ShadowSense touch technology works by polling the LEDs sequentially and collecting the resulting touch data. The onboard microcontroller then processes the data and sends it to the PC via a USB HID interface. Due to the process of collecting the touch data, the latency depends on the polling period of the particular frame being investigated. The polling period is defined as the time between successive USB packets being sent or the time between the same LED being strobed twice. For the most accurate polling period it is best to measure the time for multiple cycles and find the average. As can be seen in the figure below, there are 5 cycles that take 54.3 ms to complete. This results in a polling period of approximately 10.86 ms.

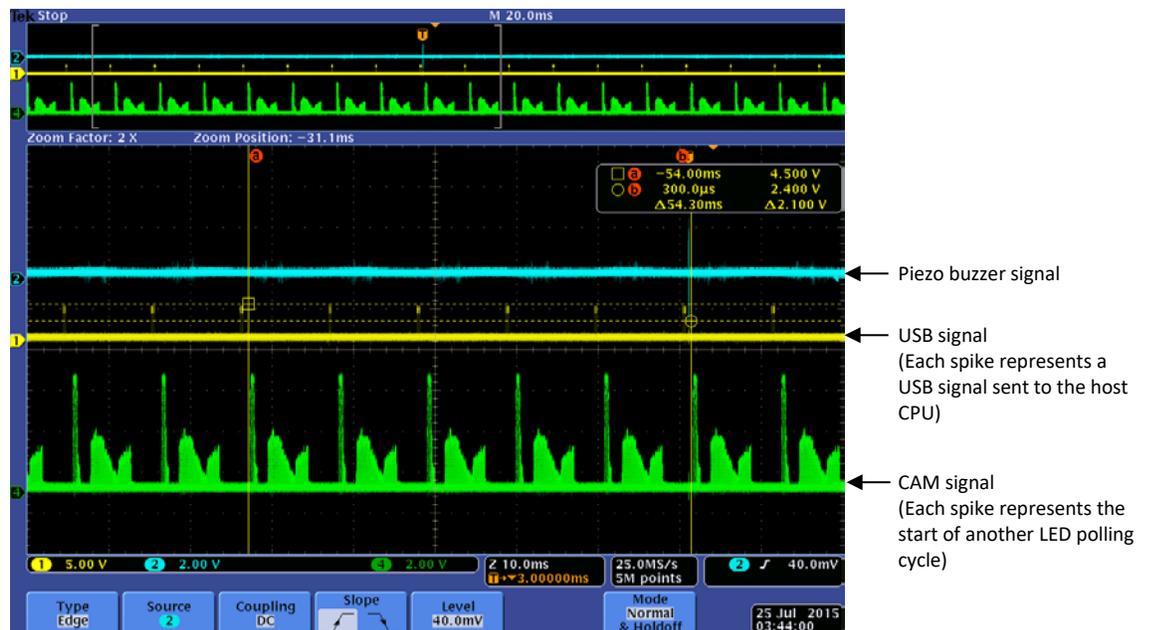


Figure 3: Frame time for SDW656

The minimum system latency occurs when the touch event is registered and the master controller sends the USB packet to the PC at the end of a single polling period. This is shown in *Figure 4*. Even with this best case scenario the latency can vary because the touch event can be triggered at any time during the polling period. If a touch event occurs near the beginning of the polling period and is not recognized, this results in the touch event being registered in the following polling period. This is shown in *Figure 5*. This is the worst latency that can be experienced using ShadowSense touch technology. To accommodate for the variation during testing, the average was calculated for each position in addition to an average for the frame as a whole.

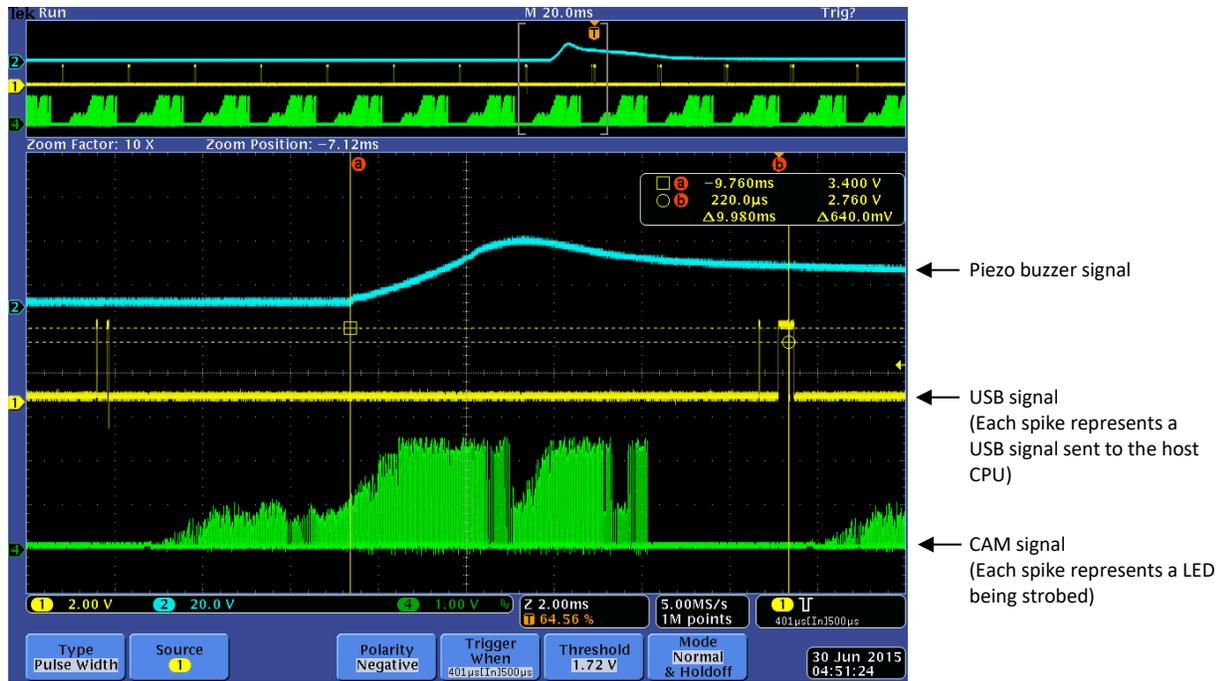


Figure 4: Best case scenario where the touch event (blue signal) is recognized and processed in the same frame (green signal) the USB packet with the touch data is sent (yellow signal)

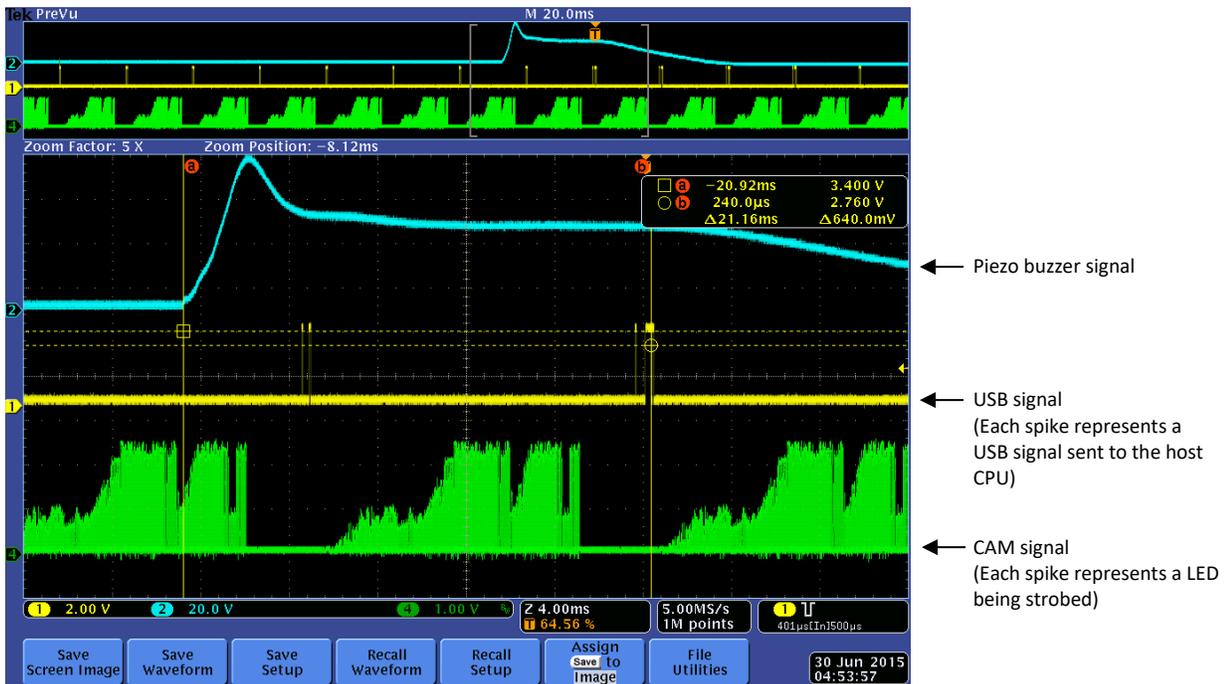


Figure 5: Worst case scenario where the touch event (blue signal) occurs in one frame (green signal) but the data is not processed and sent (yellow signal) until the following frame

As can be seen in *Table 1* below, the fastest response time recorded during the testing process was 3.5 ms and the slowest response was 16.8 ms. This results in a median of 10.15 ms, meaning the user can expect the system latency to be approximately 10.15 ms on average.

Table 1: SDW656 latency results (in milliseconds)

Trial	1	1a	2	2a	3	3a	4	4a
1	13.58	16.48	14.10	7.46	9.42	12.08	5.06	11.40
2	16.80	6.44	17.28	14.54	12.22	7.96	7.40	6.18
3	16.38	12.94	11.40	14.10	10.54	14.64	3.50	11.98
4	10.36	16.64	15.46	14.22	9.86	9.70	6.42	12.78
5	9.20	7.64	15.08	12.02	12.38	7.68	7.00	3.74

The ShadowSense touch frame’s latency is directly proportional to the size of the frame. As shown in *Table 2* below, the latency increases slightly as the frame size increases. The latency value being presented represents the time between a touch event occurring and when the resulting touch data is sent to the host PC via USB. The touch technology is not the only source of latency in a touch solution. There will be additional latency from the time it takes the host PC to process the USB interrupt. The display will also contribute to the system latency as a result of certain functions such as scaling, de-interlacing, scan rate conversion and motion compensation. It is important to be aware of these additional sources of latency when comparing various solutions with each other.

Table 2: All other SKU sizes with average latency

SKU	Median Latency (ms)
SDW319	6.02
SDW403	7.06
SDW424	7.28
SDW464	7.81
SDW486	8.04
SDW487	8.09
SDW550	8.87
SDW565	9.05
SDW656	10.15
SDW713	11.01
SDW759	11.41
SDW813	12.10
SDW873	12.77
SDW917	13.38
SDW989	14.27

2.2 Reporting Latency

Once a new touch has been detected, the ShadowSense touch frame is able to track the changes to the touch with a much lower latency. In order to confirm this, an off the shelf USB data packet analyzer was used to measure the frequency of touch packets being sent to the host.

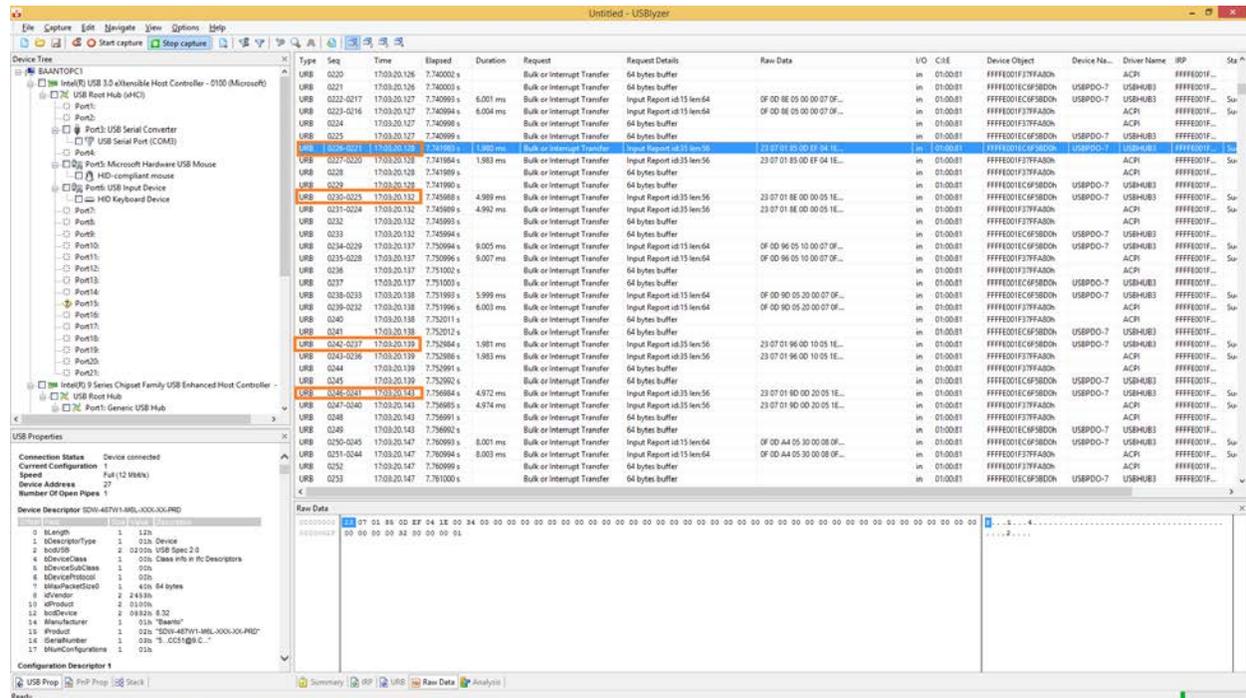


Figure 6: USB Analyzer Output Showing Frequency of Touch Packets (highlighted in orange)

As it can be seen from Figure 6, the touch packets are transmitted roughly every 5 ms. The slight variance can be attributed to latency of the OS and the USBlyzer application itself.

3.0 Conclusion

The Baanto ShadowSense touch frame's latency will vary depending on the size of the screen and the location of the touch. Latency is directly proportional to the size of the frame, and increases slightly as the frame size increases. The latency also decreases with a touch point that has moved from an initial location versus the very first time it is detected on the screen.

It is also worth noting that despite the fast response times achieved with ShadowSense, there are many other factors that will affect the overall performance of the system. This makes the selection of the computer and display just as important as the touch technology being used.