Application Brief
Improving Mobile Robot Vision Sensors With LiDAR

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High-Speed Amplifiers

Light Detection and Ranging (LiDAR), is an emerging technology to help advance the industry-wide movement towards autonomy and safety. To gain expertise on the architecture of these technologies and learn more about recommended devices such as the new specially-designed LMH34400 transimpedance amplifier, see the *Time of Flight and LiDAR – Optical Front-End Design* application brief.

Many famous films around the world show entertaining and intriguing, lifelike mobile robots navigating everyday surroundings. The robots range from androids, which can transform from an automobile into a fully functional robot with humanlike personalities, to simple robots with cameras for eyes, which allow them to come to life. What if these robots did not have a humanlike sentience to aid in movement but instead had to rely solely on electronics to navigate? Are cameras for eyes enough to move through our everyday world with all the unpredictable obstacles?

In a present-day automotive vehicle, it is easy to understand why it is beneficial to have all possible navigation methods available, not just cameras, to ensure the safety of the vehicle, passengers, and pedestrians. Using a suite of sensing modules, called sensor fusion, allows navigation methods such as LiDAR, RADAR, and cameras to work in parallel for maximum distance and velocity measurements. Sensor fusion also gives the vehicle the best view of obstacles in the environment surrounding the vehicle. But is that same level of safety needed in a robot like the ones in movies? If so, how does an engineer get started on this type of design? To answer these questions, this application brief provides some background into the differences between automotive versus industrial LiDAR and why it is beneficial to have in robotic design.

Automotive versus Industrial LiDAR

Automotive LiDAR is commonly found on commercial vehicles in the shape of a medium-sized puck on the top or side of the chassis, as Figure 1 demonstrates. These modules are often very complex, containing anywhere from 32 to 128 channels per

module and move at extremely high speeds. LiDAR modules found in automotive vehicles typically feature an optical Time-of-Flight (ToF) architecture with an Analog-to-Digital Converter (ADC) based system, which allows each module to gain additional information per channel but at the cost of a higher power consumption and size. For additional details into the architecture types, including an ADC-based system, see also the *Time of Flight and LIDAR* application brief. Systems containing an ADC are often referred to as *3D* or *4D* designs, based on the ability to create a 3- or 4-dimensional point-cloud of information. All together, these features allow the technology to get a better idea of what is around the vehicle in real-time.
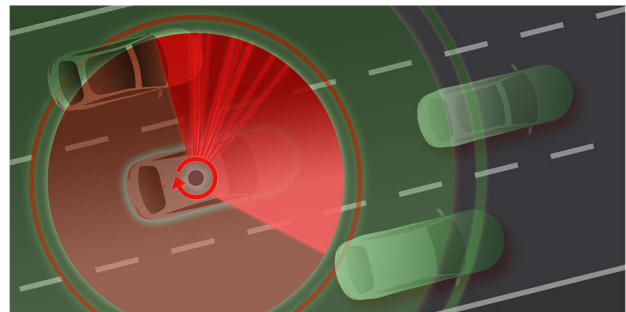

Figure 1. Automotive Vehicle With Mechanically Scanning LiDAR Module on the top, Center of the Chassis

Industrial LiDAR has the same technological fundamentals but often has fewer, or in some cases only one, channel per module. Additionally, many industrial LiDAR modules implement ToF architecture with a Time-to-Digital Converter (TDC) in replacement of an ADC resulting in fewer, more simplistic data points for a lower-power design. Because of the reduced complexity and size, industrial modules are often lower in both cost and power consumption while being easier to integrate into a robotic design. Some industrial modules do still use an ADC-based architecture but reduce the number of channels, for a design that balances the previously-mentioned trade-offs. Industrial LiDAR systems are most commonly placed in the *2D* or *1D* LiDAR category based on the ability to create a 2-dimensional point cloud or

just a single dimensional distance measurement. A few industrial applications that are currently deploying industrial LiDAR are traffic monitoring systems, port and terminal monitoring, distribution warehouse navigation and monitoring, autonomous mobile robots (AMR), autonomous industrial vehicles (AGV), and even some personal electronic applications such as smartphones and tablets.

What Benefit Does Industrial LiDAR Add for Robotics?

Now that there is an understanding on the difference between an automotive and industrial LiDAR unit, the question can be asked about why a LiDAR module is needed on an AMR? Why are cameras not enough? Robots are being designed to go new places and move more independently than ever. Imagine an AMR delivery unit is moving down a sidewalk in a neighborhood. There are houses along the street, with many day-to-day challenges such as cars, garbage bins, pedestrians, bikes, children's toys, and more. These are just a few of the many outside factors requiring long-term decisions or instant reactions that can impact the ability of the robot to complete a mission. It is important for the AMR to detect those obstacles, assess the potential impact, and react accordingly all in real-time for the safety of the community. The use of LiDAR makes sure that if a ball rolls onto the sidewalk, quickly cutting off the path of the robot, LiDAR has the necessary resolution and time response to sense the environmental change and react quickly to avoid collision and damage.

Figure 2. Autonomous Mobile Robots (AMR) Featuring a Mechanically Scanning LiDAR Module on the Top

Cameras can provide a high-resolution image; however, the cameras have poor distance measurements which is an important factor in

deciding if a robot can keep moving or if there is an obstacle and the robot needs to redirect.

Additionally, the robot needs to be able to work in all lighting conditions, such as a cloudy day or at night. LiDAR is not limited by lighting conditions nor does LiDAR require external illumination, a primary limitation to camera-based systems. This LiDAR feature allows the robot to perform well at all hours of the day.

How Do I Get Started?

How does a developer begin designing a robot? TI is the leader in integrated current-to-voltage transimpedance amplifiers (TIA) that are critical building blocks in the receiver analog front-end design of a LiDAR system. The LMH34400 features a single-ended output which is an excellent choice for a TDC-based design and includes unique features to make sure the device is safe and has enhanced sensitivity performance. This device allows implementation of a single-chip design between the photodiode and TDC, or the design can be paired with a high-speed comparator such as the TLV3801 for an even sharper signal rise time.

The LMH34400 also contains a suite of integrated components to decrease parasitic capacitances, overall size, and complexity of the system. For example, a 100mA protection clamp was designed to protect the amplifier and help the device recover quickly from an overloaded input condition. Remember the scenario where a ball rolls out right in front of the robot? This clamp helps make sure that the system is able to recover quickly from that potentially sharp input spike based on the sudden short-range object detection with minimal down time.

Additional integrated features on the LMH34400 include the following:

*   40kΩ transimpedance gain to remove the need for external passives thus making it easier to stabilize than with a discrete resistor
*   Ambient light cancellation (ALC) circuitry to filter out residual background level light that normally impacts the dynamic range of the receiver
*   Power-down mode that allows the device to be used in multichannel systems without the need for an additional discrete multiplexer (Figure 3).

All of these features are put in an ultra-small 5-pin SOT-5X3 package measuring only 1.60mm × 1.20mm, making this device an excellent choice for space-constrained and cost-sensitive projects such as an AMR.
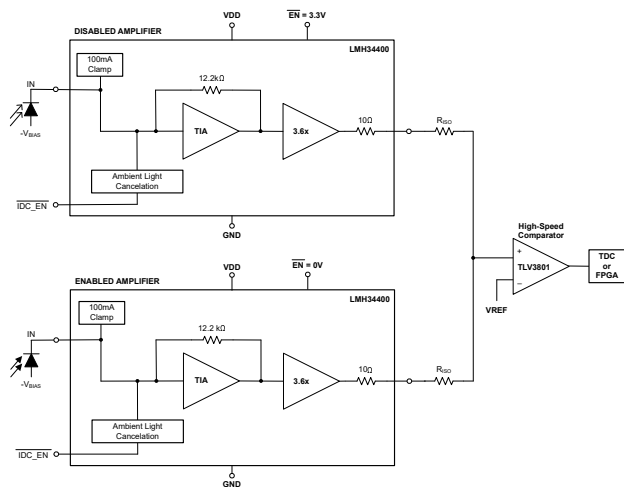

Figure 3. LMH34400 in a 2-Channel Multiplex Configuration With an Optional Comparator Into a TDC

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Conclusion

LiDAR is a critical part of the path towards mobile autonomy in both automotive and industrial vehicles. LiDAR provides the systems with key functionality such as object detection and collision avoidance in real-time, to help provide the safety of the surrounding environment and vehicle. Start a LiDAR design today by looking at TI's integrated transimpedance amplifiers or by talking to your local TI sales representative to learn more.

Additional Design Resources:
- Texas Instruments, *Time of Flight and LIDAR - Optical Front-End Design*
- Texas Instruments, *Maximizing transimpedance bandwidth for LIDAR and time-of-flight (ToF) applications*
- Texas Instruments, LiDAR Pulsed Time-of-Flight Reference Design Overview
- Texas Instruments, *An Introduction to Automotive LiDAR*
- Texas Instruments, *Application Guide - Industrial Mobile Robot*

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