LIDAR Perception Challenges

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A successful autonomous vehicle is going to have to use a tightly integrated system of sensors to replicate the driving abilities of a human being. The typical human driver uses two eyes, two ears, and the tactile feedback of the car in order to drive. Their brain processes all this information in real time and references their vast database of driving experience. The sensors required to replicate human driving will include radar, LIDAR, cameras, inertial measurement units (IMUs), and ultrasonic sensors. Each of these systems will have its strengths, but also literal blind spots. It is highly unlikely one sensor will ever be so refined as to negate the need for the others. In this article, we are going to look at the top level design considerations for LIDAR, which is a sensor that will provide significant data to any autonomous driving solution.

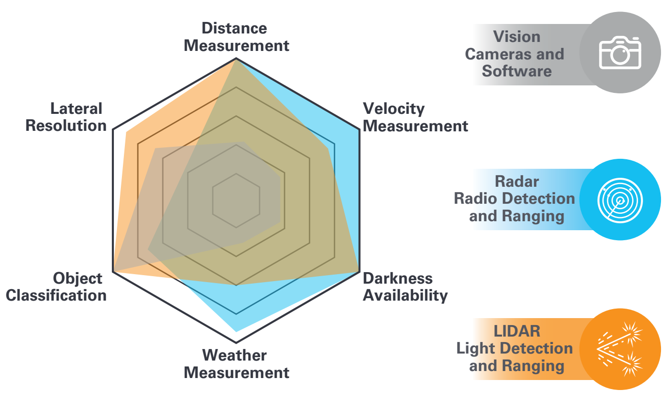

Figure 1. Spider chart comparing vision, radar, and LIDAR.

LIDAR is a close partner of radar in an autonomous vehicle. Both of these technologies operate without visible light, which is crucial for night driving or low light conditions. Radar is good for long distance detection and tracking, while LIDAR provides higher angular resolution allowing for object recognition and classification. Put another way, radar is good for detecting there might be something out there, while LIDAR can tell you more about that something once the radar finds it.

Figure 2. LIDAR perception for autonomous vehicles.

There are technical challenges when designing a LIDAR system, the obvious one being staying below the eye safety limitations for near infrared wavelengths. These safety guidelines are outlined in IEC 60825-1. This is not to diminish the importance of eye safety—the aspects discussed here all play into decisions that affect eye safety. There are many different LIDAR system topologies, with varying degrees of design complexity, which come with their own advantages and disadvantages.

At the core, all designs have the same fundamental aspects that need attention. Let's focus on considerations other than eye safety that affect system design, namely: maximizing SNR, detection requirements, field of view, thermal considerations, power consumption, and dead reckoning.

Looking at the receive path, the signal-to-noise ratio (SNR) of the system affects the ability to detect small objects at a long distance (100 m to 300 m). The ADC noise floor cannot exceed the other sources of noise in the receive path. If the background light or the signal shot noise contributions are lower than the ADC's noise floor or the printed circuit board (PCB) noise, the accuracy will be limited. Performing time of flight (ToF) calculations in a direct detect topology demands that the system can output short pulses (~1 ns to 5 ns) and detect them with a high sampling rate ADC. Sampling speeds of 1 GSPS enable this on the receive signal path. Also, keep in mind, the ADC effective number of bits (ENOB) must allow full output range from the transimpedance amplifier (TIA) without clipping the signal.

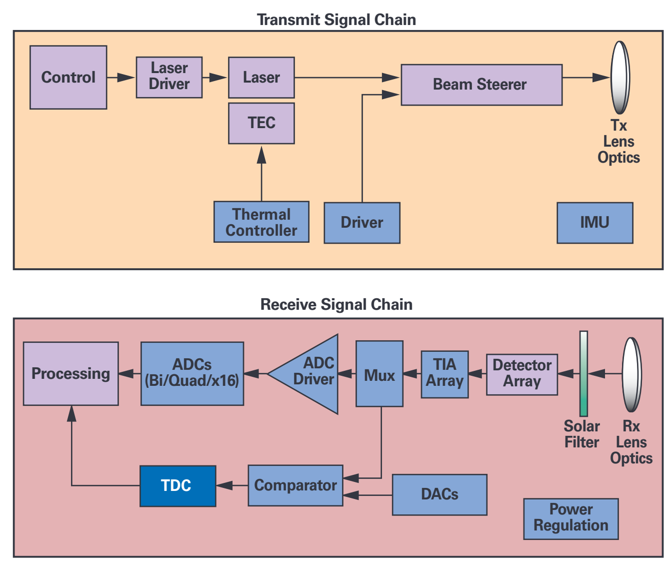

Figure 3. LIDAR electrical architecture.

Does the system need to detect a basketball at 100 m away? Determining the reflectivity and size of objects of concern, as well as the distance, limits the acceptable SNR of the TIA. The same pulses that the ADC must detect require that the TIA has a bandwidth that detects narrow pulses. Due to such a wide range of distance, reflectivity, and size of objects that systems must handle, the TIA must be capable of recovering from a saturation event. Saturation events can occur from a highly reflective object returning a high percentage of the light that was transmitted, which saturates the amplifier (for example, a close object like a speed limit sign). These events are common, and the speed at which a system can recover in order to provide accurate information is critical for safety.

The field of view and angular resolution required will also impact the ability to detect the basketball. Transmit and receive optics are the main contributing components to determine the field of view. Angular resolution will determine whether you can detect and classify an object like a basketball at some farther distance or just detect that an object exists.

Handling the power required for these systems and the heat that can be generated poses significant challenges for LIDAR system designers. And of course, lowering the power consumption of the signal chain will lower the heat generated by the solution. A component's performance over temperature can be greatly shifted, and some components of the signal chain that are more susceptible will need temperature compensation. Thermoelectric controllers are a great way of cooling or heating ICs with high accuracy. For example, laser diodes need temperature compensation to maintain operation of wavelength and efficiency over the LIDAR system's operating temperature range.

Voltage biases for avalanche photodiodes and lasers in some cases require hundreds of volts, positive or negative, to operate. Generating these voltages with high efficiency and with as few components as possible is the best design practice. Precision digital-to-analog converters (DACs) are needed to generate bias points, current, and voltage for providing accurate reference inputs. Along with the traditional voltage domains of 1.8 V to 12 V, there is an increased need for voltage levels in a LIDAR system. Careful selection of power solutions pays off, especially when another voltage is added to the solution. It is also important to choose ICs and power supplies that have a shutdown or low power mode where the system has flexibility to cycle through many channels.

IMUs integrated with LIDAR sensors provide many benefits. IMU sensors intelligently fuse multiaxis gyroscopes and accelerometers to provide reliable position and motion discernment for stabilization and navigation applications. Precision microelectromechanical systems (MEMS) IMUs deliver the required accuracy levels even in complex operating environments when faced with extreme motion dynamics.

IMUs provide an autonomous driving system with dead reckoning, localization, and stabilization capability. This in turn provides trusted data to the system when ADAS or GPS performance is degraded or unavailable. IMUs benefit from fast update rates (thousands of samples per second) and are immune to changes in the external environment. The more stable the IMU, the longer it can be trusted to provide critical insights to the system.

IMUs can be integrated directly into LIDAR modules to detect, analyze, and correct for vibrations commonly found in an automotive environment. For example, the IMU output can be used to shift LIDAR point clouds that would have otherwise been misaligned due to the vehicle running over a pothole on the road. Bearing wear on spinning LIDAR systems can also be detected using an IMU, which allows the LIDAR to be serviced before a failure occurs in the field.

Conclusion

The complexities for a LIDAR system require attention during initial product definition to determine the acceptable SNR, detection requirements, field of view, thermal limits, and power consumption. Realizing which components are the main contributors to each, along with careful IC selection, increases the chances of a successful design.

About the Author

Sarven Ipek joined ADI in 2006. During his tenure at Analog Devices, Sarven has attained a breadth of experience in failure analysis, design, characterization, product engineering, project management, and program management. Sarven is currently a marketing manager within the Autonomous Transportation and Safety Group's LIDAR division at Analog Devices in Wilmington, MA.

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