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INTELLIGENT OPTO SENSOR

Number 33.2 Appendix

DESIGNER'S NOTEBOOK

Signal, Noise, Crosstalk - TCS3771 Appendix

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Overview

TAOS proximity sensors provide the ability for measuring "relative" distance to an object. While the TCS3771 provides color sensing in addition to proximity, the color sensor allows this device to have higher sensitivity and the lower noise operation compared with the TSL2771. Many applications similar to the TSL2771 can be implemented with the TCS3771.

This appendix to DN33: Signal, Noise, Crosstalk and TAOS Proximity Sensors will discuss how to get the maximum performance from the TCS3771. It is assumed that the reader is familiar with the TCS3771 data sheet and DN33.

Noise and the TCS3771

Recall from DN33 the formular for Signal + Noise:

Signal+Noise ~ Gain * (PPULSE * ((PDRIVE *(CC+ SR / (D * D) + BR) + NOISE * sqrt (PPULSE))

The first step in the process is the measure the noise from the TCS3771in the final system implementation. This measurement is the standard deviation of the measure proximity counts. This can be done by collecting several hundred counts then using a spreadsheet such as Excel. A second way is to utilize the EVM software which supports direct measurement of the noise. In the EVM software, pull up the functional output screen which should look like Figure 1.

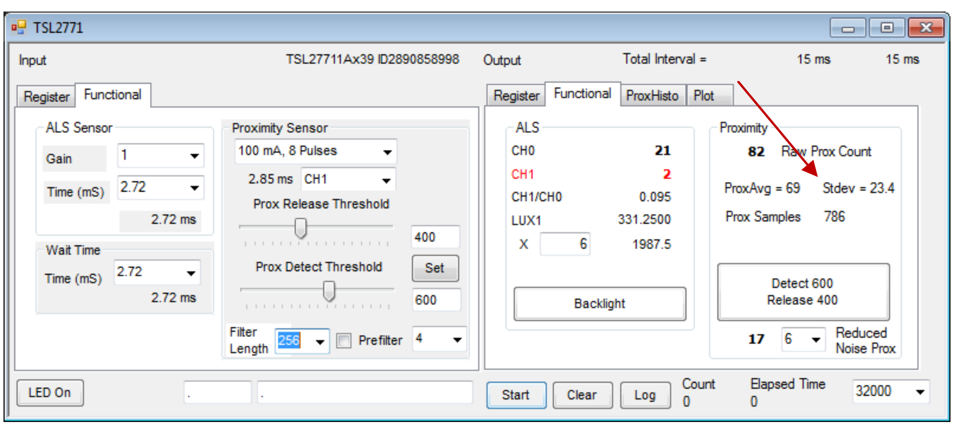
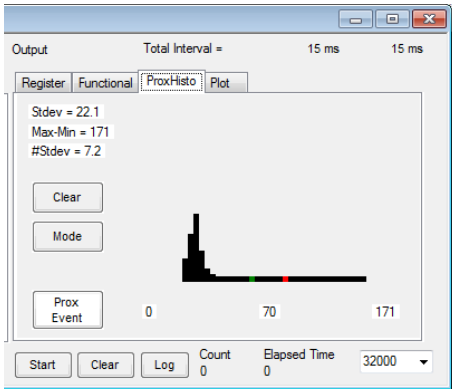
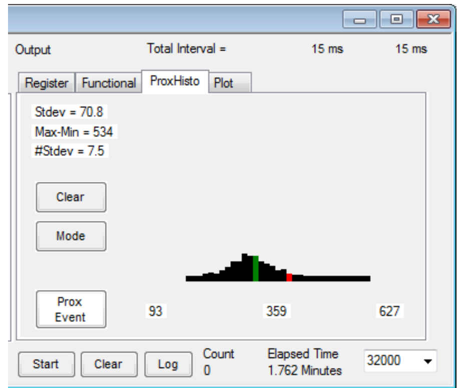


Figure 1 – EVM Software Showing Proximity Counts and Standard Deviation

To ensure a valid standard deviation, it also must be verified that all sample in the distribution are greater than zero (since a negative value would be reported as a zero). This can be easily seen using the ProxHisto tab of the EVM software, which displays a running histogram distribution of the sample prox values in 32 sample buckets.



8 Pulses



64 Pulses

Figure 2 – EVM Software Showing Proximity Count Histogram

Offset may be positive or negative. If there is a slight negative offset, a small target may be required to drive the signal such that there are no “zero” valued samples. Likewise with a target, the max value should be less than 1023. If any sample is at 1023, the results may be inaccurate. In other words, it is important to assure that the tails of the distributions (see Fig. 2) do not encroach on the lower limit at 0, or at the upper limit of 1023.

Effective Resolution

Measurement for the TCS3771 standard deviations at different pulse settings then normalized pulse shows a standard deviation of 4 counts at one pulse. Recalling the formula for R68 from DN33:

$$R68 = 10 - \log_2 (2 * 4) = 10 - \log_2 (8) = 10 - 2.5 = 7.5$$

Taking into account the number of pulses and averaging of samples:

$$R68 = 7.5 + \log_2 [\mathrm{sqrt}(\mathrm{Samples\ Averaged})] - \log_2 [\mathrm{sqrt}(\mathrm{PPulse})]$$

Distance and the TCS3771

The TCS3771 produces a similar shape curve to the TSL2771 as discussed in DN33 Appendix: TSL2771. However, the device produces about 2.5x more signal which in turn shifts the curve and enable longer distance detection. This coupled with the lower noise give the TCS3771 the ability to detect object at a further distance. Figure 1 show transfer functions comparing the two devices.

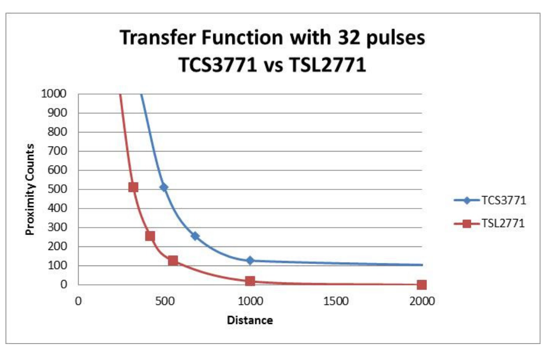


Figure 1 – Transfer Function of the TCS3771 vs the TSL2771

The data was taken using an OSRAM SFH4650 and a large white surface. Both devices were operating at 100mA of LED drive current and 32 pulses.

The lower noise operation has the additional benefit that the device can operated with a larger number of pulses. While the TSL2771 was effectively limited to 64 pulses maximum, the TCS3771 can operate at 128 pulses and 255 pulses.

Proximity Sampling Time

Figure 6 shows the state diagram from the TCS3771. The total time required to take a proximity measurement can be estimated from the diagram. For example with PPULSE = 8, PTIME = 2.4ms, WEN = 0 (no wait state) and ALS is set to the minimum ATIME = 2.4ms, the total time for a single prox reading can be calculated. Starting at the Start state, we have 2.4ms of Prox Delay, then 8 * 16us or ~ 0.13ms (almost negligible) for proximity detection, then we 2.4ms of prox conversion time, then 2.4ms of ALS delay, then 2.4ms of ALS conversion time. This is a total of 2.4 * 4 + 0.13 or 9.7ms of total time for the prox reading.

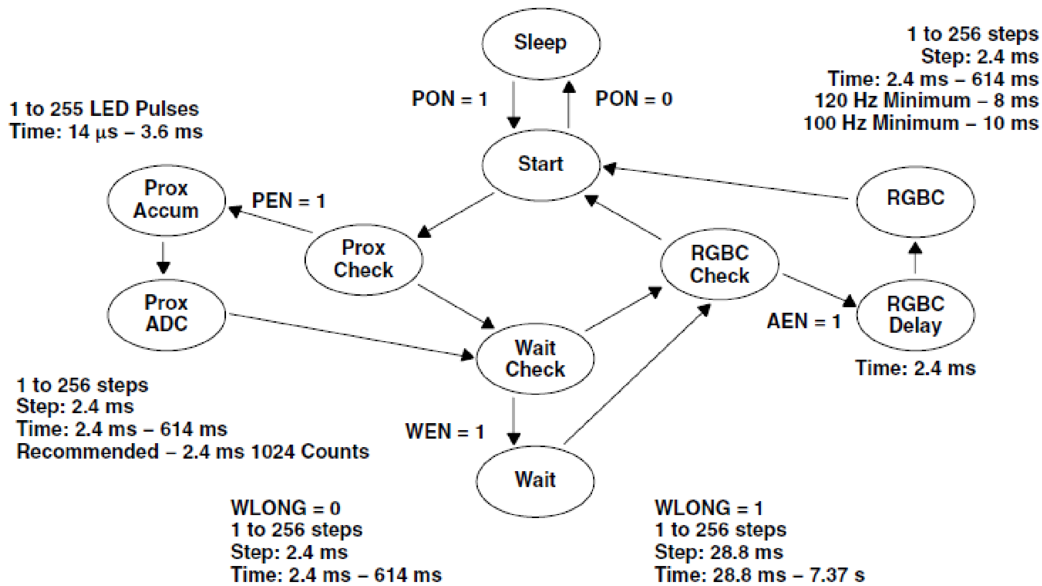


Figure 6 – TCS3771 State Diagram

Electrical Offset and Optical Crosstalk

With the TCS3771, negative offset can become an issue. This device has an electrical offset very close to zero. For operation at close distance, this can be very beneficial. However, for long distance proximity, it may be necessary to move the target object closer enough to get enough counts to detect proximity.

One method to keep the electrical offset predictable is to follow the recommendation in DN32: Layout Recommendation for the TAOS Proximity Sensors. These recommendations can greatly stabilize the noise from the power supply, especially the noise caused by the pulsing the IR LED allowing repeatable readings.

With a large number of pulses, optical crosstalk becomes a major issue. However, for long distance proximity, the separation between the device and the IR LED should be increased, reducing the possibility of optical crosstalk. 25mm has been demonstrated as a reasonable separation.

Other Factors Impacting Proximity Detection

There are many other factors that impact the accuracy and sensitivity of the proximity detection. This paper has focused on the signal, noise and crosstalk factors. Variations in the proximity sensing device, the IR LED and the systems optical design must be taken into account.

IR LED variation can also lead to variation in the output optical power and cause variation in the transfer function (by up to 3x). System calibration can eliminate this variation.

Other system optical design issues include transmissivity of the glass over the sensor, crosstalk caused by the glass, variations in the ink used to darken the glass, and variations in the distance between the top of the sensor and the glass.

Calibration is the most effective way to improve the overall system accuracy. Calibration in the final system will remove the systematic variations of the glass transmissivity and, IR LED variation as well as device to device variation.