LeddarEngine Fundamentals:
LCA2 and LCA3 LeddarCore SoCs and LeddarSP

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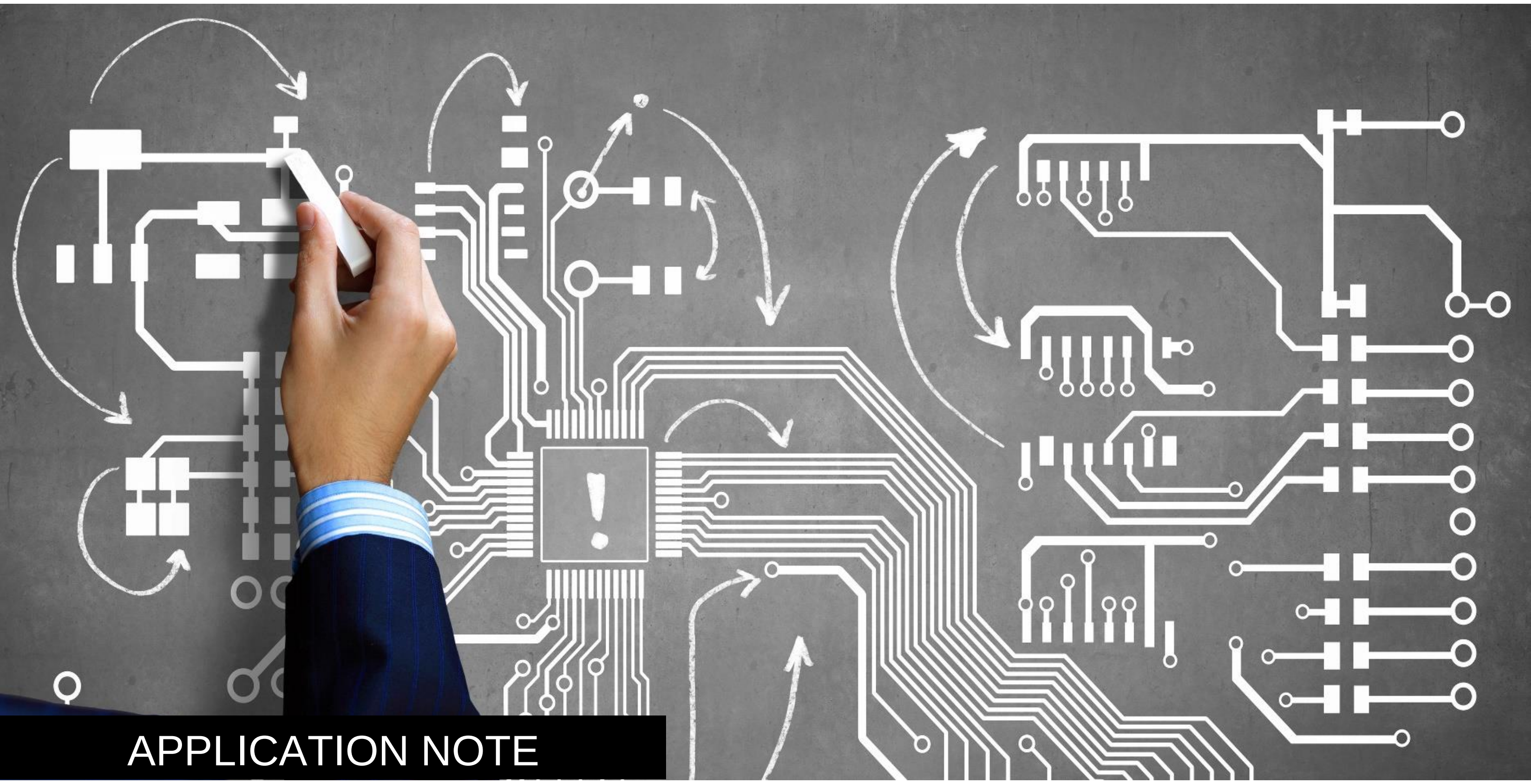

Abstract

The LCA2 & LCA3 LeddarCore™ Data Acquisition and Processing Systems on Chip (SoC) are the central hardware components of LeddarTech's® Automotive LiDAR Platform. Those two LiDAR SoCs are more than simple multi-channel data acquisition components: they act as light emission and acquisition timing controllers and perform a first layer of data pre-processing to maximize the performance of any LiDAR design based on light time of flight (ToF) measurements. An LCA2 or LCA3 LeddarCore works in parallel with the LeddarSP™ software library, which runs on a separate microcontroller (MCU). Advanced data analysis leading to high-accuracy and high-range distance measurements is performed by the LeddarSP within the MCU. The LeddarSP application programming interface (API) allows data access to any custom application co-implemented in the MCU. Together, the LeddarCore and the LeddarSP form the LeddarEngine™, designed according to ISO 26262 ASIL-B.

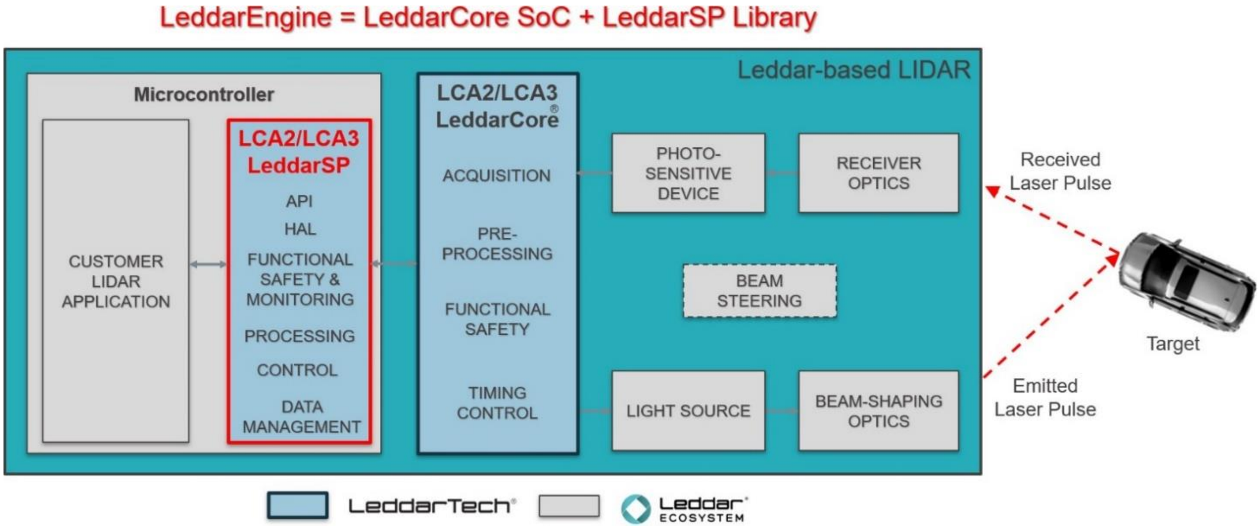

Figure 1 – Block diagram of a LiDAR based on the LeddarEngine

LCA2 & LCA3 LeddarCore

The LeddarCore LCA2 & LCA3 perform similar signal acquisition functions, that is, (1) converting current inputs from photodetector cells into amplified voltage signals, (2) sampling those signals in the digital domain through high-speed ADCs, (3) controlling the emission and acquisition timings to build waveforms having a laser trigger timing reference, (4) pre-processing the data through patented waveform combination techniques, and finally (5) transferring the pre-processed waveform data to the LeddarSP host MCU for time-of-flight calculations. On top of that, additional monitoring and testing features associated with the LiDAR functional safety are handled by the LCA2 & LCA3 LeddarCore SoCs. The different LeddarCore functional blocks are presented in Figure 2.

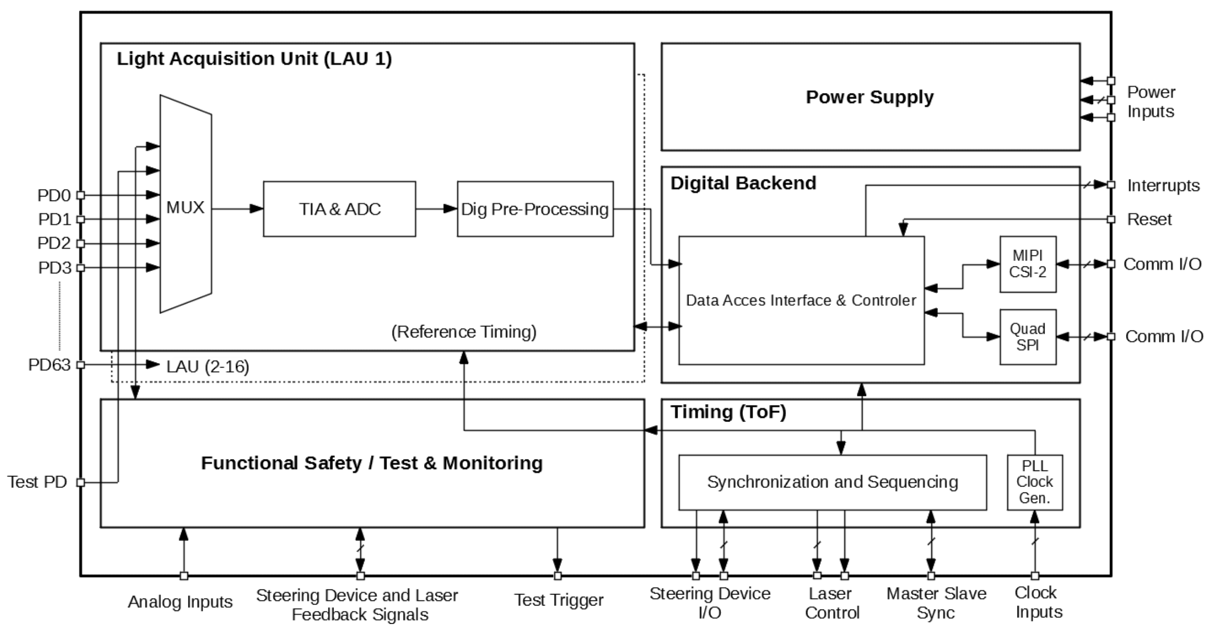

Figure 2 – LCA3 block diagram

Two Generations of LeddarCore

As detailed in Table 1, the main differences between these two generations of LeddarCore SoC are found in the ADC sampling performance, the memory capacity, and the data transfer rate. The LCA3 also features an emission steering synchronization capability which is not included with the LCA2. When enabling this feature, the LCA3 can perform data acquisition following specific laser-aiming position inputs and store this data with a specific emission steering angle index. This capability, when combined to a MEMS micro-mirror control and synchronization interface, allows to synchronize the data acquisition with a resonant MEMS steering device and perform the multi-waveform pre-processing throughout multiple mirror oscillations. Both generations of SoC feature a master-slave mode to expand the number of channels through multi-LeddarCore architectures.

Table 1 – LCA2 & LCA3 general specifications

Feature	LCA2 LeddarEngine	LCA3 LeddarEngine
Number of channels	32	64
Number of parallel acquisitions (# of waveforms/laser pulse)	16	16
Multi-LeddarCore architectures	Yes	Yes
Sampling rate per channel	100 MSps	320 MSps
Emission steering control and segment index attribution on the steering axis	MCU	LCA3 or MCU
Resonant MEMS mirror sync & control	No	Yes
Waveform data transfer	QSPI up to 200 MBps[1]	CSI up to 10 GBps[2]
Command & diagnostic communication	SPI	SPI

Signal Digitalization and Multi-Waveform Combination Pre-Processing

One of the key features of the LeddarCore SoC is the ability to sequence and combine multiple waveforms to either increase the light echo's signal-to-noise ratio (SNR) through accumulation or the echo sampling rate through oversampling. The LeddarCore's parallel photodiode inputs enable multi-channel acquisitions following a single laser pulse, which represents an edge to apply accumulation and oversampling out of a limited laser pulse budget.

The eye safety requirement and available laser technology performances limit the maximum laser pulse width and peak intensity that can be emitted by the LiDAR and delivered on the target. Having the ability to increase the SNR

1 Typical LiDAR throughput using a single LCA2 (50% QSPI overhead): 32 x 16 channels, 120 m instrumented range at 25 Hz frame rate.

2 Typical LiDAR throughput using a single LCA3 (50% CSI overhead): 64 x 300 channels, 250 m instrumented range at 25 Hz frame rate.

by allocating multiple pulses to a single detection allows us to push the LiDAR range performance above the limits driven by hardware and eye safety. While performing the accumulation and oversampling, the LeddarCore compares the waveforms together and can identify and discard any random and non-synchronized signal originating from another LiDAR, hence mitigating possible interference. Averaging over multiple waveforms also has significant advantages associated with the echo amplitude stability and to the mitigation of random environmental events (for example, non-synchronized water droplets or snowflakes passing through the field of view).

These oversampling and accumulation approaches for LiDAR applications are exclusive to LeddarTech and are protected by patents.

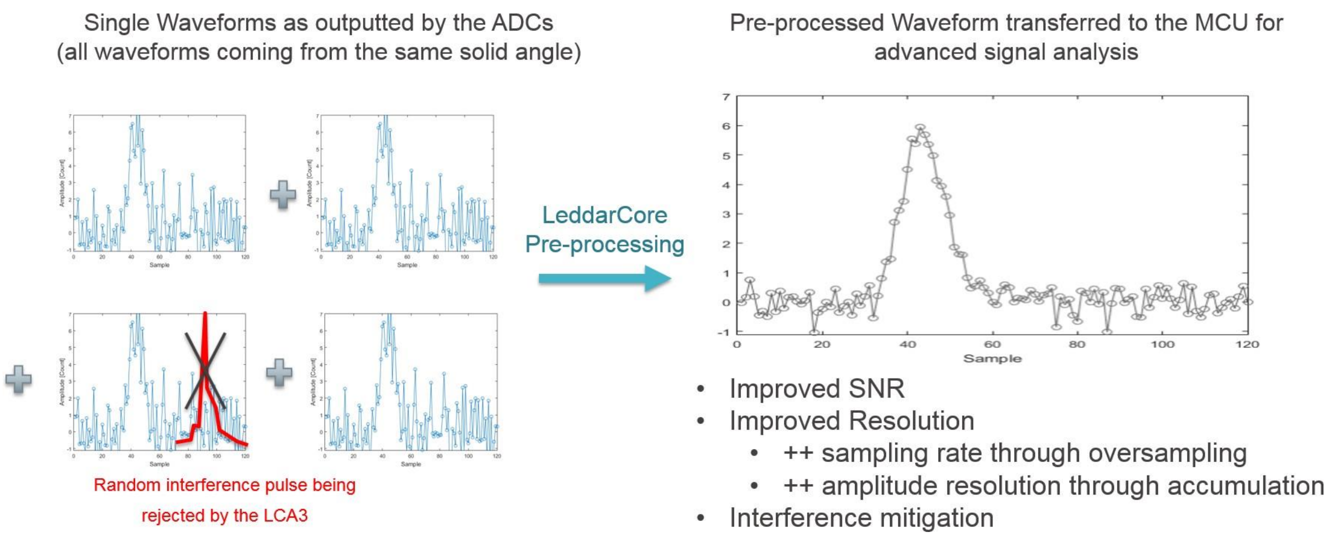

Figure 3 – Improving the light echo's waveform SNR and resolution + mitigating interference through patented multi-waveform combination techniques

Functional Safety: Testing and Monitoring Features

Driving the laser triggering and light acquisition sequencing, the LeddarCore is interfaced with important LiDAR components. In addition to its standard acquisition functions, the LeddarCore tests and monitors those LiDAR components. Extra inputs and outputs have been integrated to monitor the integrity of the laser source and photodetector cells, as well as their respective power supplies. A predefined testing sequence using a safety photodetector enables real-time laser optical power monitoring. On the receiver side, a safety dedicated LED can be triggered to provide a reference illumination signal.

LeddarSP Software Processing Library

The LeddarSP software runs on a host MCU. At the system level, its main functions are to drive the LeddarCore and to generate the "segment cloud" out of the sets of digitalized waveforms received from the LeddarCore. For every channel index associated with a specific solid angle in the FoV, the LeddarSP goes over the pre-processed waveform and determines if it contains one or many echoes associated with facing obstacles. For every detection, the LeddarSP outputs the distance, the echo amplitude, the time stamp, as well as some signal quality attributes and flags.

LeddarSP is capable of performing multiple layers of signal processing over the full waveforms, further improving the SNR and amplitude dynamic range. It also offers flexibility, allowing it to adapt to any desired frame size and to tweak the signal processing algorithms based on a given system architecture and its associated selection of hardware components.

Signal Processing Algorithms

LeddarTech has developed several generations of solid-state LiDARs based on different wide-beam approaches ("flash" illumination) since 2007. The usage of non-collimated sources and fixed receiver head collecting light over a wide FoV is particularly challenging. Consequently, LeddarTech has developed a strong expertise in retrieving dim levels of signal in noisy environments through full waveform analysis algorithmic methods. The most advanced Leddar algorithms are packaged into a software library and made available in the LeddarEngine.

Here are some examples of signal processing features handled by the LeddarSP: waveform filtering, static noise compensation, temperature compensation, echoes peak interpolation, echoes demerging, saturation management, cross-talk mitigation, etc. Alone, the waveform filtering at the LeddarSP stage reduces the equivalent input-referred noise of hardware by a minimum of 9 dB up to 11 dB.

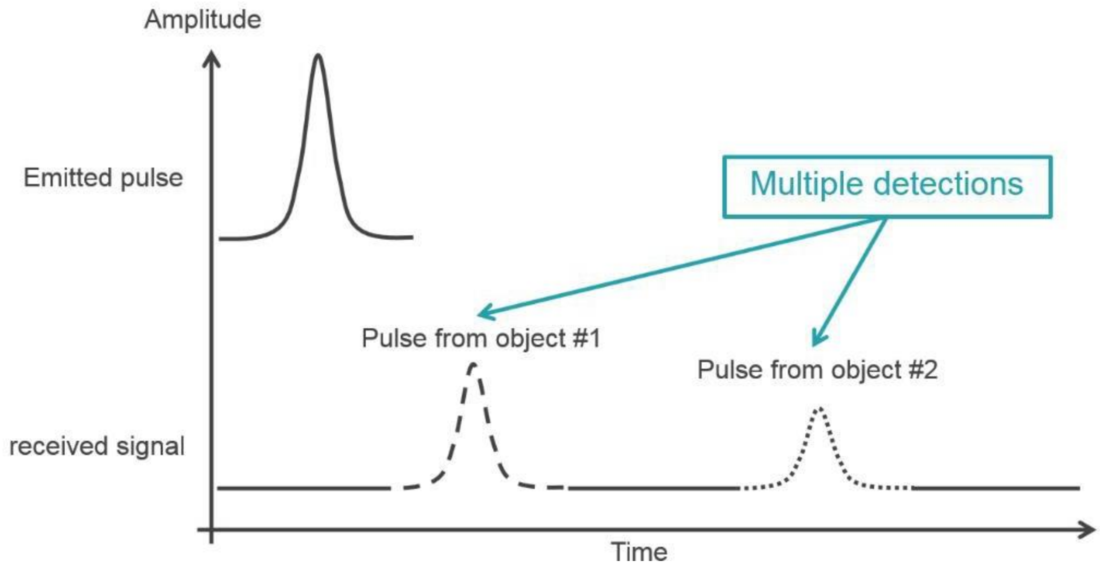

Figure 4 – Data processing of full traces allows multi-object detections

Analyzing the full signal waveforms, the LeddarSP can output multiple detections per segment (Figure 4). When considering saturation management, the peak extrapolation algorithm, which is based on the waveform signature, enables an amplitude dynamic range above the hardware limitations: 95 dB for the LCA2 and 104 dB for the LCA3. Finally, an accurate measurement of the saturated echoes' amplitude using full-waveform extrapolation techniques allows for better application of electrical and optical cross-talk corrections. Those features are presented in Figure 5.

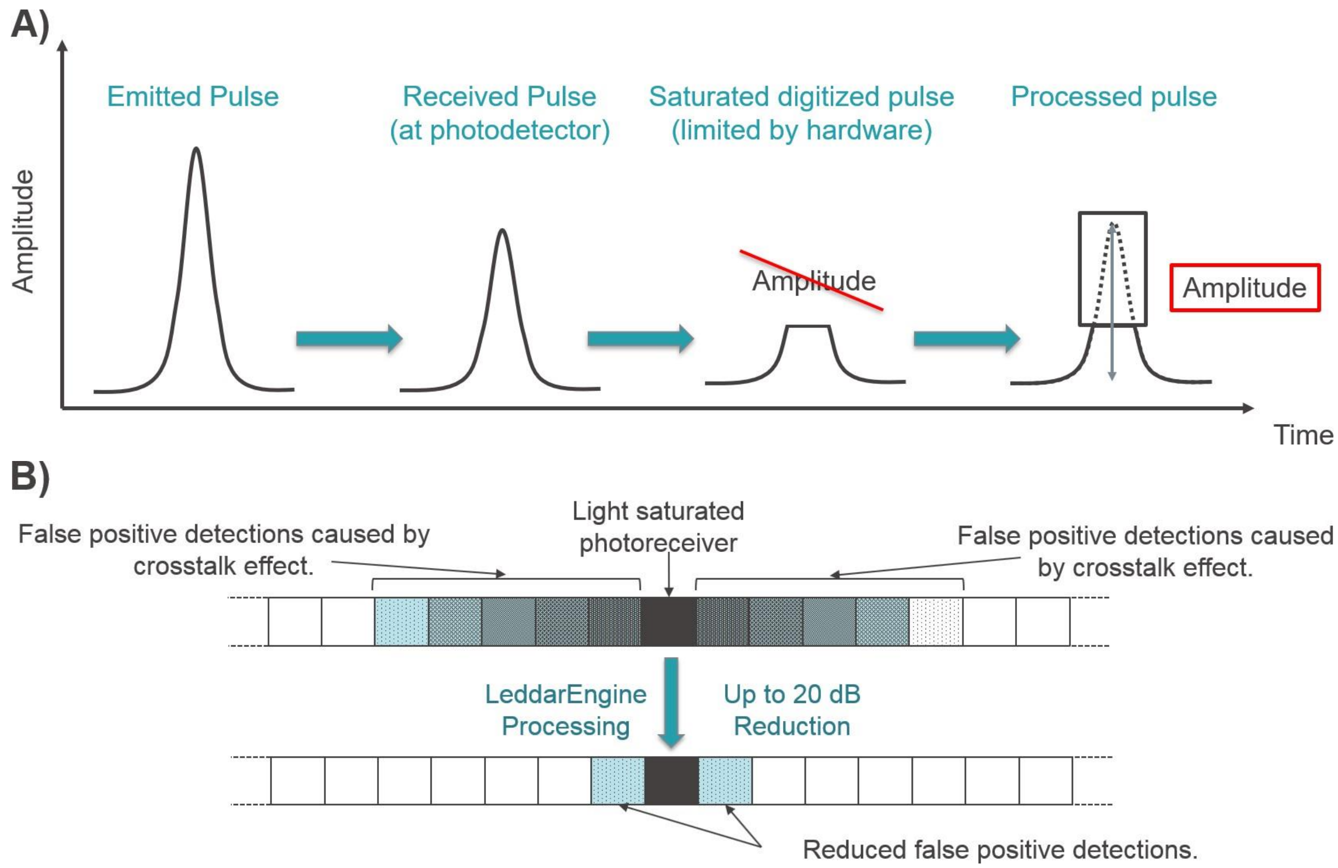

Figure 5 – Saturation management (A) and cross-talk mitigation (B)

API & Customer Application

The LeddarSP application programming interface (API) presents all the functions and methods needed to retrieve detection from the LeddarEngine. Its format was selected to make the LeddarSP simple to integrate with the customer LiDAR application. Its role is to abstract most technical changes in the LeddarEngine so that the LiDAR application is not impacted by these changes. Figure 6 on next page presents a high-level block diagram of the LeddarSP within the host microcontroller.

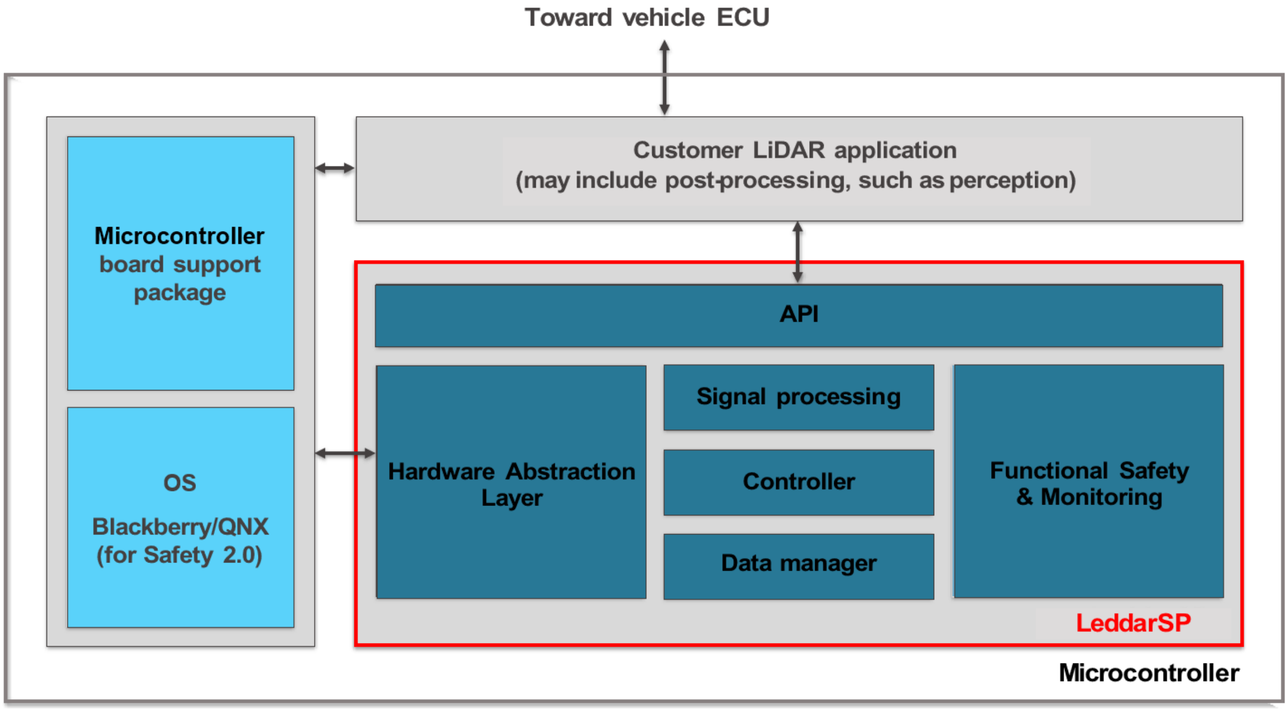

Figure 6 – LeddarSP overview

LeddarEngine Differentiation and Evolution

Among the competitive advantages offered by the LeddarEngine, it is important to first mention the reduction of cost and size of analog components and logic through their integration into the LeddarCore SoC. Also, the LeddarEngine solution designed according to ISO 26262 ASIL-B enhances the performances of any ToF LiDAR concept based on digital signal processing approaches.

At the LeddarCore SoC level, the ability to simultaneously acquire 16 waveforms allows LiDARs to gain SNR and distance accuracy through accumulation and oversampling techniques without compromising the 20-30 Hz targeted frame rate. At the LeddarSP level, the successive layers of full-waveform data processing enable multi-object detections, further SNR improvements, an expansion of the dynamic range over 100 dB, cross-talk corrections, as well as a set of detection quality and diagnostic features. Finally, the flexibility of the LeddarEngine gives the opportunity for LiDAR development partners to select their preferred architecture and set of hardware, to couple it to the SoC dedicated to signal acquisition and functional safety, and to benefit from a state-of-the-art signal processing library, accelerating drastically their LiDAR design's time to market. The efficiency and performance of the algorithms are continuously evolving, and new functions are being developed to address the market demand for perception tools.

Manufacturers and system designers developing and commercializing LiDARs based on the LeddarEngine benefit from an evolutive platform that allows them to stay at the leading edge of the LiDAR technology and leverage the breakthroughs in the semiconductor industry while keeping continuity in their software packaging through the standardized LeddarEngine's API.

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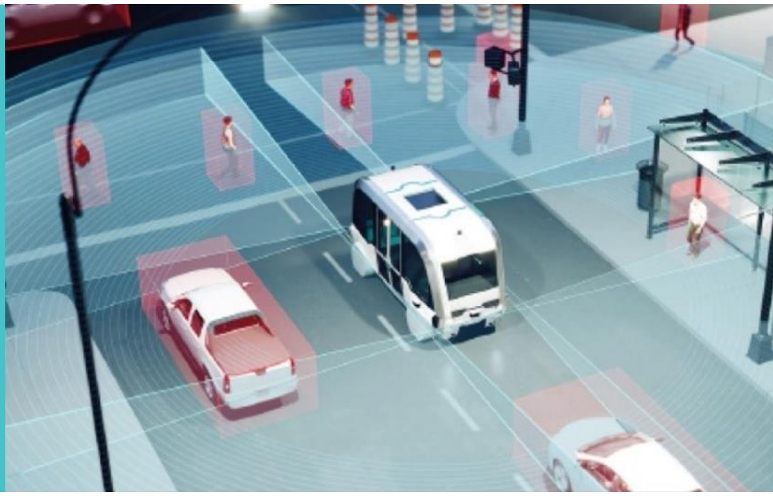
About LeddarTech

LeddarTech is a leader in environmental sensing platforms for autonomous vehicles and advanced driver assistance systems. Founded in 2007, LeddarTech has evolved to become a comprehensive end-to-end environmental sensing company by enabling customers to solve critical sensing and perception challenges across the entire value chain of the automotive and mobility market segments. With its LeddarVision™ sensor-fusion and perception platform and its cost-effective, scalable, and versatile LiDAR development solution for automotive-grade solid-state LiDARs based on the LeddarEngine™, LeddarTech enables Tier 1-2 automotive system integrators to develop full-stack sensing solutions for autonomy level 1 to 5. These solutions are actively deployed in autonomous shuttle, truck, bus, delivery vehicle, smart city/factory, and robotaxi applications. The company is responsible for several innovations in cutting-edge automotive and mobility remote-sensing applications, with over 95 patented technologies (granted or pending) enhancing ADAS and autonomous driving capabilities.

For more information: sales@leddartech.com



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