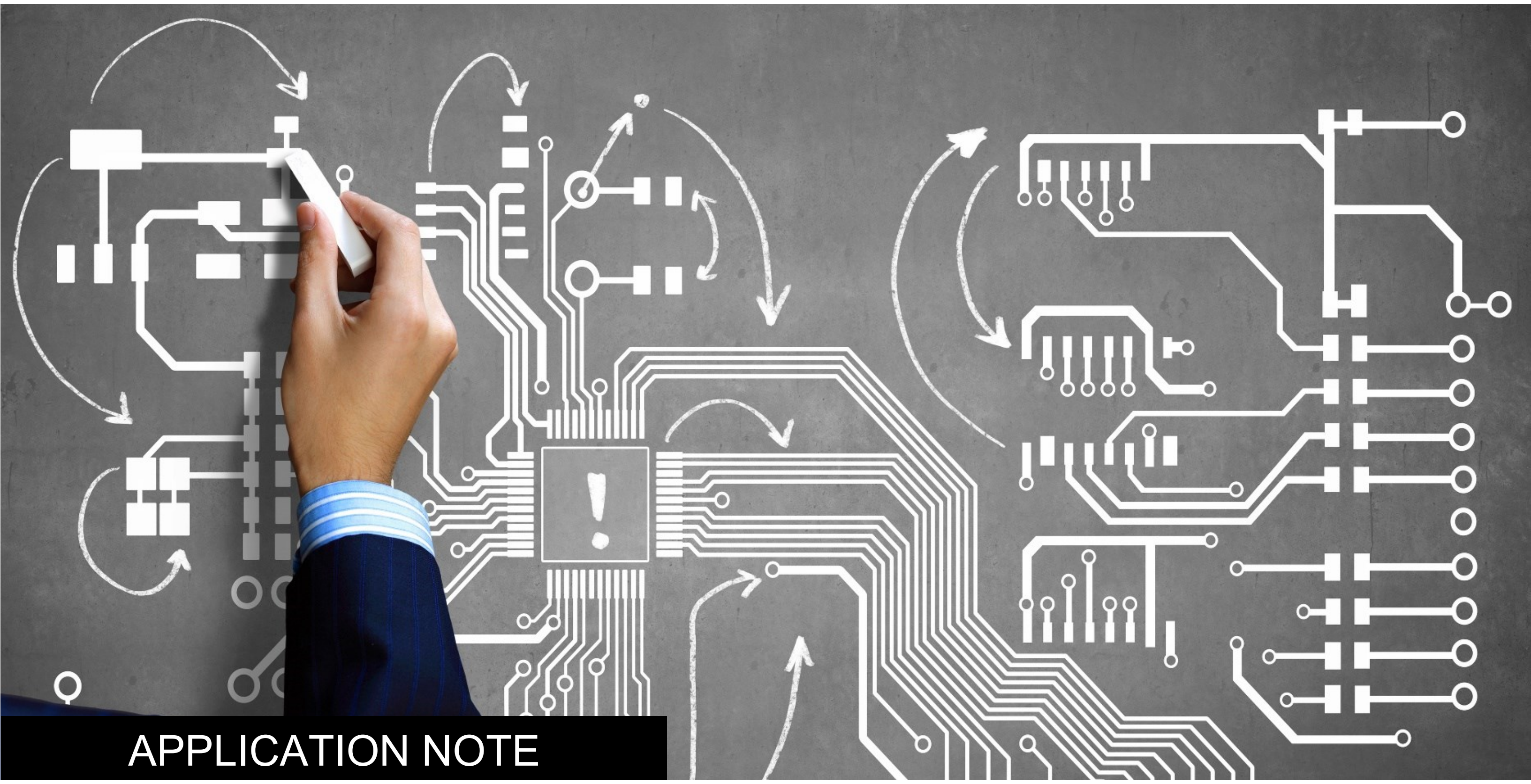
LCA2 LeddarCore Basic Configuration



Abstract

The LCA2 LeddarCore™ is a highly integrated multi-channel LiDAR front end for object detection and distance measurement in automotive applications and others.

This Application Note describes a fundamental sequence that is applicable to multiple LiDAR applications, including code examples with register settings and calculation examples for basic configurations of the SoC.

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Basic Application Configurations

Typical Application Sequence

For a wide range of typical LiDAR applications, the LCA2 LeddarCore will run in a state diagram as shown below. This state diagram starts after a proper power-on sequence of the different voltage supply rails and ends in the corresponding power-down sequence, with shutdown of the voltage supply rails. The correct power-on and power-down sequences, as well as recommendations for power supply design and filtering, can be found in LeddarTech's Application Note "LCA2 Power Supply Design and Sequencing."

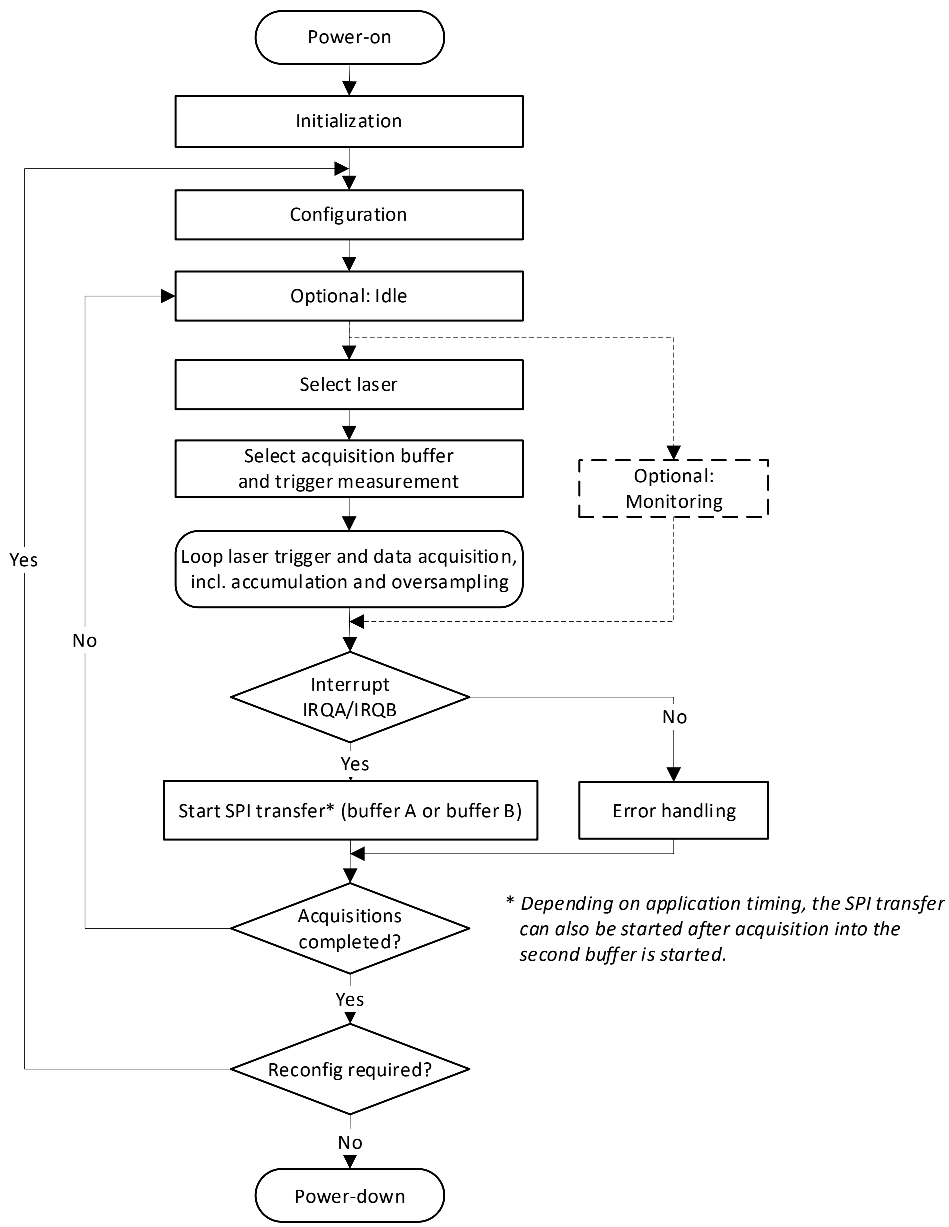

Figure 1 – Typical LiDAR application flow chart for LCA2 LeddarCore

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Description of LCA2 LeddarCore Operation States

Initialization

To ensure optimal operation of LCA2 LeddarCore, the following settings must be performed after device power-on:

```
LCA2_WriteRegister(lca2,RESERVED_1,0xFF);     // Reserved, need to be set after Power on
LCA2_WriteRegister(lca2,RESERVED_2,0xFF);     // Reserved, need to be set after Power on
LCA2_WriteRegister(lca2,TDL64K,0x3F);         // TIA Divider Lookup 64k
LCA2_WriteRegister(lca2,TDL32K,0x3F);         // TIA Divider Lookup 32k
LCA2_WriteRegister(lca2,TBUF,0x1D);           // TIA Buffer Settings
LCA2_WriteRegister(lca2,HACC,0x01);           // Start HS-ADC Calibration
LCA2_wait (50);                               // wait for 50µs
LCA2_WriteRegister(lca2,HACC,0x00);           // disable HS-ADC Calibration
LCA2_WriteRegister(lca2,IRM,0x40);            // Interrupt Mask register
LCA2_WriteRegister(lca2,IRX,0xFF);            // Clear all Interrupt Source Flags
```

Configuration

The LCA2 LeddarCore is highly configurable to cover a wide range of applications. When selecting a specific configuration, basic relations between the adjustable parameters must be considered. These basic relations can be found in this section.

Oversampling, Accumulation, Laser Trigger Rate and SPI Data Transfer Time

The LCA2 LeddarCore provides an internal state machine, which needs to be configured through register settings. Module-specific parameters like supported number of pixels, signal quality and achievable frame rate can be set. To select the appropriate configuration of the LCA2 LeddarCore for a particular LiDAR application, the following boundary conditions need to be considered:

- The ADC sampling is done with a sampling frequency of 200 MHz on eight physically implemented light acquisition units (LAUs). Each ADC switches between two photodiode inputs (either two odd channels or two even channels); therefore, 16 channels are recorded with an effective sampling frequency of 100 MHz.
- Oversampling (re-acquisition of a trace with shifted sample point to increase time resolution) is configurable from 1 (= no oversampling) to 32.
- Accumulation (re-acquisition of a trace and accumulation to reduce influence of random noise and increase SNR) is configurable from 1 (= no accumulation) to 1024 accumulations per sample.
- The memory depth per LAU is up to 1024 samples.
- The laser trigger rate can be configured from 5 kHz to 409.6 kHz.
- The QSPI max. clock speed is 50 MHz, and each sample has a width of 16 bits.

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After configuration of this internal state machine, the acquisition cycle is automatically executed in a loop as shown in Figure 2 below.

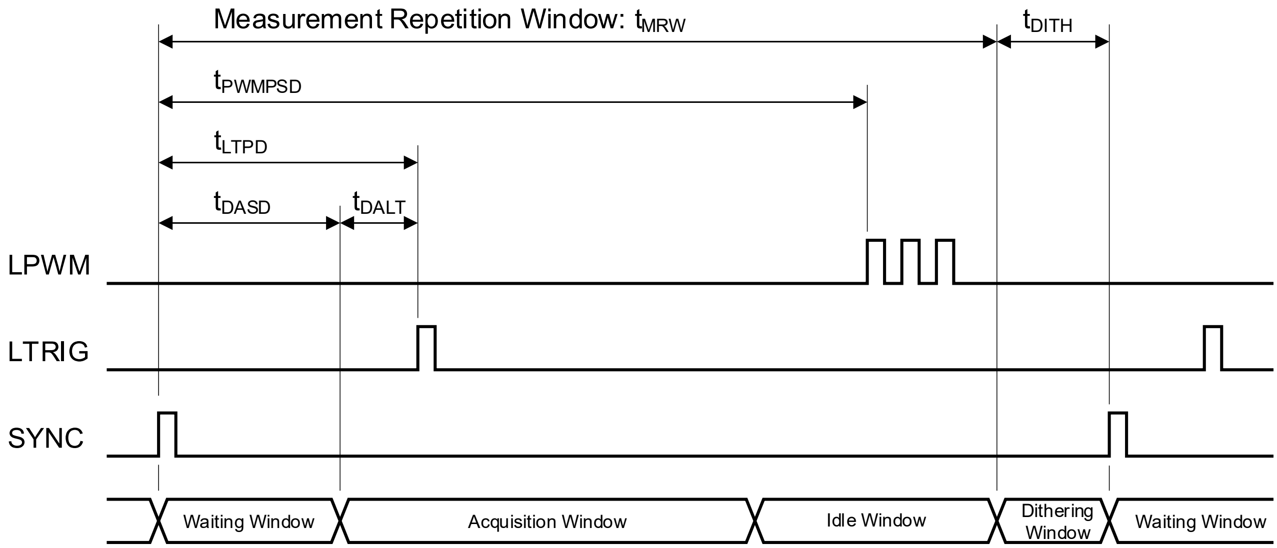

Figure 2 – Acquisition cycle timing

As the LCA2 LeddarCore can be used stand-alone or in master/slave operation to implement more complex systems, a synchronization signal has been implemented to keep the master and the slave device synchronous during operation using a connection of the SYNC pins. When used in stand-alone operation, the SYNC pulse on the pin is disabled, but still the entire acquisition cycle is timed in reference to this internal signal.

For constraining the acquisition cycle, the following timings must be configured:

- $\mathbf{t_{LTPD}}$ (Laser Trigger Pulse Delay Time). The value of t_{LTPD} can be set in the bits 11:6 [Nltpd] of the Laser Trigger Pulse Configuration Register (LTPCR). Besides a delay of the laser trigger pulse, too, the pulse width can be adjusted in bits 4:0 [Nltpw] of this register.
- $\mathbf{t_{DASD}}$ (Data Acquisition Start Delay). It is recommended to start the Acquisition Window 100 ns before the laser trigger pulse is sent, to allow for settling effects in the receive chain. The data acquired before the laser pulse should be discarded later. This start delay time must be set in the bits 7:0 [Ndasd] of the Data Acquisition Start Delay Time (DASDT) register.
- $\mathbf{t_{DALT}}$ (delay time between which the Acquisition Window starts and the laser trigger pulse is sent). This value should be >100 ns to allow for settling effects in the receive chain of the LCA2 LeddarCore.
- $\mathbf{t_{PWMPSD}}$ (PWM Pulse Start Delay). To re-charge the laser to the desired level, a PWM signal is generated. The time when the laser charging should be performed can be adjusted in bits 15:0 [Npwmpsd] of the PWM Pulse Start Delay Time (PPSDT) register. Depending on the module design, it can be beneficial to re-charge the laser during the Idle Window to avoid disturbance on the receive signal.
- $\mathbf{t_{DITH}}$ (Acquisition Frame Dithering Time). To suppress possible continuous interference from another LiDAR

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system with the same laser trigger rate, a dithering mechanism can be enabled and configured. When dithering is enabled, a pseudo-random delay time called Dithering Window is added after the Measurement Window is completed and before the next one starts. Enabling the dithering as well as setting the maximum dithering time between 155 ns and 1275 ns is done in the Dithering Control Register (DCR).

- t_{MRW} (Measurement Window Repetition Time). This time defines the length of the entire acquisition cycle (without dithering) and can be adjusted in the bits 15:0 [Nmrw] of the Measurement Repetition Time Window (MRTW) register. In sum with the average dithering time, the Measurement Window Repetition Time defines the laser trigger rate of the LiDAR module.

Power Saving

To reduce overall power dissipation, the high-speed ADCs can be switched to Power-Down mode between the acquisitions in the Idle Window (see Figure 2) when low laser pulse rates are used.

This interval can be configured by setting the Start of ADC Power-Down Interval (PDADCS) and End of ADC Power-Down Interval (PDADCE) registers.

The configuration values can be calculated according to the formulas:

NPDADCS = (tPDADCS / 5 ns) – 3

NPDADCE = (tPDADCE / 5 ns) – 3

This is only applicable when the following conditions can be fulfilled:

Conditions for PDADCS and PDADCE

tPDADCS ≥ tDASD+ (4*(Nacqu+1)*10 ns) + 200 ns

tPDADCE ≤ tMRW – 1380 ns

tPDADCS < tPDADCE

If these conditions cannot be fulfilled, leave the register values at 0xFFFF.

If not all light acquisition units are used in an application, single LAUs can be disabled permanently in the LAU Power Control Register (LPCR) to save power.

Configuration Example

An example should help to demonstrate the approach. In this example, a 3D flash LiDAR application should have a resolution of 32 * 8 pixels and a frame rate of 25 Hz. The maximum range is 60 m, and the Gaussian-shape laser pulse width should be 20 ns (at 50% of the amplitude).

To achieve this resolution, 32 photodiodes are connected to the multiplexed LAUs and eight lasers are used.

To enable proper estimation of the target distance (reflected laser peak position), at least eight samples should fall on each reflected pulse, so the maximum time between the samples can be 2.5 ns. This results in an effective sampling rate of 400 MSps.

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The physical ADC sampling frequency of 200 MHz is shared between the two multiplexed even (or odd) channels, so each trace is sampled with an effective sampling frequency of 100 MHz. To achieve the targeted sampling rate of 400 MSps, an oversampling of 4 must be selected by setting the bits 6:4 [Nosam] in the Acquisition Control (APC) register to 0x02.

For a distance of 60 m, the laser time of flight (back and forth) is 0.4 µs. The Acquisition Window should be started 100 ns before the laser trigger pulse is sent, so a total data acquisition time of 0.5 µs is required. With the sampling rate of 400 MSps, the required memory depth for each trace is 200 samples. To adjust this, the bits 14:7 [Nacqu] in the Acquisition Control (APC) register must be set to the number of acquisitions (without oversampling). The appropriate value for the register setting is calculated by: number of ADC samples (without oversampling) / 4 – 1. In our example, the formula leads to 50 / 4 - 1 = 11.5, which cannot be directly set, so the selected value is 12 (0x0C), leading to a recording total of 208 samples (including oversampling) and a resulting instrumented range of 63 m.

In this example, the accumulation is set to 16 to increase the SNR. This is achieved by setting the bits 3:0 [Naccu] in the Acquisition Control (APC) register to 0x04.

Calculating the Laser Trigger Rate

The LCA2 LeddarCore has eight physical LAUs, multiplexed in two even (or two odd), so 16 channels are acquired with one laser pulse. In this example, two laser pulses are required to capture the 32 photodiode channels. The entire image consists of eight laser lines, so 16 laser pulses are required to capture the complete scene once.

In this example, as an oversampling value of 4 and an accumulation value of 16 are selected, the number of laser pulses for one frame is 16 (laser pulses) * 4 (oversampling) * 16 (accumulation) = 1024.

Multiplied by the frame rate of 25 Hz, the required minimum laser trigger frequency is 25.6 kHz; therefore, the sum of the Measurement Repetition Window Time plus average Dithering Time needs to be 39.06 µs. When, for example, a maximum dithering time of 1275 ns (or average 637.5 ns) is selected in bits 2:1 [Ndith] of Dithering Control Register (DCR), the Measurement Repetition Window Time must cover 38.425 µs, so the bits 15:0 [Nmrw] of the Measurement Repetition Time Window (MRTW) register must be set to 0x1E05.

Power Saving

In this example, the assumed Data Acquisition Start Delay is 100 ns. The Acquisition Window, starting 100 ns before the laser trigger pulse and then covering the 63 m maximum range, is 0.52 µs. Then, 200 ns after this time, the high-speed ADCs can be switched off to reduce power dissipation. To do so, the bits 15:0 [Npdadcs] of the Start of ADC Power-Down Interval (PDADCS) register should be set to 0x00A1.

The high-speed ADCs should be re-enabled at the latest 1380 ns before the end of the Measurement Repetition Window Time. The bits 15:0 [Npdadce] of the End of ADC Power-Down Interval (PDADCE) register must be set to 0x1CEE.

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Data Transfer

Every 2.5 ms, when a line is captured including accumulation and oversampling, the data from the capturing buffer will be transferred to the host via QSPI, whilst the next line is captured in the second buffer.

This data transfer needs to be completed within 64 (= oversampling * accumulation) Measurement Window Repetition Time (or 1/16 of the frame time). In this example, data from 16 pixels of the current line, multiplied by 208 samples per pixel, multiplied by 16 bits/sample, equates to a total of 53.25 kbits that need to be transmitted. With the available QSPI, running on 50 MHz, this transfer takes approximately 266.3 µs.

Dynamic Range Improvement

For additional improvement of the dynamic range, the scene can be captured using two different TIA gains. For this example, the laser repetition frequency needs to be doubled, the Measurement Repetition Time Window needs to be reduced to half and the other settings need to be adjusted accordingly.

Monitoring

To ensure proper function of the LCA2 LeddarCore and its operating conditions, several monitoring mechanisms are implemented in the device. A detailed description of these mechanisms and how to set the warning levels can be found in the LCA2 Safety Manual.

This Application Note does not constitute a reference design. The recommendations contained herein are provided “as is” and do not constitute a guarantee of completeness or correctness.

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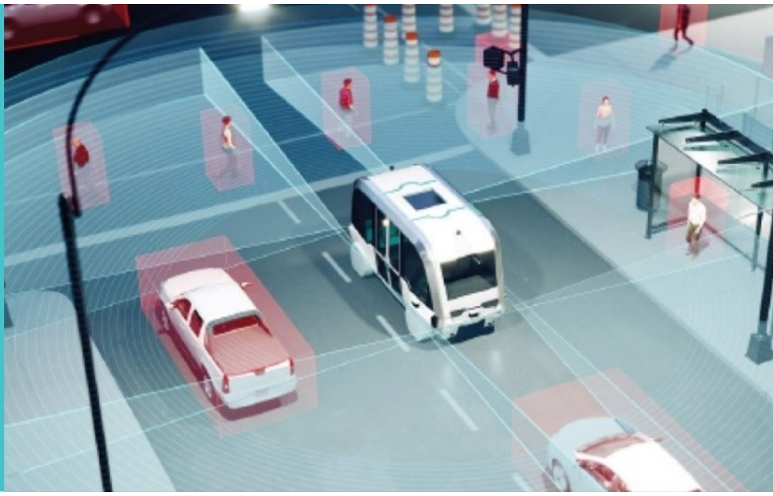

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