Application Note

TLV3602 ToF Lidar Transmitter Application Design Guide

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ABSTRACT

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Laser Detection and Ranging (Lidar) uses laser light as a carrier wave to detect the motion parameters of targets. Compared with cameras, Lidar offers more precise distance measurement capabilities; compared with ultrasonic radar, Lidar provides longer detection range and higher resolution; while millimeter-wave radar can miss alerts in scenarios such as traffic cone roadblocks, Lidar remains unaffected by such limitations. As intelligent driving evolves toward higher levels of autonomy, Lidar has become an indispensable, critical sensor within the entire automotive integrated perception system.

The ToF architecture is a widely used ranging principle in Lidar, and to guarantee sufficient ranging accuracy and detection distance, ToF requires the laser to emit laser pulses at the nanosecond (ns) level. The LMG1025 is a low-side GaN driver for Lidar applications that is broadly utilized throughout the industry; however, the LMG1025 requires the high level of the input pulse signal to reach above 2.6V, which is difficult to satisfy for general SOCs/FPGAs. With its high bandwidth and low latency features, the TLV3602 can serve as a level shifter between the SOC/FPGA and the LMG1025. This paper primarily introduces the design considerations for applying the TLV3602 in Lidar transmitter modules.

Table of Contents

List of Figures

1 Introduction

Laser Detection and Ranging (Lidar) uses laser light as a carrier wave to detect the motion parameters of targets. In addition to basic target detection functions, Lidar can implement several advanced features, such as achieving low-resolution optical detection of targets based on changes in the received light intensity of the detector; determining target shapes based on echo waveforms; and judging day and night conditions based on ambient background light intensity variations. Providing high-resolution 3D (Horizontal H, Vertical V, and Distance R) point cloud maps is a unique and unparalleled advantage of Lidar, as shown in Figure 1-1 illustrating the Lidar detection dimensions and point cloud results. As intelligent driving evolves toward higher levels of autonomy, Lidar has become an indispensable, critical sensor within the entire automotive integrated perception system.

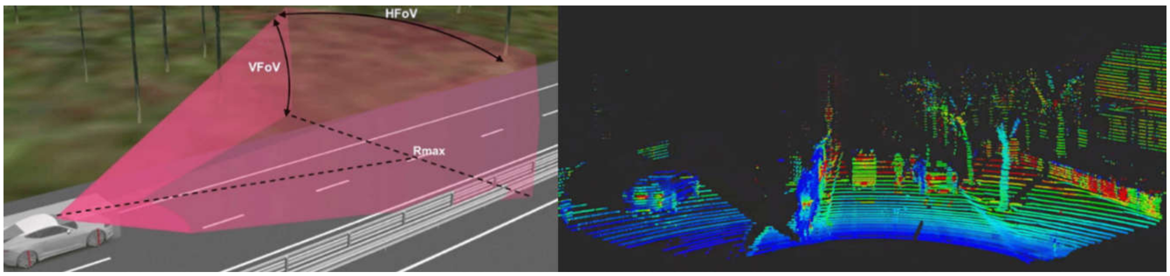

Figure 1-1. Schematic Diagram of the Three Detection Dimensions of Lidar and 3D Point Clouds

The ToF principle is a commonly used ranging method in Lidar, which calculates target distances by transmitting short ns-level pulses and having the receiver compare the time difference between the transmitted and received pulses after reflection from the target. The target distance is given by the following equation:

$$r = (c \cdot t)/2 \quad (1)$$

where c is the speed of light in a vacuum, t is the time from transmission to return of the laser pulse, and r is the distance from the target to the Lidar.

Lidar modules can be roughly divided into four parts according to their functionality, as shown in Figure 1-2: first, the laser transceiver system, which includes the transmitting and receiving transducer devices as well as the optical section, where the transducer devices refer to the laser at the transmitting end and the APD or SPAD at the receiving end, responsible for the mutual conversion between electricity and light, and the optical section is responsible for the calibration of transmitted light and the focusing of received light; second, the digital processing portion, primarily consisting of the SOC or FPGA small system (SOC/FPGA + core power supply), where the SOC or FPGA handles the generation of transmitted pulses and the processing of received point clouds, and the core power supply delivers low-voltage, high-current power to the SOC or FPGA; third, the optical scanning section, responsible for deflecting the laser beam to achieve a certain scanning angle, with common scanning architectures including mechanical scanning, semi-solid-state rotating mirror scanning, and MEMS galvanometer scanning; fourth, auxiliary systems such as system power supply, monitoring, and defogging, where the system power supply provides power for the motor, SOC small system, defogging, and other functional modules, the monitoring module oversees the current, voltage, and temperature at key nodes of the entire system to improve system reliability, and the defogging function heats the window to prevent condensation from attenuating the laser energy.

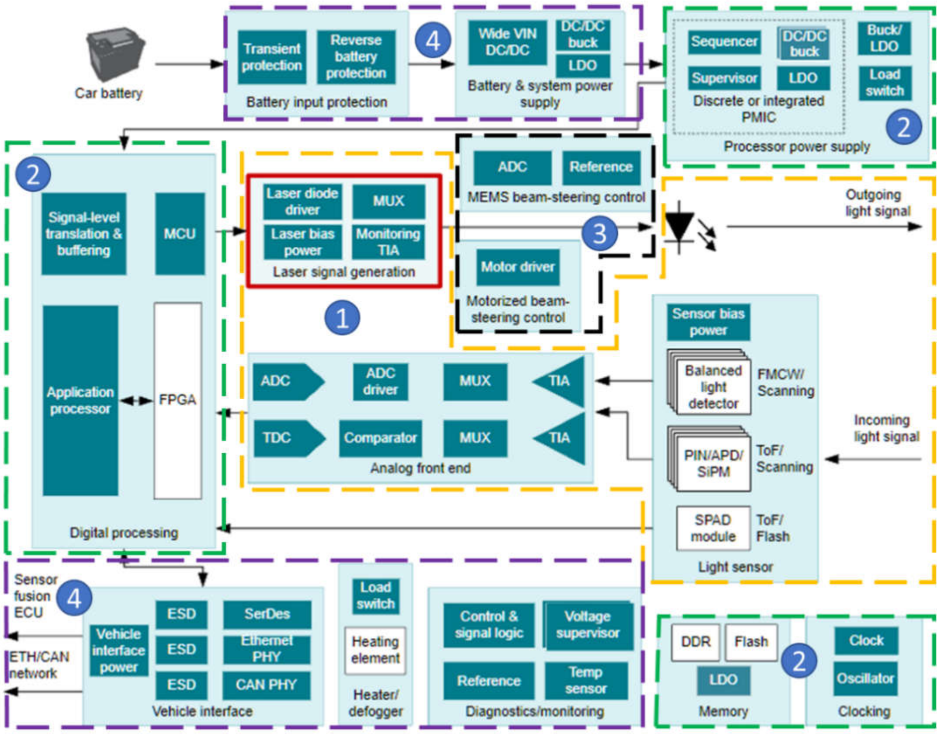

Figure 1-2. Schematic Diagram of Lidar System

2 Application of TLV3602 in Lidar Transmitter Systems

2.1 Lidar Transmitter Section

The portion enclosed by the red solid line box in Figure 1-2 is the transmitter section of the Lidar, and its system schematic and operating principle are shown in Figure 2-1. C1 is an energy storage capacitor, which is charged by Vin via R_{IN} to a predetermined voltage within a certain period (the duration being greater than the pulse emission interval); D_L is a laser diode, and when Q1 is turned on, C1 provides energy, causing D_L to emit a laser beam. Depending on the specific application, the peak current of D_L can reach up to approximately 50A; Q1 is driven by the Gate Driver, and the Gate Driver is driven by the $V_{command}$ pulse signal, which is generally generated by an FPGA with a pulse width typically in the range of 1-10ns. To provide such narrow pulse signals, the output swing of the FPGA is generally only 1.8V.

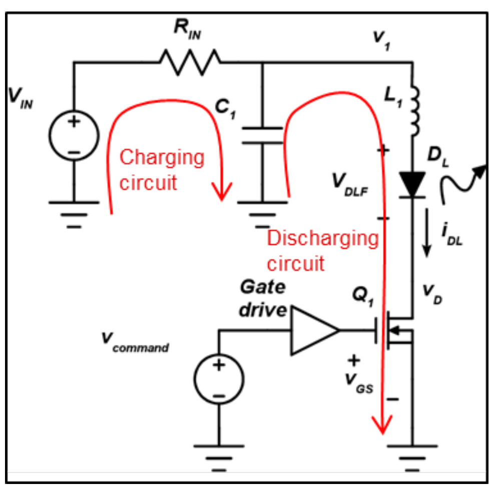

Figure 2-1. Schematic Diagram of Lidar Transmitter System and Operating Principle

The LMG1025-Q1 is one of the excellent choices for the Gate Driver in transmitter systems. The LMG1025-Q1 is a high-performance low-side 5V gate driver designed for driving the gates of GaN and MOSFETs. It is well-suited for high-speed application scenarios such as wireless power transmission and Lidar, supporting a minimum drive pulse width of 1.25ns. However, the input high-level threshold requirement for the LMG1025 is greater than 2.6V, as shown in the partial datasheet screenshot in Figure 2-2, making it difficult for the common 1.8V output signals from FPGAs to meet its required high-level threshold.

Input DC Characteristics					
V_{IH}	IN+, IN- high threshold		1.7	2.6	V
V_{IL}	IN+, IN- low threshold		1.1	1.8	V
V_{HYST}	IN+, IN- hysteresis		0.38	1	V

Figure 2-2. LMG1025 Input Voltage Threshold

2.2 TLV3602 as a High-Speed Level Shifter

Conventional level shifters, such as the SN74LVC4T245, do not support level translation for ns-level pulses. In this context, utilizing a high-speed comparator as the level shifting device is a superior choice. The TLV3602, with its various advantages, is ideally suited to perform the level shifting function in Lidar transmitter systems:

1. It supports level translation for ns-level pulses, as shown in Figure 2-3 measured waveform with an input pulse of 1.8V swing and 1.25ns pulse width (yellow line) and an output of 5V swing (magenta line).

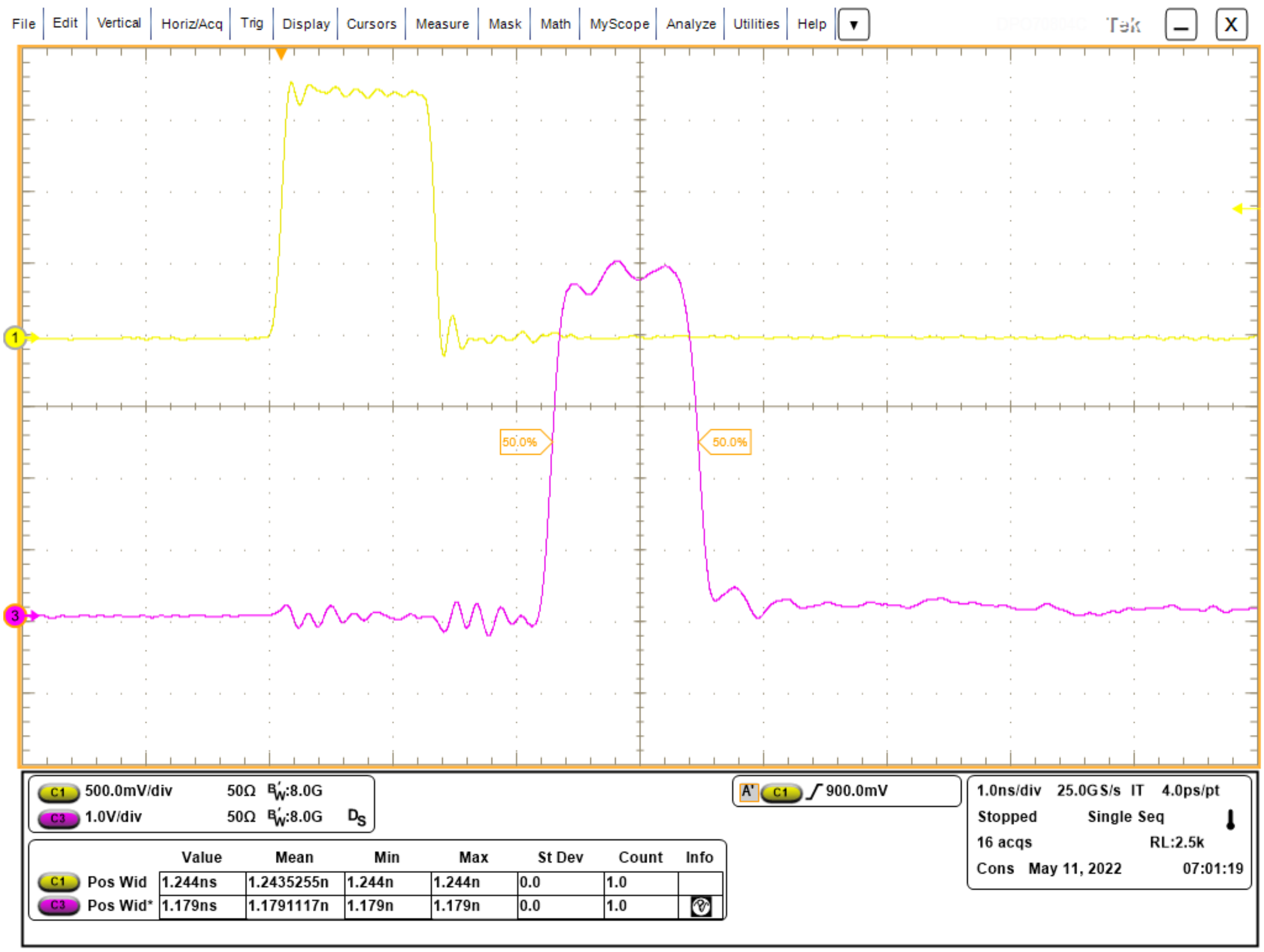

Figure 2-3. LMG1025 Input Voltage Threshold

2. Dual-channel integration, enabling a single chip to support the differential input operation scenarios of the LMG1025, i.e., the architecture shown in Figure 2-4. Delays between differential signals can cause edge

misalignment, resulting in pulse width expansion or reduction after subtraction. The dual-channel design of the TLV3602 guarantees minimal delay differences between differential signals at the device level (sharing the same die and package), thereby minimizing pulse width distortion at the output of the LMG1025.

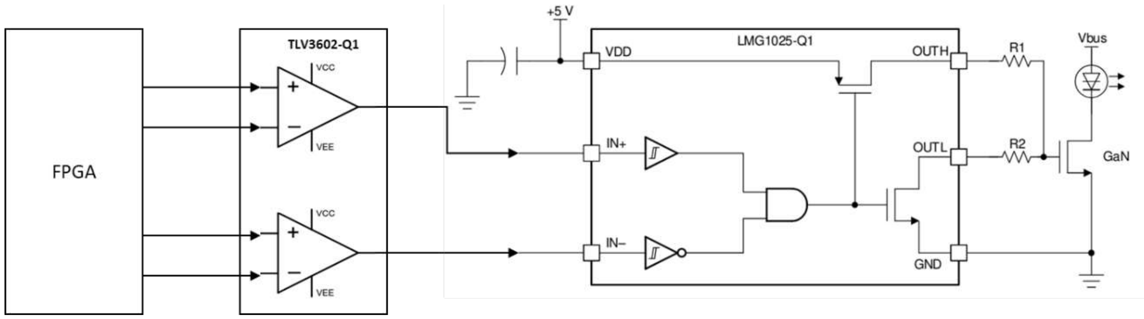

Figure 2-4. Schematic Diagram of Differential Drive Architecture

3. A toggle frequency of up to 325MHz supports the us-level pulse interval requirements found in Lidar application scenarios.

Table 2-1 illustrates a comparison of major specifications between the TLV3602 and a competitor's similar device. The TLV3602 features faster rising edges, lower skew, higher toggle frequency, and a wider operating temperature range.

Table 2-1. Comparison of Main Device Specifications

Specifications	TP1961/2	LT1713/4	TLV3601/2
Manufacturer	3Peak	ADI	TI
Num Channels	1/2	1/2	1/2
Vs min (V)	2.5	2.4	2.4
Vs max (V)	5	7	5.5
Prop delay (ns)	7	4.5	2.5
Tr(ns)	1	4	0.75
Tf(ns)	1	4	0.75
Skew(ps, dual channel only)	400	-	24
Toggle freq(MHz)	50	-	325
Vos max @ 25C (mV)	10	6	5
Iq typ (mA) per channel	2.4	15	4.9
Iq max @ 25C (mA)	-	19	7
Output type	Push-Pull	Push-Pull	Push-Pull
Ibias typ (pA)	6	5	1000
Operating Temperature (°C)	-40 to 125	-40 to 85	-40 to 125
Release Status	Active	Active	Active
Available Packages	**Single**: SOT-23-5, SC70-5 **Dual**: SOIC-8, MSOP-8, DFN-8	**Single**: MSOP-8 **Dual**: SSOP-16	**Single**: SOT-23-5, SC70-5 **Dual**: SOIC-8, MSOP-8, DFN-8

2.3 Application Recommendations for STLV3602

For a comparator, there is a delay between the input signal crossing the reference voltage (V_{REF}) and the output response edge, known as propagation delay (T_p), which is measured from the midpoint of the input to the midpoint of the output. Depending on the direction in which the input signal crosses the reference voltage, there are low-to-high propagation delay (T_{pLH}) and high-to-low propagation delay (T_{pHL}), and their values may differ. In addition to the internal design of the device, the propagation delay varies with the overdrive (V_{OD}) and underdrive (V_{UD}) voltages.

Overdrive refers to the portion of the input voltage that exceeds the reference voltage, while underdrive refers to the portion of the input voltage that falls below the reference voltage. In the example shown in Figure 2-5, both the V_{OD} and V_{UD} voltages are 100mV. Both V_{OD} and V_{UD} affect propagation delay. The Figure 2-6 curve shows the relationship between V_{OD}/V_{UD} and propagation delay for the TLV3511 (the current TLV3602 datasheet does not have similar data yet and will be updated later; the TLV3511 is used here as an example). It can be observed that smaller V_{OD} voltages lead to longer propagation delays, particularly when <100mV, where the propagation delay increases sharply. For high-speed application scenarios, it is recommended to appropriately increase V_{OD}. Conversely to V_{UD}, a larger V_{UD} leads to an increase in tp. Therefore, in scenarios with large input signal swings, an inappropriate reference voltage setting will cause a significant difference between the rising and falling edge propagation delays (T_{pLH} and T_{pHL}), which in turn leads to a discrepancy between the input pulse width and the output pulse width. Simultaneously, large V_{OD} and V_{UD} can cause the device propagation delay to change substantially with temperature, affecting system performance across high and low temperatures. As seen in the lower part of Figure 2-6, when V_{UD} is above 100mV, the propagation delay varies by more than 3 ns over temperature.

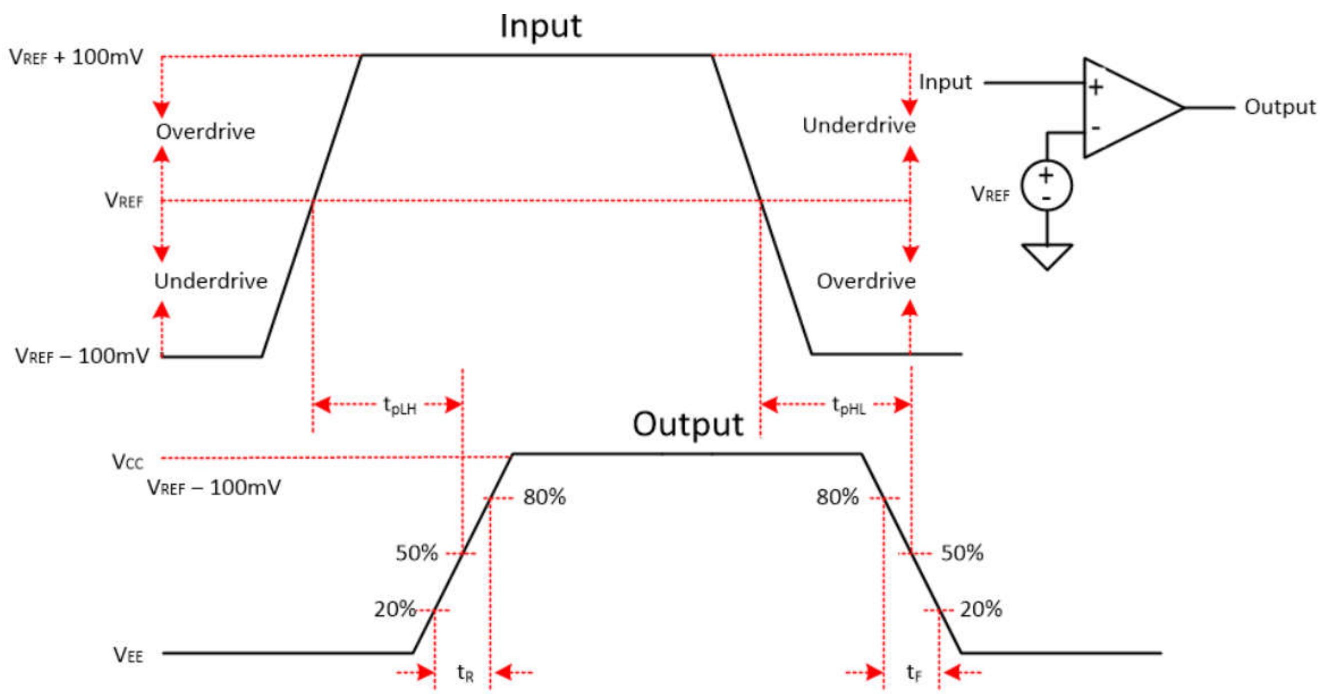

Figure 2-5. Example of Overdrive and Underdrive Effects on Propagation Delay

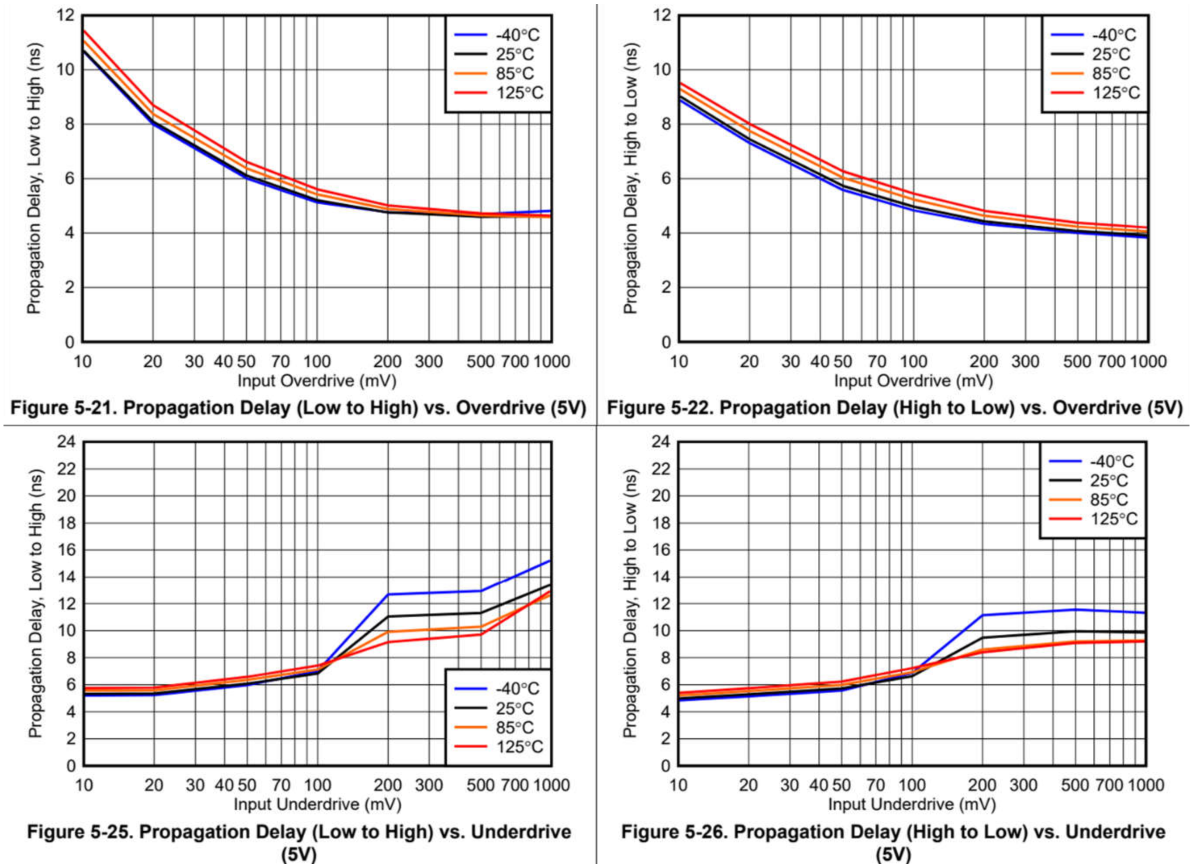

Figure 2-6. Schematic of Overdrive and Underdrive

Therefore, in application designs, careful attention must be paid to the appropriate setting of the reference voltage, which is recommended to be set at the midpoint of the actual output swing of the FPGA. In the example shown in Figure 2-7, although the FPGA is a 1.8V system, the actual output high level is only around 1.5V. If a Vref of 0.9V is still used under these conditions, output pulse edge jitter may be observed on individual chips (propagation delay is also related to the chip manufacturing itself, and this phenomenon can appear on certain chips when coupled with inappropriate V_{OD} settings). After appropriately lowering the reference voltage, the improved effect can be observed as shown in Figure 2-8.

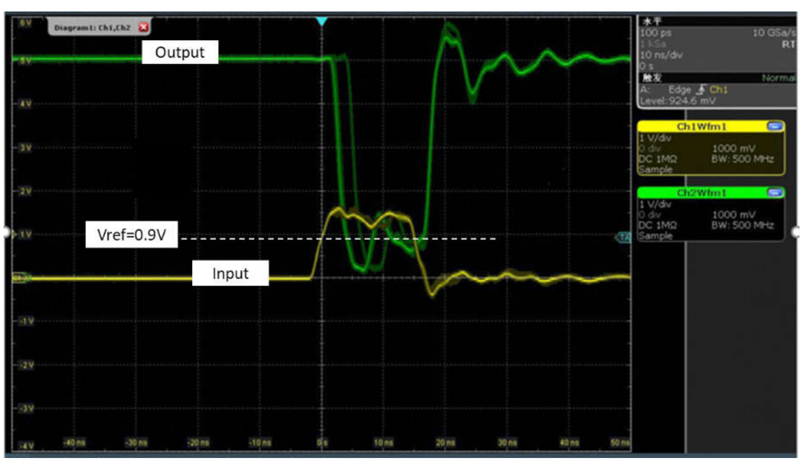

Figure 2-7. TLV3602 Operating Waveform with Inappropriate Overdrive and Underdrive Settings

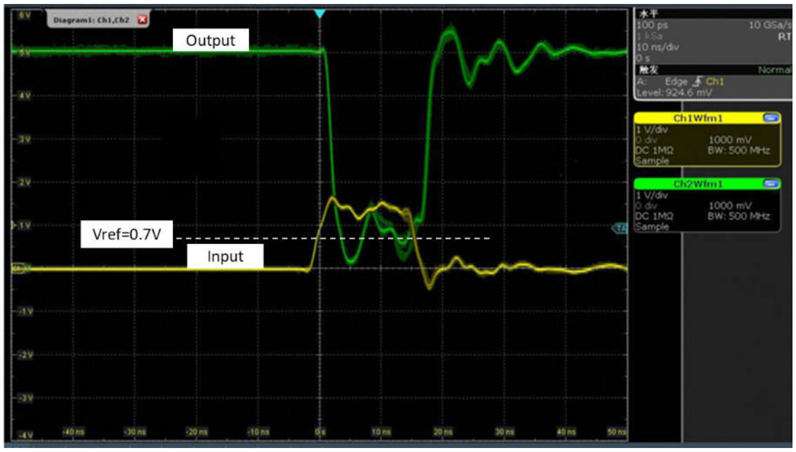

Figure 2-8. TLV3602 Operating Waveform with Optimized Overdrive and Underdrive Settings

In multi-channel transmitter system applications, delay differences between multiple channels can lead to pulse asynchronous behavior across channels, thereby impacting measurement accuracy. Delay variations between individual TLV3602 devices can further degrade pulse synchronization between channels. To address this, a calibration loop can be introduced at the system level, with the system architecture shown in Figure 2-9. After the system powers up, all channels synchronously transmit a first pulse as a calibration pulse, and the FPGA detects the errors of the signals on each feedback loop as calibration values. The subsequent pulse transmission times are then adjusted by subtracting this calibration value from the original timing. After undergoing a single-point calibration at room temperature, the TLV3602 can achieve a channel-to-channel delay error of less than 100ps across the entire temperature range, as shown in Figure 2-10.

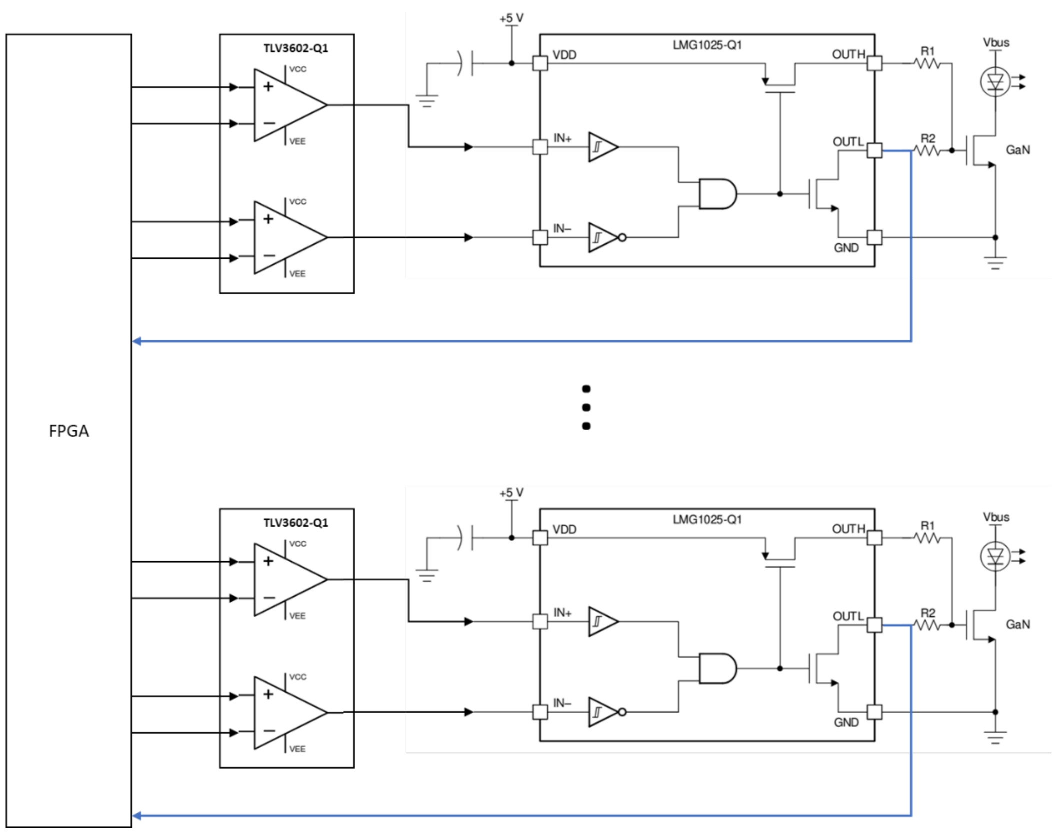

Figure 2-9. Application Architecture Diagram of TLV3602 in Lidar Transmitter System

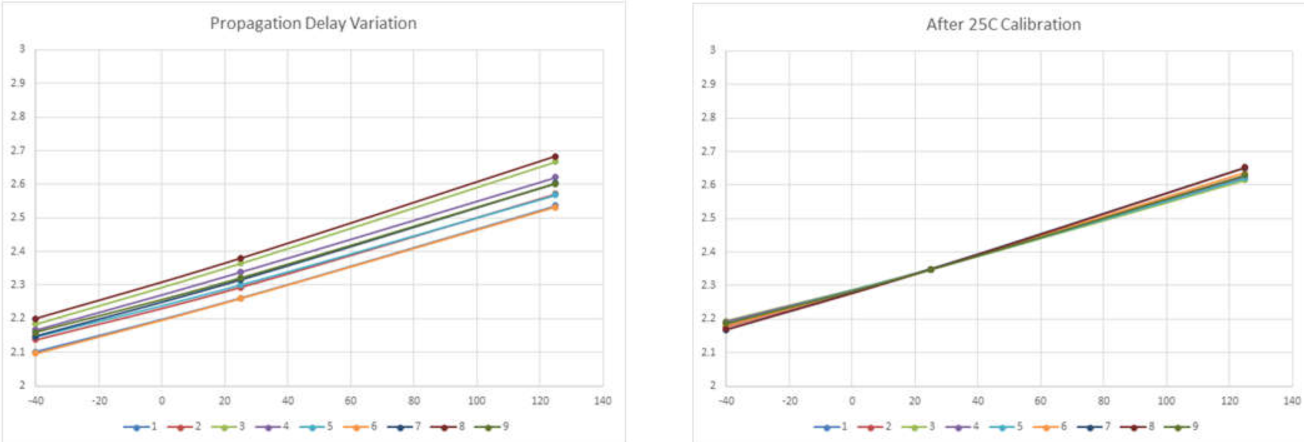

Figure 2-10. Delay Characteristics of TLV3602 with Room Temperature Single-Point Calibration

3 References

1. Datasheet "TLV360x-Q1 325 MHz High-Speed Comparators with 2.5 ns Propagation Delay"
2. Datasheet "LMG1025-Q1 Automotive Low Side GaN and MOSFET Driver For High Frequency and Narrow Pulse Applications"
3. Datasheet "TLV3511 6ns High-Speed Comparator with Rail-to-Rail Input"
4. Datasheet "TLV181x-Q1 and TLV182x-Q1 Family of 40V Automotive Rail-to-Rail Input Comparators with Push-Pull or Open-Drain Output Options"