Best Practices for TOF Crosstalk Calibration

Crosstalk in a system is a fairly simple concept. It is the unwanted coupling of one signal on to the path of a second signal. In a Time-of-Flight (TOF) application, crosstalk can be from an electrical connection but also from optical coupling. To mitigate the effect of crosstalk, Renesas has provided a calibration/correction scheme inside the chip. To achieve sound calibration, care must be taken in the setup to ensure that only crosstalk is measured and corrected. This application note addresses the optical setup when doing crosstalk calibration. It does this by describing areas that deserve careful attention and recommends a process that produces good results.

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1. Crosstalk Definition

Crosstalk in an ISL29501 application can simply be defined as a signal that reaches the detector that was not reflected from a target. This can be from parasitic electric and magnetic fields on the circuit board, decoupling and internal paths within the chip. Optical crosstalk can come from a direct path, bouncing within a glass cover or window or from reflections in the cavity surrounding the optical components.

2. Crosstalk Measurement

A crosstalk measurement is similar to a ISL29501 distance measurement, but is different in two important ways. The first is that there must be no return signal reflected from a target. In the optical setup, the user must ensure that the optical pulses sent out by the emitter do not reach the Photo Diode (PD). With no return signal, anything left over is considered crosstalk. The second difference is that we only are interested in the signal magnitude. The distance has no meaning in a crosstalk measurement.

Crosstalk is a good predictor of system performance. At the maximum range, the signal to crosstalk ratio limits system performance. Every effort should be made to minimize crosstalk in the application design.

A crosstalk measurement is setup as previously described and is done after a magnitude calibration is performed. Registers 0x24 to 0x2B, 0x2F, and 0x30 should all be at their default or 0.

3. Eliminating the Return Signal

There are a couple of ways to eliminate the return signal to ensure a measurement contains only crosstalk. One way, called the infinity method, makes a measurement where there is no possibility of any return signal reaching the PD. A large room with low reflectivity walls might work. The trouble is, that with more power or if the system has lenses, the room becomes increasingly large. Another variation of the infinity method is to point the emitter toward the night sky with no obstacles in the emitter cone of light/signal. This is not convenient or practical for production.

3.1 Covering the Emitter and PD

An alternate method is to cover the optical components and make a measurement. Previously, Renesas recommended using the piece of cardboard provided in the evaluation kit to cover both the emitter and PD. This works fairly well for initial evaluation. This becomes a problem when the optical components are covered by glass, which we expect is the case in almost all applications. Figure 1 shows the reflections inside the glass when both optical components are covered.

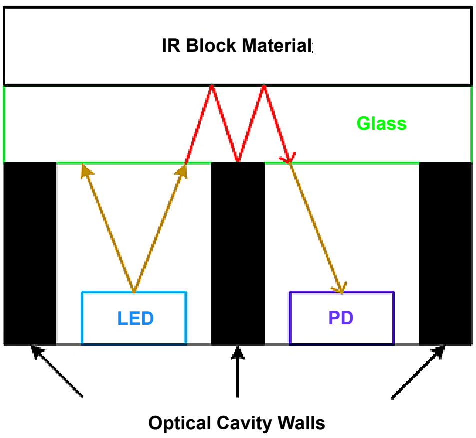

Figure 1. Reflections with Covered Emitter and Pd

The light from the emitter strikes the bottom of the glass and ~96% continues to the black cardboard. This material has some reflectivity, let's assume ~10%. This means that of the original signal that struck the glass, 9.6% bounces back toward the cavity wall. Just to make the math simple, let's assume that 9.6% of the remaining light reflects off the cavity barrier, and 9.6% of that from the 2nd cardboard bounce. This implies that the PD sees 0.096 * 0.096 * 0.096 = 0.000885. The amount of light at the angle shown is small but it is important to realize that ~0.088% of that incident ray reaches the PD. This is optical crosstalk caused by the setup and has no relevance to the crosstalk in normal operation. If this setup were used for calibration, the calibration factors would be wrong. This would introduce large errors in distance measurements as well as reduce the range significantly.

3.2 Covering the PD Only

This is the new recommended method. The problem with covering both components is that a large reflection bounces off the optical blocker and reflects back into the glass. By covering only the PD, we allow most of the light to pass through the glass with only a small amount left bouncing within the glass. Any reflection off the walls or the room returns to the covered PD and at a very low magnitude and with an effective cover be eliminated. Figure 2 shows the light rays with only the PD covered.

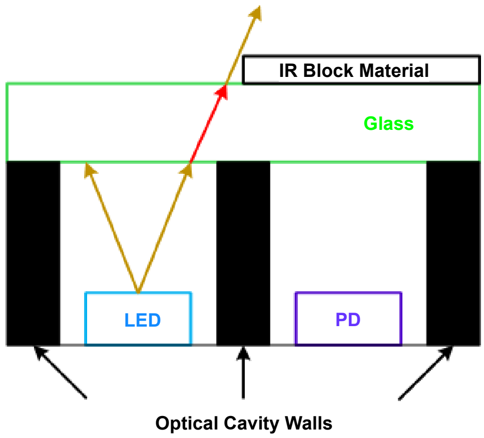

Figure 2. Light Path with only the PD Covered

The drawing shows that the light passes through the glass and any reflection from the environment strikes the back of the light blocker. The blocker looks different than in Figure 1. This is not accidental, we are recommending a different material.

3.3 Light Blocker

The light cover (blocker) has only 1 critical parameter: it must not allow 850nm light to pass through it. It does not matter if it absorbs or reflects, the light signal must not pass through. Future evaluation kits will use the following Poron: 4701-60-20031-04, Product # 2304547. There is nothing magical about this material, it was available and easy to cut to size. The sizing is less critical, but it's also important for it to work properly. This material is thin, making it easier to position it out of the Field of View (FOV) of the emitter. There are many materials that can accomplish this but they must block all emitted IR light from passing to the PD.

4. Configuring for Crosstalk Calibration

Figure 3 shows the Sand Tiger evaluation kit with glass configured for crosstalk calibration using the new method. Notice that there is a space (Y direction) between the LED source and the light blocker. The blocker must be completely out of the beam of the emitted light. The space is wider than this absolute minimum to allow the light to reflect and bounce a couple of times within the glass before it strikes the blocker. Each bounce within the glass before reaching the blocker reduces the optical power of any light by >96%. The second requirement is that the blocker completely covers the FOV of the PD (hidden by blocker). This guarantees that any light passed through the glass and is reflected back by the environment cannot directly strike the PD. The last requirement is that the blocker is flat against the glass.

Why use tape? The tape is not a requirement, but it makes it easy to compare crosstalk with and without the cover. It also brings the blocker down to the glass. Could I use a finger? The answer is not easily. The trouble is that it is hard to keep the blocker flat against the glass. A finger is thick and might enter the FOV of the emitter which causes it to light up (with IR). This could reflect back into the glass as additional, setup introduced, crosstalk. The goal is to block the light path to the PD without introducing additional crosstalk into the setup.

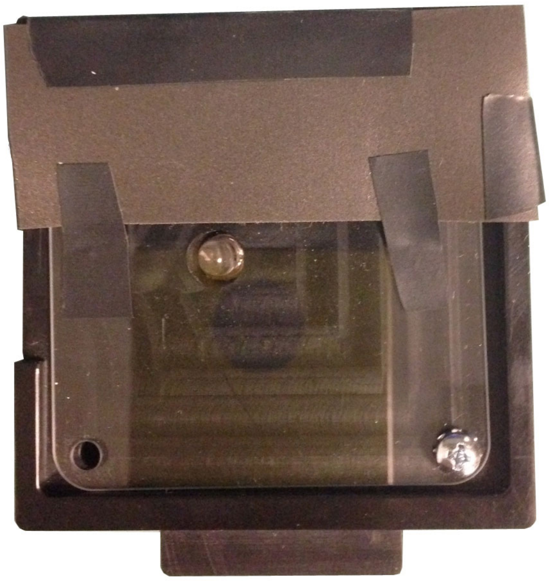

Figure 3. Sand Tiger Configured for Crosstalk Calibration

5. Remaining Crosstalk

The recommendations thus far drastically reduce the crosstalk, however, some light through multiple bounces still reaches the PD. Anti-reflective coatings can reduce their magnitude but never completely eliminate it. Although there is still some crosstalk in the system, if the above steps are followed, it should closely match the crosstalk in the system during normal operation. If this is true, crosstalk calibration measures the crosstalk accurately, programs calibration coefficients back into the chip and that quantity is subtracted in real time from each distance measurement.

6. Calibration Without Glass

The technique described works just as well when no glass is present. Why not use the old method covering both the emitter and PD? The old method works reasonably well without glass because the cardboard and the optical components are very close to each other. There are sill bounces off the cardboard and case, but since they are so close together it takes many, many bounces for light from the emitter to reach the PD.

7. Summary and Final Thoughts

Important: Both electrical and optical crosstalk are almost directly proportional to emitter current. For this reason, the emitter current must be set to normal application conditions before doing crosstalk calibration.

The following list summarizes the considerations in crosstalk calibration:

1. Magnitude calibration must be done first and the coefficients loaded into registers 0x2C to 0x2E.
2. Use a 850nm optical blocker over the PD only.
3. Ensure that the light blocker is positioned completely out of the FOV of the emitter and completely covers the FOV of the PD.
4. Ensure that the light blocker is reasonably flat against the glass, particularly the edge nearest the emitter.

8. Revision History

Revision	Date	Description
1.00	Apr 6, 2022	Applied new template.
0.00	Oct 27, 2016	Initial release.

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Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

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Contact Information

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