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Enhancing LiDAR Performance Using Multi-LCA2 Architectures

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Abstract

The LeddarCore™ LCA2 data acquisition and processing SoC is the central hardware component of LeddarTech's® automotive LiDAR platform. The LCA2 SoC is a multi-channel LiDAR front end for object detection in advanced driver assistance systems (ADAS), autonomous driving (AD) or other applications. Associated with the LeddarSP™ software library, they form the LeddarEngine™ LCA2, which uses the time-of-flight principle of light pulses reflected by one or more objects to measure the distance between the LiDAR and detected objects.

Each LCA2 SoC has 32 parallel light acquisition channels that amplify, sample and process the reflected light pulse signals converted by photodetectors. The SYNC feature allows for the operation of two LCA2 SoCs in master-slave mode to increase the number of parallel light acquisition channels to 64. The purpose of this White Paper is to provide an overview of a multi-LCA2 SoC architecture, specifically in the context of using two LeddarCore LCA2 SoCs, and the performance benefits associated with this configuration.

Table of Contents

1. Single LCA2 Architecture

1.1. Typical Architecture

Before providing an overview of how multi-LCA2 architectures are configured, it is important to outline a typical architecture configuration using the LeddarCore LCA2 SoC. The LCA2 3D Flash Evaluation Kit system architecture and frame construct are presented in Figure 1 and Figure 2. This architecture integrates a single LCA2 SoC and is used as a reference throughout this paper.

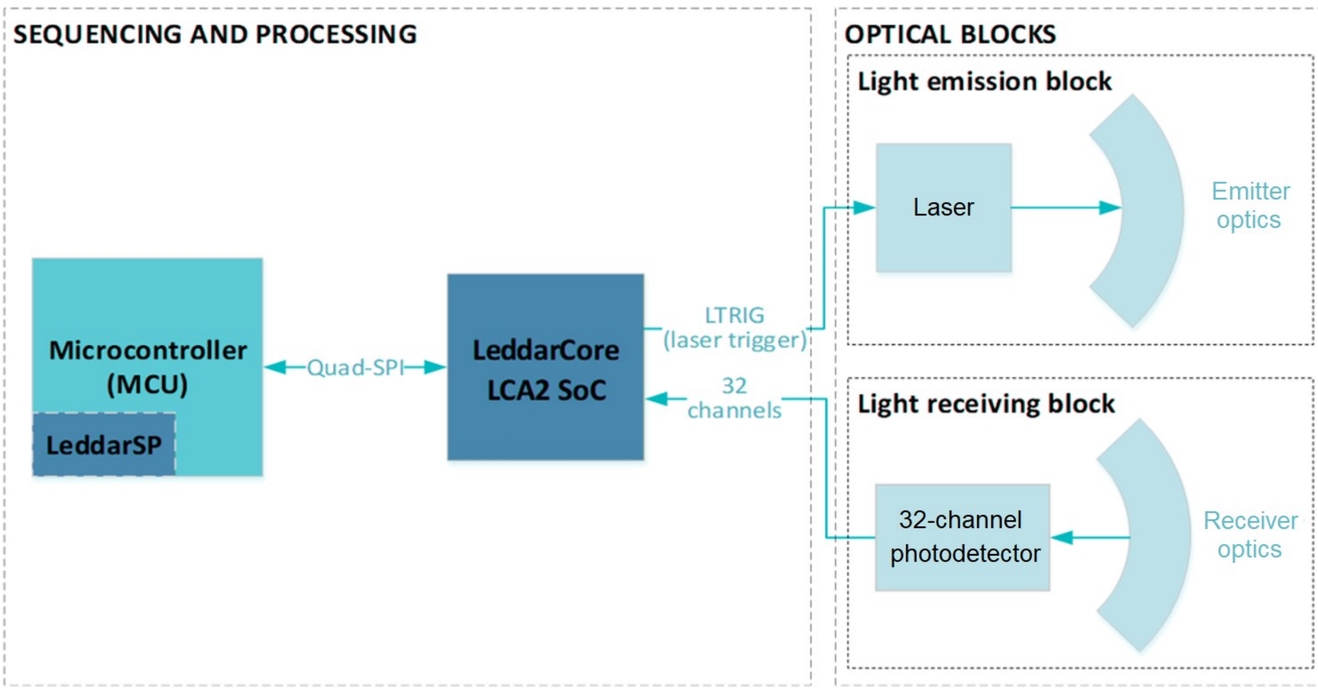


Figure 1 – LCA2 3D Flash Evaluation Kit system architecture (single LCA2 SoC)

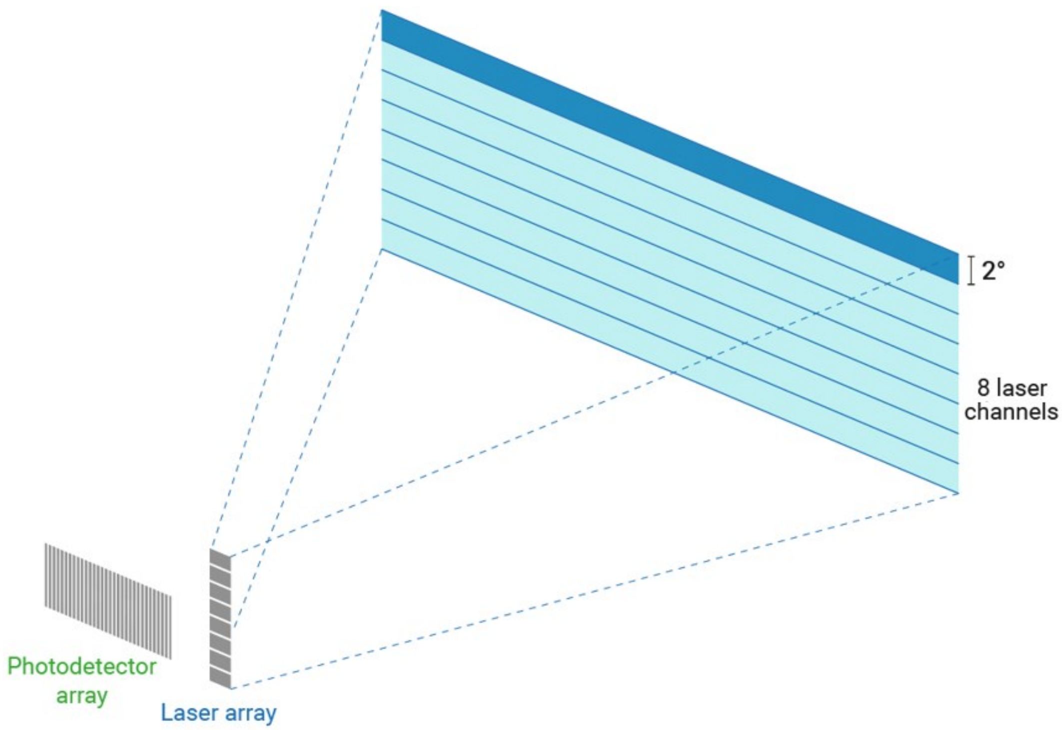
The Leddar™ sensor architecture consists of the following sub-systems:

1. Sequencing and processing:
   i. **LCA2 SoC**: Also referred to as LeddarCore, the LCA2 SoC is responsible for timing control, signal acquisition and pre-processing (accumulation, oversampling, interference mitigation).
   ii. **Microcontroller**: Also referred to as the MCU, the microcontroller includes the LeddarSP signal processing software library and is responsible for waveform processing, surface cloud generation and other LiDAR functionalities, such as safety management and monitoring.

2. Optical blocks:
   i. **Light emission block**: This sub-system is comprised of a laser and emitter optics and is responsible for emitting and shaping light pulses that will sequentially illuminate the full field of view (FoV).
   ii. **Light receiving block**: This sub-system is comprised of the receiver optics and the photodetector and is responsible for collecting and converting light pulses into electrical signals that can be read by the LCA2 SoC.

In this architecture, the LCA2 SoC sends a “laser trigger” (LTRIG) command to the laser. The laser emits a light pulse that goes through the emitter optics and ends up being shaped to fit the LiDAR field of view and resolution requirements. The beam hits objects in the scene and reflects back to the sensor unit. The receiver optics capture this returning light pulse and focus it on the photodetector array, where each of the 32 channels is associated with a specific area of the scene.

The LCA2 3D Flash Evaluation Kit is comprised of 8 laser channels, with each channel illuminating a distinct portion of the field of view (e.g., 60° x 2° horizontal laser lines stacked on top of each other). On the receiving end, the 32 photodetector channels, combined with the receiver optics, provide a 1.9° resolution on the horizontal axis. The resulting frame layout is shown in Figure 2.



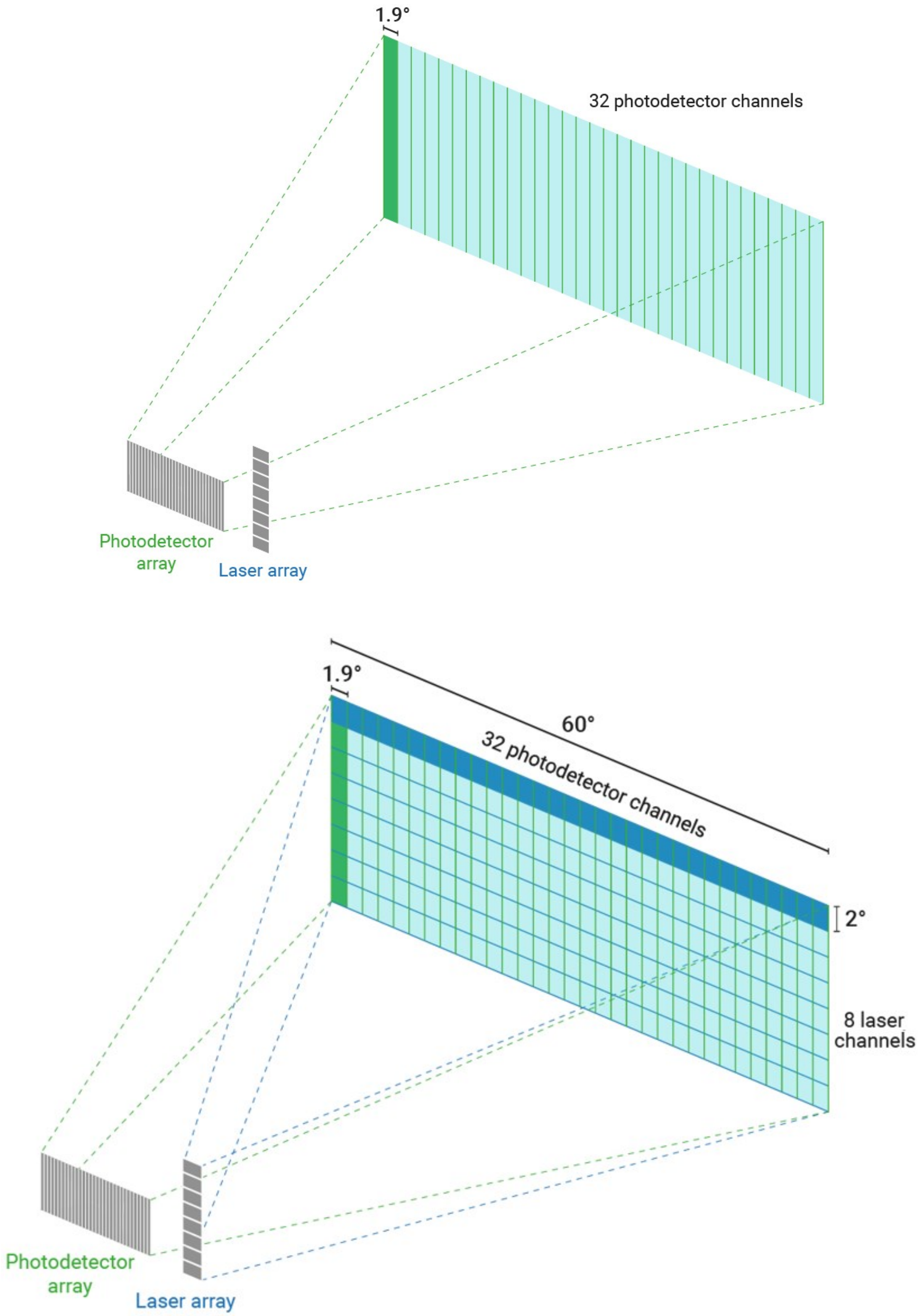


Figure 2 – LCA2 3D Flash Evaluation Kit frame layout (single LCA2 SoC)

The specifications for the LCA2 3D Flash Evaluation Kit are listed below:

- Horizontal field of view (HFoV): 60°
- Vertical field of view (VFoV): 16°
- Horizontal segments: 32 (photodetector array in the horizontal axis)
- Vertical segments: 8 (laser channels sequentially pulsed in the vertical axis)
- Horizontal resolution: 1.9°
- Vertical resolution: 2°
- Frame rate: 20 Hz (using acquisition parameters: Accumulation 64, Oversampling 4)

The master-slave architectures that will be presented in this paper are simple adaptations of the LCA2 3D Flash Evaluation Kit system concept. The specifications outlined above can be used as a baseline to highlight the performance enhancements linked to an increase in the number of LCA2 SoCs.

1.2. General Considerations

1.2.1. Laser Selection and Trigger

It is important to note that the MCU controls the selection of an appropriate laser channel. However, the LCA2 SoC controls the laser trigger and laser charging sequence.

1.2.2. Clock Input

An external clock signal oscillator with low periodic jitter (~1 ns) must be supplied at the RCLK pin of the LCA2 SoC. This external oscillator should be automotive-qualified and have a 25 MHz oscillating frequency. The oscillator will be used in an internal PLL to generate a 200 MHz system clock in the LCA2 SoC.

The total performance of the whole LiDAR system is directly related to the periodic jitter. Signal edges need to be both fast and stable. Therefore, the external oscillator needs to be connected via a microstrip trace as close as possible (e.g., <10 mm) to the LCA2 LeddarCore SoC, thereby minimizing trace capacitance.

1.2.3. Communication With the Microcontroller

The LeddarCore LCA2 SoC must be used in conjunction with the LeddarSP Software Library running on a compatible host MCU. The LCA2 SoC is executing acquisition and pre-processing of the digitized waveform (accumulation, oversampling, interference mitigation). It then transfers the data to the MCU for additional processing and surface cloud generation.

A 50 MHz Quad-SPI interface (also denoted QSPI) is used to transfer data from the LCA2 SoC to the MCU. This 50 MHz transfer frequency gives a maximum data rate of 200 MB/s on the QSPI interface.

2. Master-Slave Architectures

The default configuration of an LCA2 SoC is its “stand-alone” mode, which is to be used in a single SoC architecture. However, this mode can be switched to a “master” or a “slave” mode when having a multi-LCA2 architecture.

Using multiple LCA2 SoCs in the “master-slave” mode increases the number of available input channels, as well as the data transfer capabilities. At the system level, this can result in either one of the following key improvements:

- Increased field of view
- Increased resolution
- Increased frame rate

In this section, master-slave architectures will be presented using one master and one slave. It is possible to utilize a multi-LCA2 architecture using three or more SoCs to reach a larger field of view or better resolution. In this case, it will be necessary to add external logic components like an FPGA to synchronize the LCA2 SoCs.

If you are interested in exploring this architecture configuration, please contact a LeddarTech representative.

2.1. Master-Slave Architecture Configuration and Associated Benefits

2.1.1. Increased Field of View

A single LCA2 SoC can be connected to a 32-channel photodetector. By using two LCA2 SoCs in a master-slave configuration, the number of available input channels is doubled, which allows for up to 64 photodetector channels to be connected to the system. An example of master-slave architecture is shown in Figure 3.

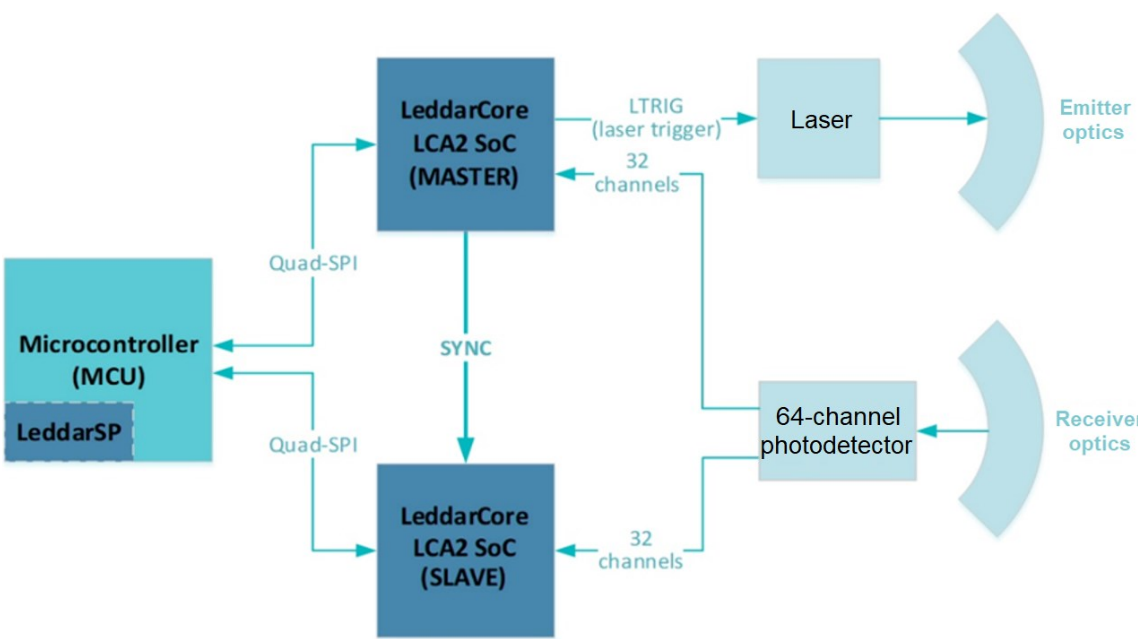


Figure 3 – LCA2 master-slave architecture configuration (64 channel photodetector)

As previously explained in Figure 2, the photodetector array is aligned on the horizontal axis. Considering that each photodetector channel still covers 1.9°, doubling the number of photodetector channels is equivalent to enlarging the horizontal field of view by a factor of two (from 60° to 120°). The frame layout associated with this change in the field of view is shown in Figure 4.

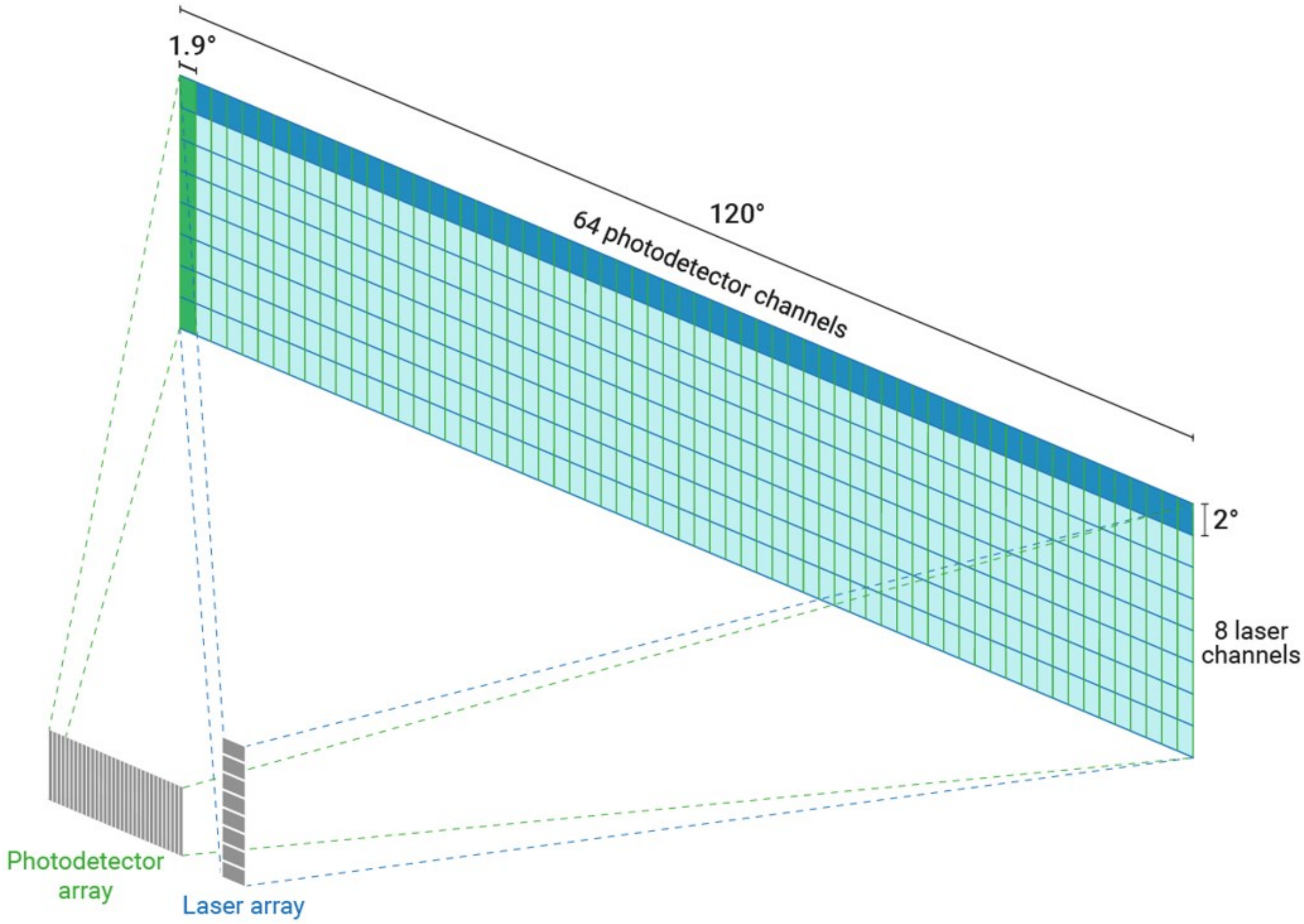


Figure 4 – Master-slave LCA2 architecture frame layout for 64 channels with an enlarged horizontal field of view

The features of the frame layout in Figure 4 are outlined as follows:

- **Horizontal field of view (HFoV): 120°**
- Vertical field of view (VFoV): 16°
- **Horizontal segments: 64** (photodetector array in the horizontal axis)
- Vertical segments: 8 (laser channels sequentially pulsed in the vertical axis)
- Horizontal resolution: 1.9°
- Vertical resolution: 2°
- Frame rate: 20 Hz (using acquisition parameters: Accumulation 64, Oversampling 4)

2.1.2. Increased Resolution

Another way to benefit from an increased number of photodetectors at the system performance level is to improve the resolution. Considering that the horizontal field of view still covers 60°, doubling the number of photodetector channels will improve horizontal resolution by a factor of 2. The frame layout associated with this change in resolution is presented in Figure 5.

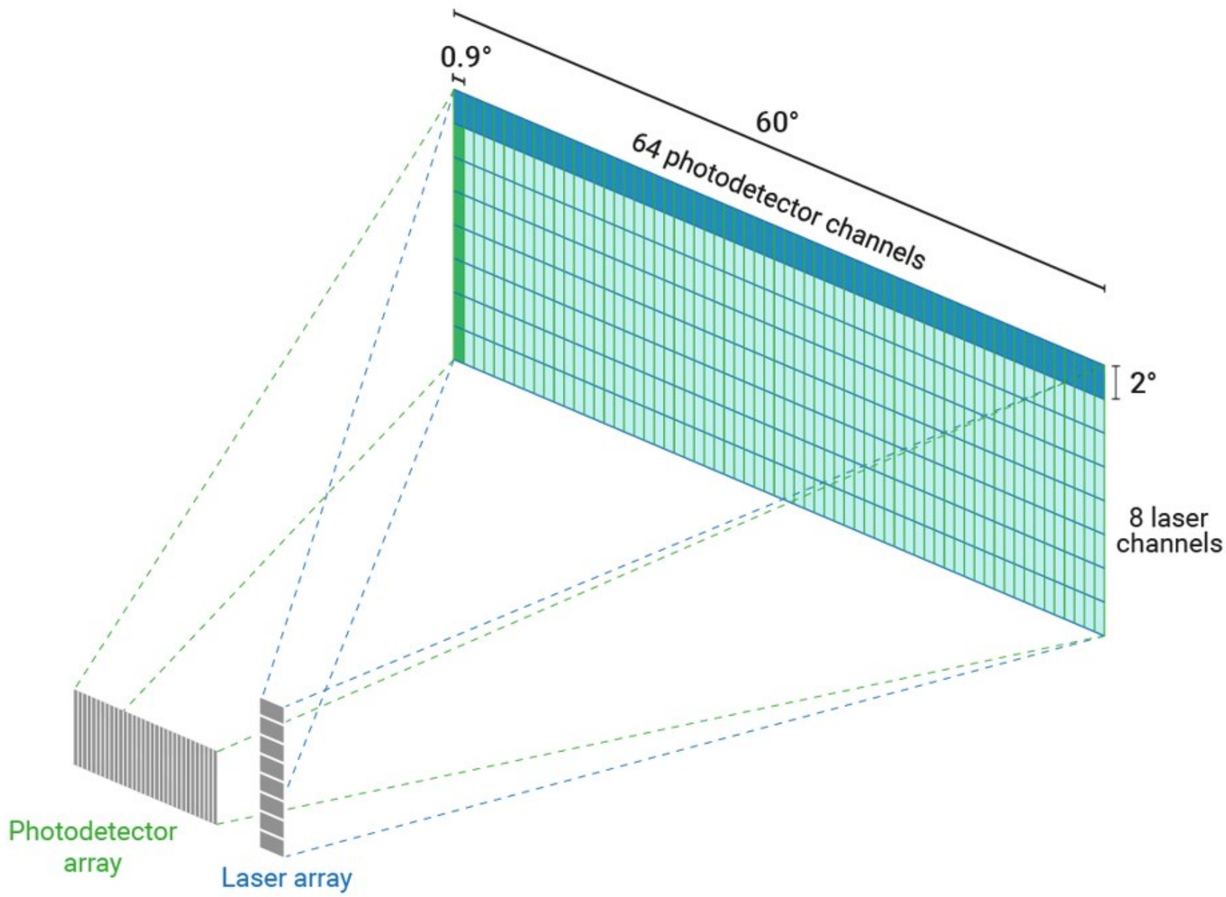


Figure 5 – Master-slave LCA2 architecture frame layout for 64 channels with an increased horizontal resolution

The features of the frame layout in Figure 5 are outlined as follows:

- Horizontal field of view (HFoV): 60°
- Vertical field of view (VFoV): 16°
- **Horizontal segments: 64** (photodetector array in the horizontal axis)
- Vertical segments: 8 (laser channels sequentially pulsed in the vertical axis)
- **Horizontal resolution: 0.9°**
- Vertical resolution: 2°
- Frame rate: 20 Hz (using acquisition parameters: Accumulation 64, Oversampling 4)

2.1.3. Increased Frame Rate

A master-slave architecture can also be used to connect two LCA2 SoCs to a 32-channel photodetector, splitting the photodetector channels to be connected to the LCA2 SoCs (see Figure 6). This provides each LCA2 SoC with 16 photodetector channels (instead of 32 for a single LCA2 SoC architecture), which in turn increases the frame rate.

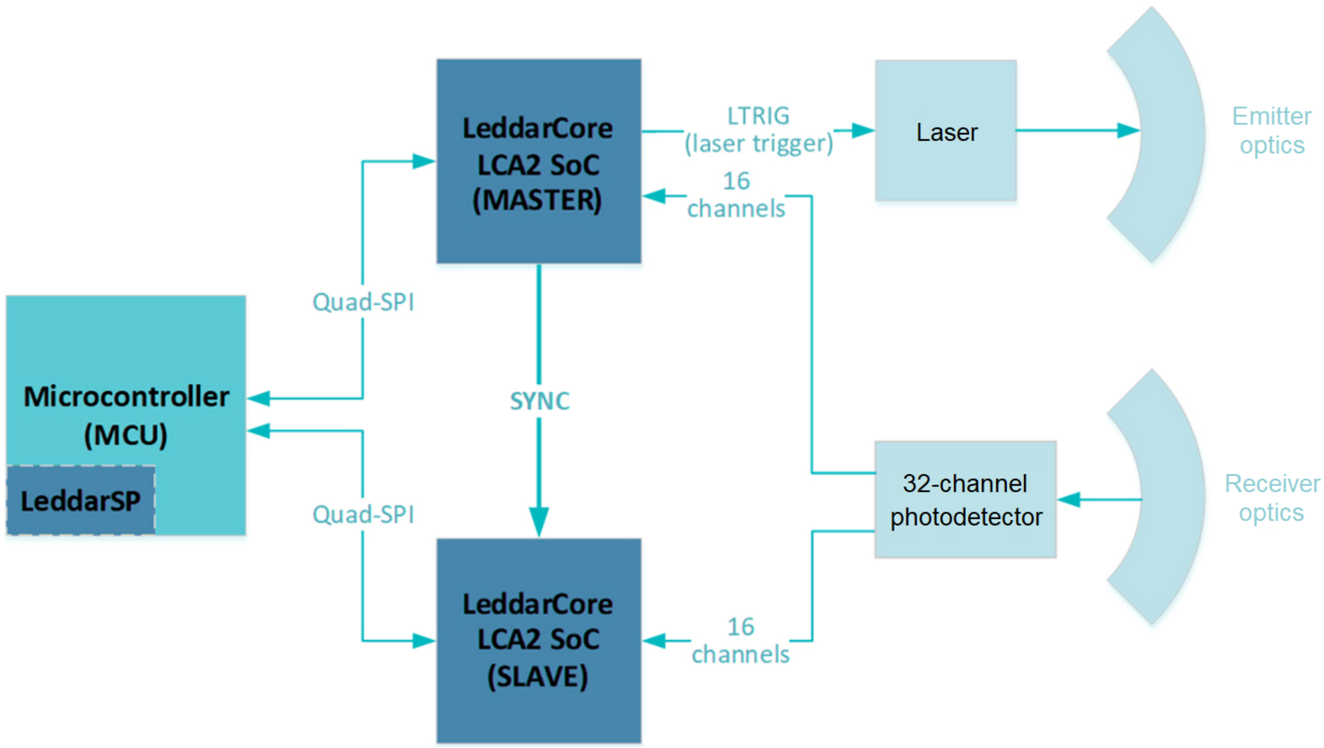


Figure 6 – LCA2 master-slave architecture configuration on a 32-channel photodetector

The frame layout will be the same as with a single LCA2 SoC (see Figure 2). However, the frame rate will be higher since each LCA2 SoC will have half the photodetector channels to perform acquisition and processing; as a result, the configuration will be capable of outputting waveforms twice as fast:

- Horizontal field of view (HFoV): 60°
- Vertical field of view (VFoV): 16°
- Horizontal segments: 32 (photodetector array in the horizontal axis)
- Vertical segments: 8 (laser channels sequentially pulsed in the vertical axis)
- Horizontal resolution: 1.9°
- Vertical resolution: 2°
- **Frame rate: 40 Hz** (using acquisition parameters: Accumulation 64, Oversampling 4)

2.2. Master-Slave Mode: General Considerations

2.2.1. Laser and Photodetector

In a master-slave architecture, only the master LCA2 SoC triggers the laser diodes that light the scene. Both the master and slave LCA2 SoCs are used to acquire and process the photodetector(s) current pulses (refer to Figure 3 and Figure 6). The master informs the slave of the laser trigger timing through the SYNC pin (see 2.2.4 below).

2.2.2. Clock Input

When using two LCA2 SoCs in the master-slave mode, the clock generator needs to be synchronously shared by both SoCs. The clock signal needs to be routed to both RCLK inputs with the same signal delay using a symmetrical "Y" or "T" layout. The clock chip needs to be placed in the middle, or an identical signal path length needs to be set by adjusting the PCB routing. Any difference in propagation delay translates to a distance error in the time-of-flight measurement. The RCLK signals of master and slave mode LCA2 SoCs need to be phased synchronously, so it is not possible to use two dedicated clock oscillators in this configuration.

2.2.3. Master-Slave Mode Designation

To designate an LCA2 SoC as a master or as a slave, it needs to be programmed in the LiDAR application in the MCU of a given master-slave LCA2-based system. LeddarSP will then send this configuration to the appropriate register of the respective LCA2 SoCs during the initialization of the system at power-up.

2.2.4. Master-Slave Mode Synchronization

The SYNC pulse (made available on the SYNC pin of the LCA2 SoC) is used for controlling LCA2 SoCs in a master-slave configuration.

- If the LCA2 SoC is configured as a master, the SYNC pin is working as a digital output. This master LCA2 SoC will provide a SYNC pulse once it is ready to start a measurement cycle.
- If the LCA2 SoC is configured as a slave, the SYNC pin is working as a digital input. It will receive the SYNC pulse from the master to execute its measurement cycle synchronously.

2.2.5. Communication With Microcontroller

Both LCA2 SoCs (in master and slave mode) will transfer data to the MCU synchronously using their respective QSPI interface (refer to Figure 3). On the MCU side, a Dual QSPI interface is receiving the data. The transfer rate between LCA2 SoCs and MCU is still 50 MHz, providing a maximum data rate of 400 MB/s.

2.2.6. Optical Component Adaptations

Changes to the field of view or resolution may imply changes in the optical components for the light to be emitted and received accordingly. Enlarging the field of view will require replacing the light diffuser (part of the light emission block) to spread light over a wider area. Both enlarging the field of view and increasing the resolution may require the receiver optics to be redesigned to ensure appropriate imaging performance on the photodetector.

3. Conclusion

The purpose of this paper was to provide an overview of a multi-LCA2 SoC architecture, specifically in the context of using two LeddarCore LCA2 SoCs, and the performance benefits associated with this configuration. Before that, the basics of multi-LCA2 SoC architecture configuration were explained. Some concepts using two LCA2 SoCs in a master-slave mode configuration have been used to demonstrate the benefits of using multiple LeddarCore units to achieve higher performance.

Although the emphasis of this White Paper has been on using two LCA2 SoCs, it is also possible to use three or more LCA2 SoCs in a multi-chip concept to further increase capabilities.

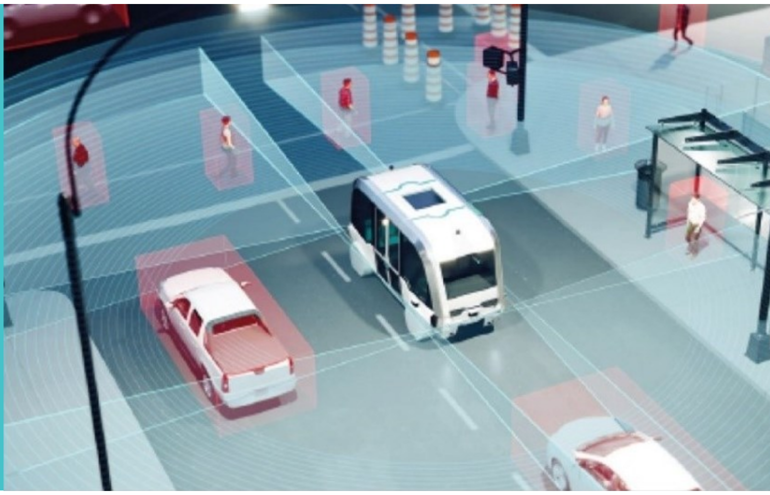
If you are interested in exploring multi-LCA2 SoC architectures, please contact a LeddarTech representative to obtain additional information.

This White Paper does not constitute a reference design. The recommendations contained herein are provided as-is and do not constitute a guarantee of completeness or correctness.

About LeddarTech

LeddarTech provides the most flexible, robust and accurate sensing technology for advanced driver assistance systems (ADAS) and autonomous driving (AD). LeddarTech enables customers to solve critical environmental sensing, fusion and perception challenges across the entire value chain. The company offers cost-effective, scalable solutions such as LeddarVision™, a raw-data sensor fusion and perception platform that generates a comprehensive 3D environmental model with multi-sensor support for camera, radar and LiDAR configurations. LeddarTech supports LiDAR makers and Tier 1-2 automotive system integrators with LeddarSteer™, a digital beam steering device, and the LiDAR XLRator development solution for automotive-grade solid-state LiDAR based on the LeddarEngine™ and core components from global semiconductor partners. LeddarTech is responsible for several cutting-edge remote-sensing innovations, with over 100 patented technologies (granted or pending) enhancing ADAS and autonomous driving capabilities.

For more information: sales@leddartech.com



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