Application Brief

How to Improve Accuracy With High-Speed Comparators in LIDAR and Proximity Sensing

TEXAS INSTRUMENTS

Introduction

In common time-of-flight (ToF) applications like automotive LIDAR and industrial proximity sensing, the signal that reflects from the designated target (echo) varies in amplitude and pulse width. For example, smooth surfaces reflect better than rough surfaces, while white objects reflect better than black objects.

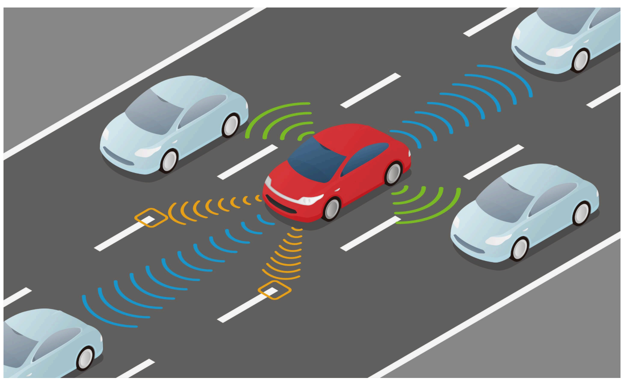

Figure 1. Automotive LIDAR

Amplifying the echo with a high-speed amplifier can help get the echo out of the noise floor, but achieving accuracy with one's ToF measurement requires the use of a comparator with minimum input overdrive dispersion.

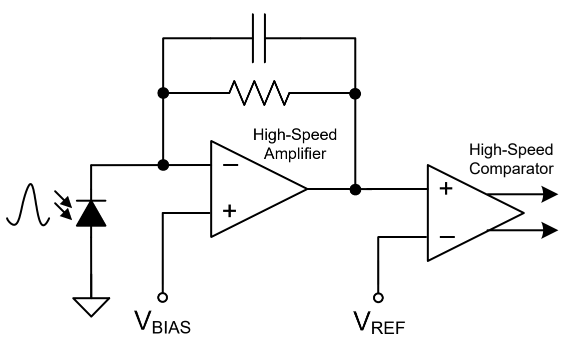

Figure 2. Pulse Receiver Circuit

Overdrive Dispersion Definition

For those less familiar with this comparator specification, overdrive dispersion refers to the variation in propagation delay for the amount of voltage the input signal exceeds the reference voltage (switching threshold). Figure 3 showcases the propagation delay response of a comparator with varying input overdrives. Note how the propagation delay of the input with 100-mV overdrive has a faster response time than the input with 10 mV overdrive.

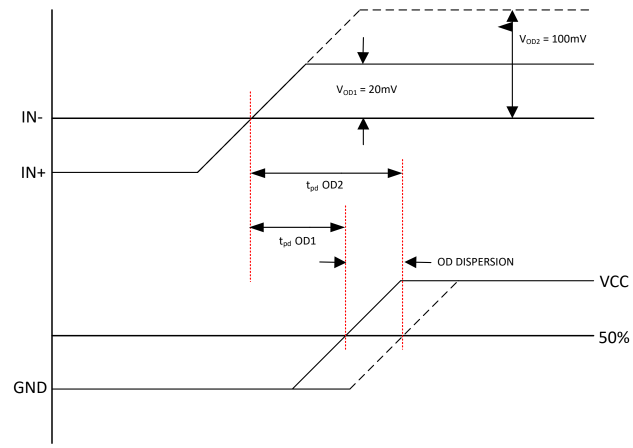

Figure 3. Overdrive Dispersion Effect

Looking for comparators with fast propagation delay is a good start, but overdrive dispersion is the key for minimizing error in end equipment utilizing a ToF architecture.

Overdrive Dispersion Challenge

System designers can calibrate (deskew) for ToF variations due to different environmental conditions such as temperature, humidity, and medium density or medium viscosity, but it is the echo signal amplitude and its associated prop delay variation that offers the greatest design challenge for accurate ToF measurement.

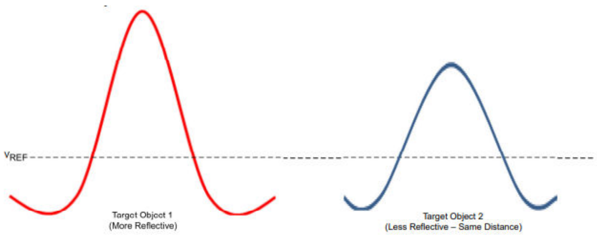

Figure 4. Varying Signal Strengths

As mentioned previously, surfaces can have different reflective properties. This means that the amplitude of the echo received will vary even if the objects are the same distance from the transmitting source. Laser range finders (proximity sensing) tools, as Figure 5 shows, also face this challenge. Using a high-speed comparator with minimum overdrive dispersion significantly reduces the error contributed by this varying signal strength, enabling the system to calculate an accurate distance to an object regardless of the amplitude of the reflected pulse. Since there is not a simple solution to calibrate the different propagation delay times according to different input overdrives, it is important to select a comparator with very small input overdrive dispersion.

Figure 5. Laser Range Finder

Solution to the Challenge of Varying Echo Amplitudes

The solution seems quite simple: use the fastest comparator with the smallest amount of overdrive dispersion. Unfortunately, the fastest comparators generally have output stages that are not compatible with many off-the-shelf time-to-digital converters (TDC) such as the TDC7200. Ultra-fast comparators such as the TLV3801 have propagation delays in the 225-ps range with overdrive dispersion as low as 5 ps, but this performance comes with a specialized output stage that is low-voltage differential signaling (LVDS) compliant. LVDS is a protocol that is fully differential and has relatively low amplitude swing which enables its high-speed response capability.

Unfortunately, TDCs generally have single-ended complementary metal–oxide–semiconductor (CMOS) input stages that are best suited for high-speed comparators with push-pull outputs. Devices such as TLV3601 with 600 ps of overdrive dispersion are available, but this also means that the system now needs to tolerate as much as 600 ps of ToF measurement variation.

The good news is that the solution is not as difficult as one may think. One can use the high-speed, super-low overdrive performance of an LVDS comparator such as TLV3801 to digitize the echo at the output of the amplifier stage, and then use a high-speed comparator with a push-pull output stage, like the TLV3601, to translate the differential LVDS signal to the more user-friendly single-ended CMOS level.

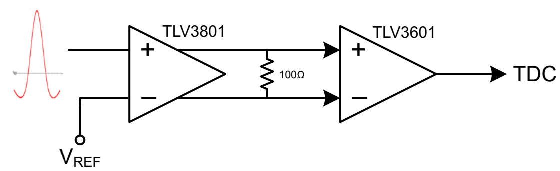

Figure 6. LVDS to Single-Ended Conversion

Conclusion

This method looks like a contradiction because the high-speed comparators with push-pull output stages cause too much error because of overdrive dispersion. However, since the TLV3601 is receiving a differential LVDS signal that is centered around 1.2 V from the TLV3801, there is no overdrive dispersion contribution to the signal path (that is, the overdrive level is always the same regardless of the echo signal amplitude because the TLV3801 already digitized it). In this proposed solution, the TLV3601 is really just acting like an LVDS to single-ended CMOS converter. The LVDS TLV3801 minimizes overdrive dispersion error for the ToF measurement and the TLV3601 translates the signal to be compatible with common TDC devices.

Table 1. Device Recommendations

Device	Prop Delay	Dispersion	Toggle Frequency	Minimum Pulse Width
TLV3801/11 TLV3801/2-Q1	225 ps	5 ps	3 GHz	240 ps
TLV3604/5/7	800 ps	350 ps	1.5 GHz	600 ps
TLV3601/2/3, TLV3601/2/3-Q1	2.5 ns	600 ps	325 MHz	1.25 ns

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