



## A111 – Pulsed Coherent Radar (PCR)

Datasheet v2.4



## A111 Overview

The A111 is a radar system based on pulsed coherent radar (PCR) technology and is setting a new benchmark for power consumption and distance accuracy – fully integrated in a small package of 29 mm<sup>2</sup>.

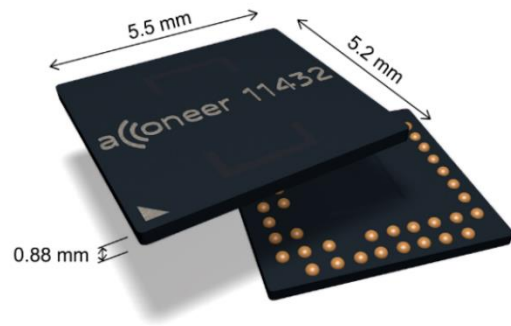
The A111 60 GHz radar system is optimized for high precision and ultra-low power, delivered as a one package solution with integrated Baseband, RF front-end and Antenna in Package (AiP). This will enable easy integration into any portable battery driven device.

The A111 is based on leading-edge patented sensor technology with pico-second time resolution, capable of measuring absolute distance with mm accuracy up to a range of 2 m<sup>(1)</sup> and with configurable update rate.

The A111 60 GHz radar remains uncompromised by any natural source of interference, such as noise, dust, color and direct or indirect light.

## Applications

- High precision distance measurements with mm accuracy and high update rate.
- Proximity detection with high accuracy and the possibility to define multiple proximity zones
- Motion detection, Speed detection
- Enables material detection
- High precision object tracking, enabling gesture control
- High precision tracking of 3D objects
- Monitor vital life signs such as breathing and pulse rate



## Features

- **Fully integrated sensor**
  - 60 GHz Pulsed Coherent Radar (PCR)
  - Integrated Baseband, RF front-end and Antenna in Package (AiP)
  - 5.5 x 5.2 x 0.88 mm fcCSP, 0.5 mm pitch
- **Accurate distance ranging and movements**
  - Measures absolute range up to 2 m<sup>(1)</sup>
    - Absolute accuracy in mm
  - Relative accuracy in  $\mu\text{m}$
  - Possible to recognize movement and gestures for several objects
  - Support continuous and single sweep mode
  - HPBW of 80 (H-plane) and 40 degrees (E-plane)
- **Easy integration**
  - One chip solution with integrated Baseband and RF
  - Can be integrated behind plastic or glass without any need for a physical aperture
  - Single reflowable component
  - 1.8 V single power supply, enable with Power on Reset (PoR)
  - Clock input for crystal or external reference clock, 20-80 MHz
  - SPI interface for data transfer, up to 50 MHz SPI clock support
  - INTERRUPT support

<sup>(1)</sup> 2m ranging is guaranteed for an object size, shape and dielectric properties corresponding to a spherical corner reflector of 5 cm radius.



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# 1 Revision History

| Revision | Comment   |
|----------|---|
| V1.0     | Released version  |
| V1.1     | Minor reference correction in chapter 5.1. A111 marking info added in chapter 2.  |
| V1.2     | Relative phase accuracy added in chapter 6.3  |
| V1.3     | Ordering information added in chapter 2. Equation corrected in XTAL chapter 8.1.  |
| V1.4     | <ul style="list-style-type: none"> <li>- EU declaration of conformity added, chapter 9.0.</li> <li>- Pin configuration alphabetically order corrected, chapter 3.</li> <li>- Acconeer Software chapter 7.1 updated including updated software integration info, chapter 7.2.</li> </ul> |
| V1.5     | Removed introduced error in chapter 3, pin configuration.   |
| V1.6     | FCC modular approval added, chapter 9.2.  |
| V1.7     | Power supply specification added, chapter 8.4.  |
| V1.8     | <p>Added clarifications, section 9.2.<br/>         Added clarification, section 10.1.<br/>         Added clarification, section 3 (pin A2, B1 must no connect)</p>  |
| V1.9     | <p>Updated Table 4.6 footnotes.<br/>         Updated chapter 7.3.<br/>         Updated Figure 7.4.</p>  |
| V2.0     | <p>Updated with FCC/IC/EN approvals, section 8.<br/>         Updated A111 marking, section 2.</p>   |
| V2.1     | Updated with hibernation power mode support I.e. Table 3.1, pin A9 dedicated as optional Ctrl signal. Chapter 7.3 Power up sequence updated accordingly.  |
| V2.2     | Updated figure 10.3 " <i>Physical layout of the A111 sensor, side view</i> " with missing figure. Added separate chapter 10.2 " <i>RoHS and REACH statement</i> "   |
| V2.3     | Added I/O minimum positive and negative pulse figure in Table 4.5   |
| V2.4     | Operating temperature ( $T_{op}$ ) clarification made on table 4.5 <i>Electrical AC conditions</i> , table 4.6 <i>Maximum and average current at power terminals</i> .  |



## 2 Description

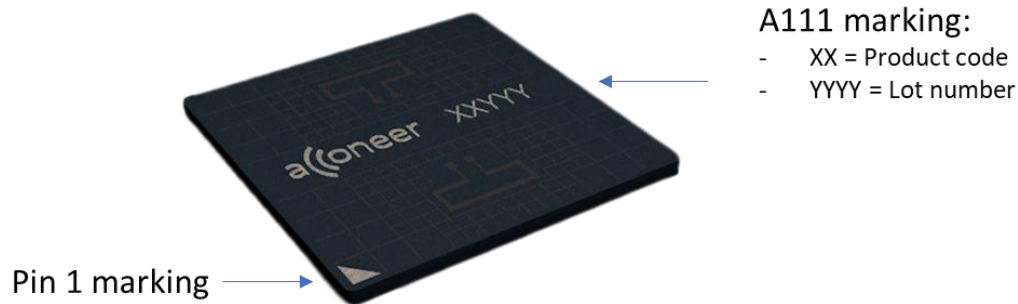
The A111 is an optimized low-power, high-precision, 60 GHz radar sensor with integrated Baseband, an RF front-end and an Antenna in Package (AIP).

The sensor is based on pulsed coherent radar (PCR) technology, featuring a leading-edge patented solution with picosecond time resolution. The A111 is the perfect choice for implementing high-accuracy, high-resolution sensing systems with low-power consumption.

### Ordering information

| Part number  | Package | Size (nom)          | Primary component container |
|--------------|---------|---------------------|-----------------------------|
| A111-001-T&R | fcCSP50 | 5.2 x 5.5 x 0.88 mm | Tape & reel                 |
| A111-001-TY  | fcCSP50 | 5.2 x 5.5 x 0.88 mm | 13" Tray                    |

### Acconeer A111 marking





## 2.1 Functional Block Diagram

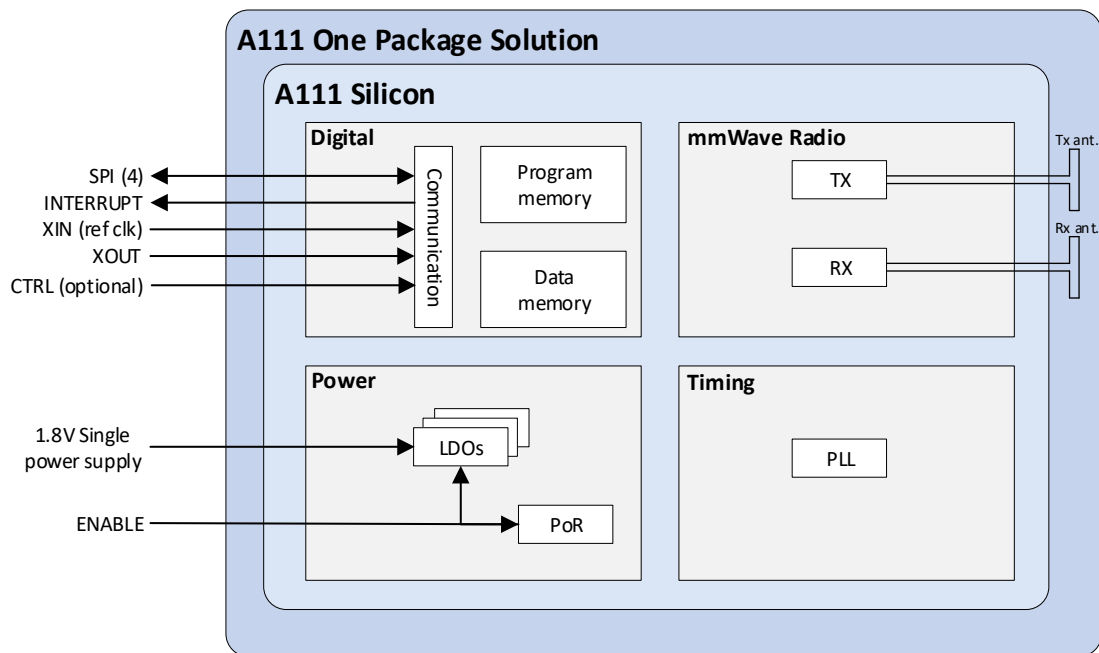


Figure 2.1. The A111 functional block diagram.

The A111 silicon is divided into four functional blocks: Power, Digital, Timing and mmWave radio.

The Power functional block includes LDOs and a Power on Reset (PoR) block. Each LDO creates its own voltage domain. The PoR block generates a Reset signal on each power-up cycle. The host interfaces the Power functional block of the sensor via 1.8V Single power supply and ENABLE.

The Digital functional block includes sensor control. The data memory stores the radar sweep data from the ADC. The host interfaces the Sensor via an SPI interface, a Clock (XIN, XOUT), INTERRUPT signal and optional CTRL signal.

The Timing block includes the timing circuitry.

The mmWave radio functional block generates and receives radar pulses and includes transmitter (TX), receiver (RX) and interfaces toward the integrated antennas.



### 3 Pin Configuration and Functions

The below figure shows the A111 pin configuration, top view:



Figure 3.1. Pin configuration of the A111 sensor, top view.

The below table shows the A111 total number of 50 pins:

| Pin             | Pin name | Pin type       | Description   | Comment  |
|-----------------|----------|----------------|---|----------|
| A2              | NC       |                | Must no connect   |          |
| A3-A8           | GND      | Ground         | Must be connected to solid ground plane                                 |          |
| A9              | CTRL     | I/O            | Optional control signal. Must be connected to either host MCU or ground | optional |
| B1              | NC       |                | Must no connect   |          |
| B2, B9          | GND      | Ground         | Must be connected to solid ground plane                                 |          |
| B10             | GND      | Ground         | Must be connected to solid ground plane                                 |          |
| C1              | GND      | Ground         | Must be connected to solid ground plane                                 |          |
| C2              | VIO_1a   | Supply voltage | Supply voltage, RF part <sup>(1)</sup>                                  |          |
| C9              | VIO_2a   | Supply voltage | Supply voltage, RF part <sup>(1)</sup>                                  |          |
| C10             | GND      | Ground         | Must be connected to solid ground plane                                 |          |
| D1              | VIO_1b   | Supply voltage | Supply voltage, RF part <sup>(1)</sup>                                  |          |
| D2, D9          | GND      | Ground         | Must be connected to solid ground plane                                 |          |
| D10             | VIO_2b   | Supply voltage | Supply voltage, RF part <sup>(1)</sup>                                  |          |
| E1, E2, E9, E10 | GND      | Ground         | Must be connected to solid ground plane                                 |          |



| Pin            | Pin name  | Pin type       | Description   | Comment               |
|----------------|-----------|----------------|---|-----------------------|
| F1             | GND       | Ground         | Must be connected to solid ground plane   |                       |
| F2, F9         | GND       | Ground         | Must be connected to solid ground plane   |                       |
| F10            | ENABLE    | I/O            | Must be connected to host MCU available GPIO. ENABLE is active high   |                       |
| G1, G10        | GND       | Ground         | Must be connected to solid ground plane   |                       |
| H1             | GND       | Ground         | Must be connected to solid ground plane   |                       |
| H2, H9         | GND       | Ground         | Must be connected to solid ground plane   |                       |
| H10            | XOUT      | CLK            | XTAL out  | No connect if no XTAL |
| J1             | VBIAS     | Analog         | The analog VBIAS must be connected to VIO_3   |                       |
| J2             | SPI_SS    | I/O            | SPI slave select, active low select.  |                       |
| J3, J5, J6, J8 | GND       | Ground         | Must be connected to solid ground plane   |                       |
| J9             | VIO_3a    | Supply voltage | Supply voltage, digital part <sup>(1)</sup>   |                       |
| J10            | XIN       | CLK            | XTAL input OR external ref clk input  | 1.1V domain           |
| K2             | SPI_CLK   | I/O            | SPI Serial Clock  |                       |
| K3             | SPI_MISO  | I/O            | Master Input – Slave Output   |                       |
| K4             | GND       | Ground         | Must be connected to solid ground plane   |                       |
| K5             | GND       | Ground         | Must be connected to solid ground plane   |                       |
| K6             | SPI_MOSI  | I/O            | Master Output – Slave Input   |                       |
| K7             | GND       | Ground         | Must be connected to solid ground plane   |                       |
| K8             | INTERRUPT | I/O            | Interrupt signal, that is used as an interrupt in the host, more details are found in section 7, <i>Description</i> . | mandatory             |
| K9             | VIO_3b    | Supply voltage | Supply voltage, digital part <sup>(1)</sup>   |                       |

Table 3.1. A111 sensor pin list

(1) VIO\_1a and VIO\_1b are short circuit inside the sensor. VIO\_2a and VIO\_2b are short circuit inside the sensor. VIO\_3a and VIO\_3b are short circuit inside the sensor.





## 4 Specifications

### 4.1 Absolute Maximum Ratings

The below table shows the A111 absolute maximum ratings over operating temperature range, on package, unless otherwise noted:

| Parameter            | Description                                     | Min. | Max.      | Unit |
|----------------------|---|------|-----------|------|
| VIO_1 <sup>(2)</sup> | 1.8 V RF power supply                           | 0    | 2.0       | V    |
| VIO_2 <sup>(2)</sup> | 1.8 V RF power supply                           | 0    | 2.0       | V    |
| VIO_3                | 1.8 V digital power supply                      | 0    | 2.0       | V    |
| XIN <sup>(1)</sup>   | Clock input port for crystal or reference clock | -0.5 | 1.6       | V    |
| I/O                  | I/O supply voltage                              | -0.5 | VIO_3+0.5 | V    |
| T <sub>OP</sub>      | Operating temperature range                     | -40  | 85        | °C   |
| T <sub>STG</sub>     | High temperature storage                        |      | 150       | °C   |

Table 4.1. Absolute maximum ratings

- (1) XIN input may not exceed 0V when ENABLE is low.  
 (2) VIO\_1 and VIO\_2 must never exceed VIO\_3.

Stresses beyond those listed in table 4.1 may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions or at any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods of time may affect device reliability.

### 4.2 Environmental Sensitivity

The below table shows the A111 environmental sensitivity:

| Parameter                                   | Standard                   | Max.               | Unit |
|---|----------------------------|--------------------|------|
| Storage temperature                         | JESD22-A103 <sup>(1)</sup> | 150 <sup>(1)</sup> | °C   |
| Reflow soldering temperature <sup>(1)</sup> | J-STD-020 <sup>(1)</sup>   | 260                | °C   |
| Moisture Sensitivity Level                  | JESD22-A113 <sup>(1)</sup> | MSL3               |      |
| ESD, Charge Device Model (CDM)              | JS-002, Class C2           | 500                | V    |
| ESD, Human Body Model (HBM)                 | JS-001, Class 1C           | 1000               | V    |
| Latch-up                                    | JESD78, Class I            | Pass               |      |

Table 4.2 Environmental sensitivity

- (1) For reference only. The package is generically qualified by the manufacturer. Acconeer does not guarantee adherence to standard.



### 4.3 Recommended Operating Conditions

The below table shows the A111 recommended operating conditions, on package:

| Parameter                                | Min. | Typ. | Max.      | Unit |
|--|------|------|-----------|------|
| Operating power supply voltage, VIO_1    | 1.71 | 1.8  | 1.89      | V    |
| Operating power supply voltage, VIO_2    | 1.71 | 1.8  | 1.89      | V    |
| Operating power supply voltage, VIO_3    | 1.71 | 1.8  | 1.89      | V    |
| I/O operating range                      | -0.3 |      | VIO_3+0.3 | V    |
| XIN operating range <sup>(1)</sup>       | -0.3 |      | 1.2       | V    |
| Operating temperature (T <sub>op</sub> ) | -40  |      | 85        | °C   |

Table 4.3. Recommended operating conditions

(1) XIN input must not exceed 0V when ENABLE is low.

### 4.4 Electrical Specification

The below table shows the A111 electrical DC specification conditions, on package, at T<sub>A</sub> = 25°C:

| Parameter                                     | Min.       | Typ. | Max.       | Unit |
|---|------------|------|------------|------|
| Current into any power supply                 |            |      | 100        | mA   |
| I/O V <sub>IL</sub> Low-level input voltage   | -0.3       |      | 0.10*VIO_3 | V    |
| I/O V <sub>IH</sub> High-level input voltage  | 0.90*VIO_3 |      | VIO_3+0.3  | V    |
| I/O V <sub>OL</sub> Low-level output voltage  |            |      | 0.4        | V    |
| I/O V <sub>OH</sub> High-level output voltage | 1.6        |      |            | V    |
| I/O I <sub>OL</sub> (VOL = 0.4V)              |            | 7.8  |            | mA   |
| I/O I <sub>OH</sub> (VOH = VIO_3-0.4)         |            | 5.8  |            | mA   |
| I/O I <sub>IL</sub> Low-level input current   |            | <1   |            | µA   |
| I/O I <sub>IH</sub> High-level input current  |            | <1   |            | µA   |
| XIN V <sub>IL</sub> Low-level input voltage   | -0.3       |      | 0.4        | V    |
| XIN V <sub>IH</sub> High-level input voltage  | 1.0        |      | 1.2        | V    |
| XIN I <sub>IL</sub> Low-level input current   |            | <1   |            | µA   |
| XIN I <sub>IH</sub> High-level input current  |            | <1   |            | µA   |

Table 4.4. Electrical DC conditions



The below table shows the A111 electrical AC specification conditions, on package, at  $T_{op} = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ :

| Parameter                               | Min. | Typ. | Max.              | Unit |
|---|------|------|-------------------|------|
| I/O output operating frequency          |      |      | 100               | MHz  |
| I/O load capacitance                    |      |      | 20                | pF   |
| I/O minimum positive and negative pulse | 6.25 |      |                   | ns   |
| XIN operating frequency                 | 20   |      | 80 <sup>(1)</sup> | MHz  |
| XIN capacitance                         |      | 0.2  |                   | pF   |

Table 4.5 Electrical AC conditions

(1) The maximum external reference clock frequency is 80 MHz and the maximum XTAL frequency is 50 MHz.

## 4.5 Power Consumption Summary

The below table summarizes the power consumption, maximum current ratings and average current ratings at all power terminals (VIO\_1, VIO\_2, VIO\_3), VIO 1.8 V, at  $T_{op} = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ :

| Parameter   | Min. | Typ.               | Max. | Unit          |
|---|------|--------------------|------|---------------|
| Current consumption, continuous TX active mode              |      | 71                 |      | mA            |
| Average power consumption, 0.1 Hz sweep rate <sup>(2)</sup> |      | 0.2 <sup>(1)</sup> |      | mW            |
| Average power consumption, 10 Hz sweep rate <sup>(2)</sup>  |      | 3 <sup>(1)</sup>   |      | mW            |
| Average power consumption, 100 Hz sweep rate                |      | 20 <sup>(1)</sup>  |      | mW            |
| Current leakage at ENABLE low                               |      | 66                 |      | $\mu\text{A}$ |

Table 4.6. Maximum and Average current ratings at power terminals.

(1) Measuring window set to 0.24 m.

(2) Leakage current in ENABLE low not removed.

## 4.6 RF Specification

The below table shows the A111 RF specification:

| Parameter                             | Min. | Typ. | Max. | Unit    |
|---------------------------------------|------|------|------|---------|
| Center frequency fc                   |      | 60.5 |      | GHz     |
| EIRP                                  |      |      | 10   | dBm     |
| HPBW, elevation plane <sup>(1)</sup>  |      | 40   |      | degrees |
| HPBW, horizontal plane <sup>(1)</sup> |      | 80   |      | degrees |

Table 4.7 A111 RF specification

(1) See chapter 6 Typical Characteristics for elevation (E-plane) and horizontal (H-plane) HPBW.



## 5 Timing Requirements

### 5.1 Serial Peripheral Interface

The Serial Peripheral Interface (SPI) is a 4-wire serial bus, used for configuration and reading output from the A111 radar sensor. The A111 radar sensor is an SPI slave device connected to the SPI master, as described in figure 5.1. The A111 allows several devices to be connected on the same SPI bus, with a dedicated slave-select signal. Daisy-chain is not supported.

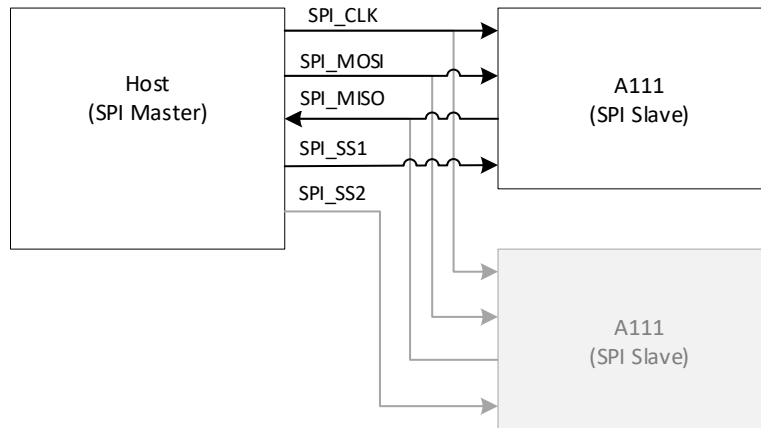


Figure 5.1. SPI master-slave connection

The serial data transfer input (MOSI) and output (MISO) to the A111 are synchronized by the SPI\_CLK. The Slave Select signal (SS) must be low before and during transactions. The MOSI is always read on the rising edge of SCLK and the MISO changes value on the falling edge of SPI\_CLK (SPI mode 0, CPOL/CPHA = 0). SS requires release in between transactions. See figure 5.2 and table 5.1 for timing characteristics.

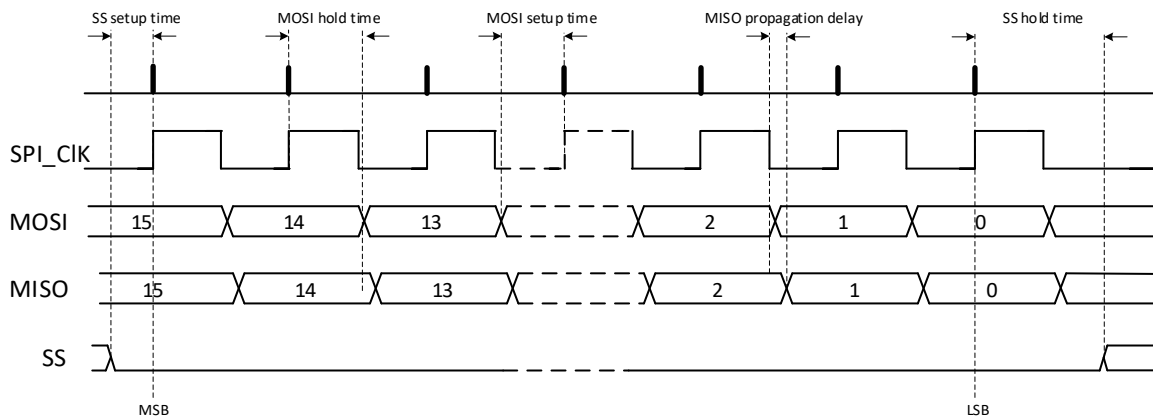


Figure 5.2: Timing diagram of SPI, CPOL=0 and CPHA=0.



| Parameter                             | Min. | Typ. | Max. | Unit |
|---------------------------------------|------|------|------|------|
| Clock frequency <sup>(1)</sup>        |      |      | 50   | MHz  |
| SS setup time                         | 1.0  |      |      | ns   |
| SS hold time                          | 2.0  |      |      | ns   |
| MOSI setup time                       | 1.0  |      |      | ns   |
| MOSI hold time                        | 2.5  |      |      | ns   |
| MISO propagation delay <sup>(2)</sup> |      |      | 5.5  | ns   |

*Table 5.1 SPI timing characteristics*

(1) The 50 MHz clock frequency requires that the reference clock is at least 20.625 MHz

(2) 10pF load on SPI\_MISO



## 6 Typical Characteristics

### 6.1 Half Power Beamwidth (HPBW)

Conditions:  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 1.8\text{ V}$ . Statistical result based on sweep count 100, tested on 20 XR111 devices.

The below figure shows the normalized radiation pattern at Elevation plane (E-plane), HPBW for E-plane is  $\pm 20$  degrees.

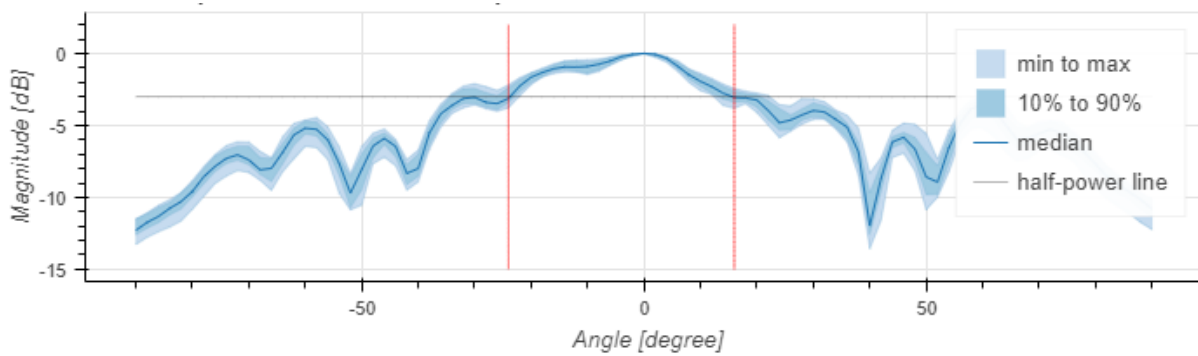


Figure 6.1. Normalized radiation pattern at E-plane.

The below figure shows the normalized radiation pattern at Horizontal plane (H-plane), HPBW for H-plane is  $\pm 40$  degrees.

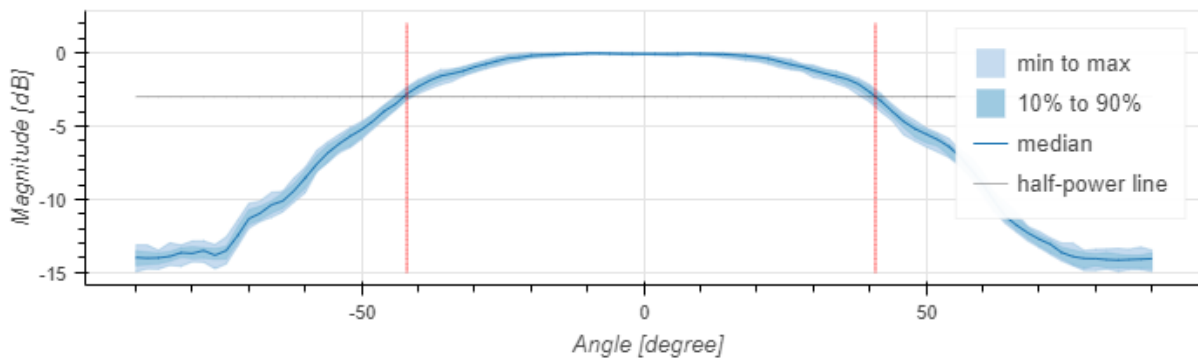


Figure 6.2. Normalized radiation pattern at H-plane

### 6.2 Relative Phase Accuracy

Conditions:  $T_A = 25\text{ }^\circ\text{C}$ ,  $V_{DD} = 1.8\text{ V}$ . Statistical result based on sweep count 100, 20 tested devices.

Standard deviation of phase estimation, measured at a distance of 0.35 m. Object metal cylinder, 40 mm in diameter.

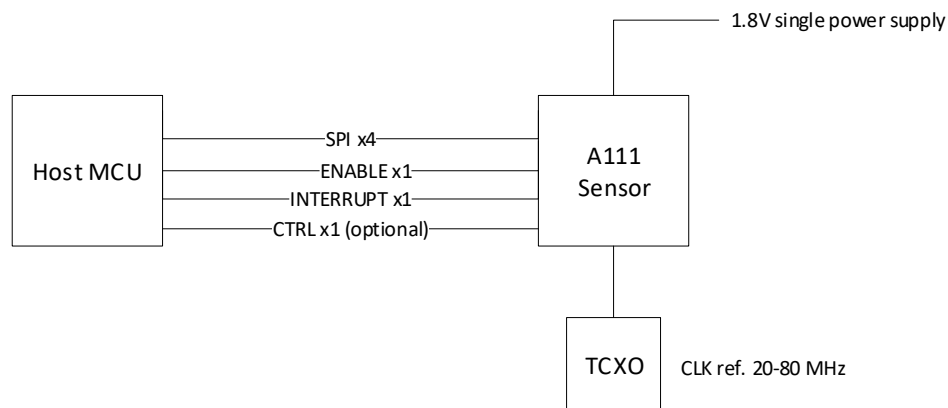
Average STD of relative phase estimation:

6.1 degrees in relative phase accuracy, translates to  $42\text{ }\mu\text{m}$  in relative distance accuracy.



## 7 Functional Description

The below figure shows the A111 system integration with Host MCU:



*Figure 7.1. System integration*

The Acconeer software is executed on Host MCU that handles sensor initiation, configuration, sweep acquisition and signal processing.

The Serial Peripheral Interface (SPI) is a 4-wire serial bus, used for configuration and reading output from the A111 radar sensor. The A111 radar sensor is an SPI slave device, connected to the SPI master (Host MCU), and allows several devices to be connected on same SPI bus, with a dedicated slave-select signal. Daisy-chain is not supported.

The sensor provides support for ENABLE and INTERRUPT as interrupt signal, always output, that is used as an interrupt in the Host MCU. The sensor supports an optional control signal: CTRL, which is configured through software, e.g. for controlling the operating state of the sensor to idle in Hibernate.



## 7.1 Acconeer Software

The Acconeer software has been written in C and is portable to any OS and HW platform. The Acconeer software is executed on Host MCU and delivered as binaries, except for integration software that is delivered as source code.

The below figure shows the A111 software offer.

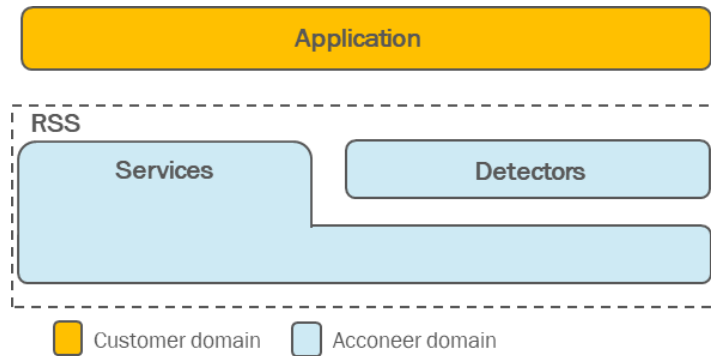


Figure 7.2. Acconeer Software offer

The RSS (Radar System Software) provides output at two different levels, Service and Detector. RSS provides an API (Application Programming Interface) for Application utilization of various Services and Detectors.

The Service output is pre-processed sensor data as a function of distance E.g. Envelope data (amplitude of sensor data), Power bin data (integrated amplitude data in pre-defined range intervals), IQ modulated data (representation in cartesian) etc.

Detectors are built on Service data as input and the output is a result E.g. Distance detector that presents distance and amplitude result based on envelope Service etc.

Customer can either use Acconeer detector or develop their own signal processing based on Service data.

Acconeer provides several example applications to support customer own application development. Also, customer guidelines are provided for application development utilizing the Acconeer RSS API.

Acconeer provides several reference drivers as source code, e.g. Support for Cortex M4, Cortex M7 MCU's.

## 7.2 Software Integration

Integration software shall implement functions defined in a definitions file provided in Acconeer Software offer. This includes handling of SPI, ENABLE, INTERRUPT and CTRL, as well as potential OS functions.

See reference HAL - User Guide for guideline on software integration and HAL implementation (<https://www.acconeer.com/products>).





### 7.3 Power Sequences

The power-up sequence is described using the recommended integration shown in the below figure:

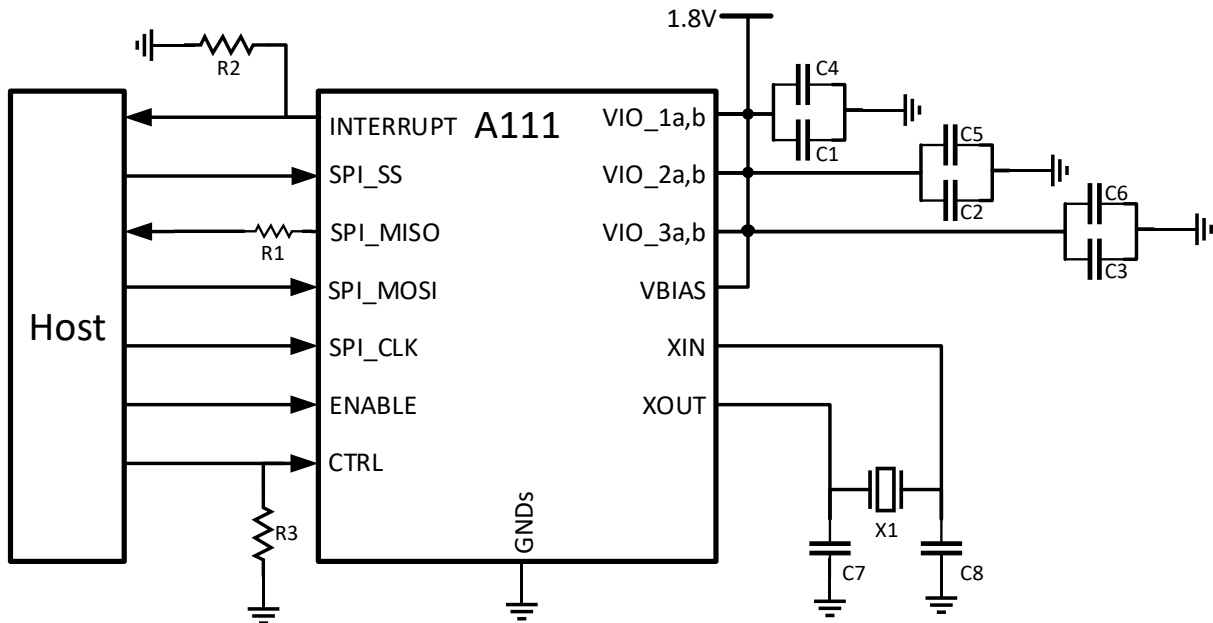


Figure 7.3. Recommended integration of the A111 radar sensor.

The power up sequence is shown in below figure.

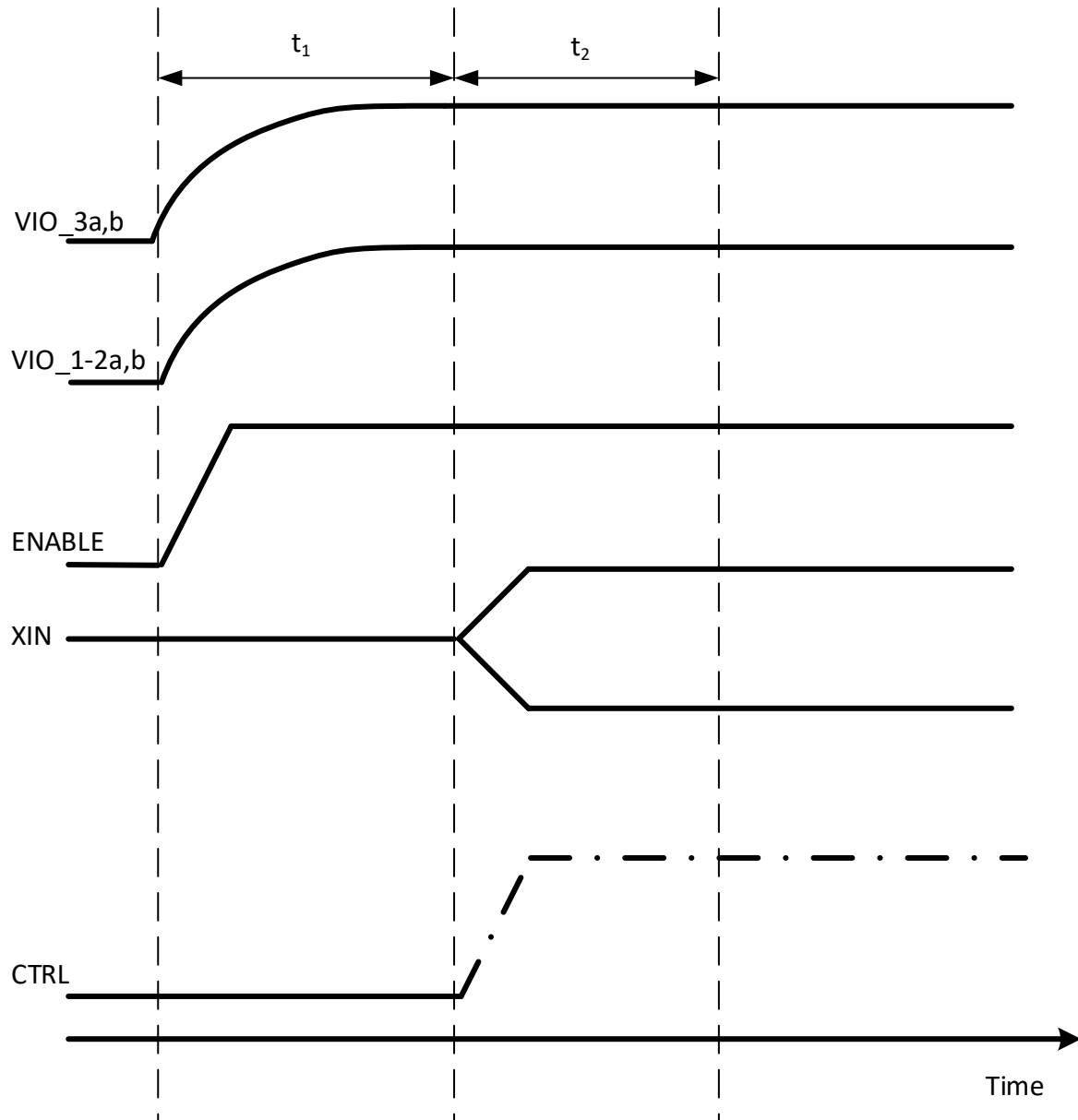


Figure 7.4. Power up sequence

The power up sequence is initiated by turning on VIO\_3a,b. It must be turned on before or simultaneously with ENABLE and VIO\_1-2a,b. ENABLE and VIO\_1-2a,b can be turned on in any order and independently of each other. A111 should however not be considered as in state “ON” until all supply voltage levels are stable and ENABLE is high. The time constant  $t_1$  in figure 7.4 denotes this time. The actual value of  $t_1$  depends on the power supply and the decoupling capacitors used. If the CTRL signal is used, it must be held at 0V during time  $t_1$ .

Next step in the power up sequence is to have a settling time for the XTAL oscillator to stabilize, shown as time  $t_2$  in figure 7.4. This may take up to several milliseconds depending on the XTAL performance. The sensor does not require any settling time if it is integrated using an external reference clock. It is advised to have the clock inactive at 0 V while ENABLE is inactive.

Now the A111 radar sensor is ready for SPI communication.



After power up is complete, the sensor is loaded with a program. Up until the point where the sensor's program is started, the INTERRUPT is high impedance. However, after the sensor's program has started the INTERRUPT is configured to a push-pull CMOS output. It is therefore required that the host I/O is configured as input before any programs are started on the sensor.

The power down sequence is described in Figure 7.5.

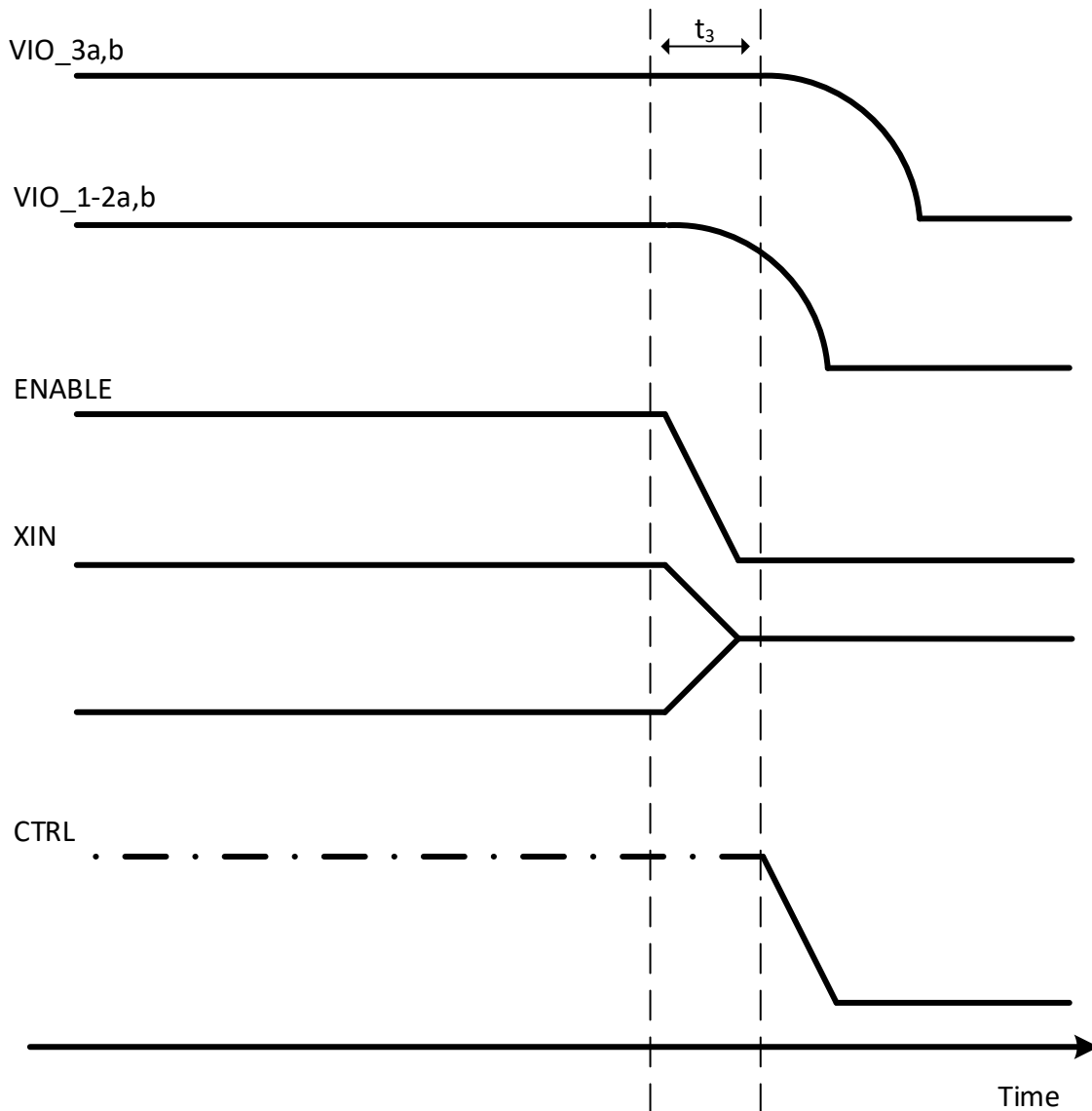


Figure 7.5. The power down sequence

The power down sequence is initiated by setting “ENABLE” low. The crystal oscillator will be disabled when ENABLE is set low. If an external reference clock is used, it is advised to disable it simultaneously with ENABLE.

After that, VIO\_1-2a,b can be turned off. Time constant  $t_3$  (refer to Figure 7.5) later, VIO3a,b can be disabled. The constant  $t_3 \geq 0$ . The I/O inputs on A111 (including CTRL if it is being used) must be set to 0V before or simultaneously with VIO3a,b going low, otherwise the internal ESD protection diodes will draw current from the I/O source.



## 8 Layout Recommendations

A111 sensor free space integration should take the following into consideration:

- Any material above the sensor should have as low permittivity and loss as possible, e.g. plastic or glass with low permittivity.
- To conclude on optimum distance from the sensor, a simulation/measurement investigation is required.

The sensor antennas are of a folded dipole type, with its ground reference in the package ground plane, extending over the whole area of the sensor. To further enhance the directivity of the sensor, the package ground plane should be extended to the package by soldering all GND connections of the sensor to the board top layer ground. This top layer ground plane below the sensor should be continuous and should have low impedance.

The below table shows the sensor gain loss versus solid ground plane area.

| Ground plane area   | Sensor gain loss |
|---------------------|------------------|
| 625 mm <sup>2</sup> | 0 dB             |
| 425 mm <sup>2</sup> | -0.2 dB          |
| 225 mm <sup>2</sup> | -0.4 dB          |
| 127 mm <sup>2</sup> | -2.2 dB          |
| 29 mm <sup>2</sup>  | -4.0 dB          |

*Table 8.1 Simulated relative maximum gain as function of extended solid ground plane area. The area is quadratic.*

It is recommended to keep the layout around XIN and XOUT symmetrical to the XTAL and capacitors.

VIO\_1a and VIO\_1b are short circuit inside the sensor and are recommended to be connected to each other on the PCB as well. VIO\_2a and VIO\_2b are short circuit inside the sensor and are recommended to be connected to each other on the PCB as well. VIO\_3a and VIO\_3b are short circuit inside the sensor and are recommended to be connected to each other on the PCB as well. It is recommended to have decoupling capacitors on the supplies placed as close as possible to the supply terminals. It is recommended as minimum 100 nF in parallel with 1 uF decoupling capacitance on each supply.



## 8.1 Bill of Material (BoM)

The below table shows BOM for integration of the A111:

| Component  | Value               | Description                            |
|------------|---------------------|--|
| C1, C2, C3 | 100 nF              | VIO_1, VIO_2, VIO_3 decoupling         |
| C4, C5, C6 | 1 $\mu$ F           | VIO_1, VIO_2, VIO_3 decoupling         |
| R2, R3     | 100 k $\Omega$      | INTERRUPT and CTRL pull down resistor  |
| R1         | 30 $\Omega$         | SPI_MISO series resistance (optional)  |
| X1         |                     | XTAL 24 MHz, Epson TSX-3225 (optional) |
| C7, C8     | 8 pF <sup>(1)</sup> | XTAL freq. tuning capacitor (optional) |

*Table 8.2 BOM list*

(1) See details in chapter 7.1 XTAL for C7, C8 value calculation.

See figure 8.1 that shows the optional XTAL populated.



## 8.2 XTAL

The input clock can originate from a crystal (XTAL), connected to XIN and XOUT.

The A111 sensor has a built-in XTAL oscillator and by adding an external XTAL component, as shown in the below figure 8.1, a reference design without any external clock reference supplied is possible. Note however, that the external clock reference still is supported and if used instead of an external XTAL, it is connected to XIN.

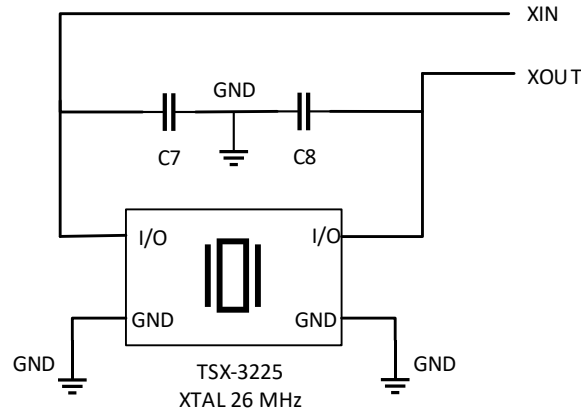


Figure 8.1. External XTAL schematics.

To enable the internal XTAL oscillator to drive the external resonator, the relation in equation 1 must be fulfilled.

### Equation 1

$$f * C_{pin}^{0.8} * R_{ESR}^{0.61} < 0.7$$

### Equation 2

$$C = 2(C_L - C_{stray})$$

### Equation 3

$$C_{pin} = C + C_{stray} * 2$$

The capacitance values are calculated in equation 2.  $C_L$  and  $R_{ESR}$  are XTAL parameters and vary from XTAL to XTAL. The stray capacitance is the sum of the capacitance between XIN and XOUT, which are found in the traces on PCB and in the package; 2 to 5 pF is a general estimation.

### Example:

- $f = 26 \text{ MHz}$
- $C_L = 9 \text{ pF}$
- $R_{ESR} = 40 \text{ ohm}$

Assuming that  $C_{stray} = 5 \text{ pF}$  gives  $C7, C8 = 8 \text{ pF}$  and that the condition is met with the result  $0.63 < 0.7$ .



### 8.3 External Clock Source

The input clock can origin from an external clock source connected to XIN, with XOUT left open.

As an example given in table 8.3, maximum phase noise figures are given using 40 MHz external clock reference.

| Offset frequency (Hz) | Min. | Typ. | Max. | Unit   |
|-----------------------|------|------|------|--------|
| 1000                  |      |      | -80  | dBc/Hz |
| 10 000                |      |      | -100 | dBc/Hz |
| 100 000               |      |      | -120 | dBc/Hz |
| 1 000 000             |      |      | -140 | dBc/Hz |
| 10 000 000            |      |      | -155 | dBc/Hz |

*Table 8.3. Phase noise using 40 MHz external clock reference*



## 8.4 Power Supply

The A111 sensor has got three power supplies where the VIO\_3 power supply is sensitive to power supply ripple. Power supply ripple on VIO\_3 may degrade performance since VIO\_3 supplies the internal clock generation blocks. Table 8.4 provides the required power supply ripple specification for VIO\_3.

| Frequency (Hz) | Min. | Typ. | Max. | Unit             |
|----------------|------|------|------|------------------|
| 10 000         |      |      | 18.7 | mV <sub>pp</sub> |
| 100 000        |      |      | 2.6  | mV <sub>pp</sub> |
| 1 000 000      |      |      | 0.26 | mV <sub>pp</sub> |
| 3 000 000      |      |      | 0.09 | mV <sub>pp</sub> |
| 10 000 000     |      |      | 0.23 | mV <sub>pp</sub> |
| 100 000 000    |      |      | 3.0  | mV <sub>pp</sub> |

Table 8.4: Required power supply ripple specification for VIO\_3

### Low-cost LC filter solution

Acconeer provides recommended low-cost LC filter solution, the recommended filter is displayed in figure 8.2. The values of the component demonstrate an example filter design, exact values depend on switching frequency and ripple amplitude of the supply regulator. However, be aware of LC filter peaking at the series resonance frequency  $1/(2\pi*\sqrt{LC})$ . A small resistor, 250 mΩ in the example filter, can be inserted to lower the Q factor of the filter. In certain applications, where disturbances at the series resonance frequency is present, the filter may not be an optimal solution and an external LDO such as TPS7A8801 or equal is recommended to use instead of the low-cost LC filter.

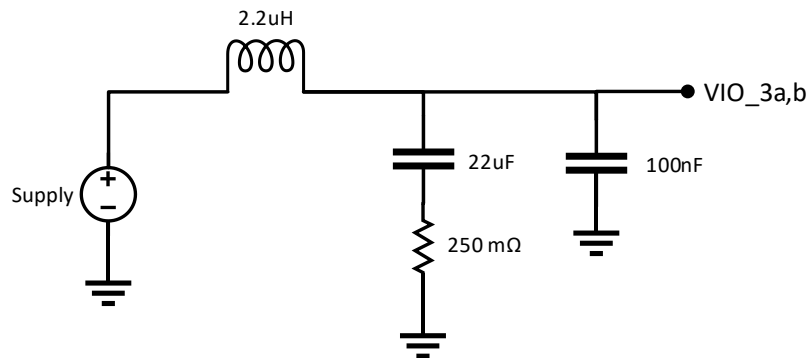


Figure 8.2: Low cost LC supply filter



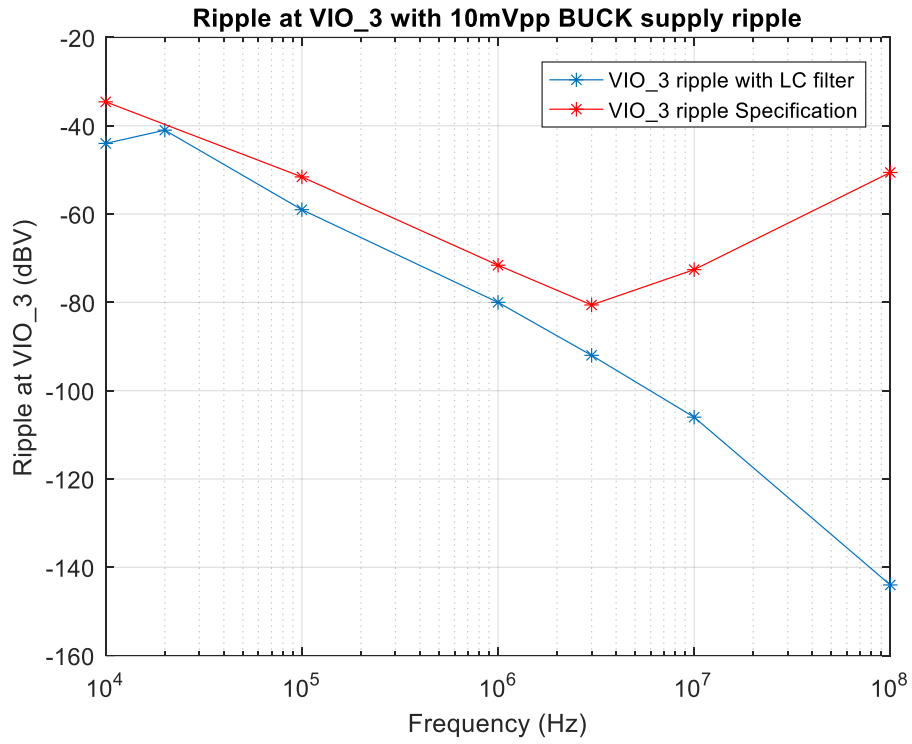


Figure 8.3: Simulated performance with 10mV<sub>pp</sub> supply ripple with low cost LC supply filter.



## 9 Regulatory Approval

To be noted is that some regulatory specifications also specify the usage of the sensor, so users of the sensor must check regulatory requirements for their own use case and determine if the regulatory approvals described below are sufficient.

### 9.1 ETSI

Hereby, Acconeer declares that the A111 sensor is compliant with directive 2014/53/EU.

#### 9.1.1 EU type examination certificate

EU Type Examination Certificate



**Certificate Holder:** Acconeer AB  
 Ideon Gateway, Scheelevägan 27  
 223 70 Lund  
 Sweden

**Product Manufacturer:** See Certificate Holder

**Product Designation:** A111

**Product Description:** 60 GHz Module for SRD Radar

**Conformity Assessment:**

| Essential requirements             | Examined documentation                        | Result  |
|------------------------------------|---|---------|
| Radio spectrum<br>RED, Article 3.2 | Technical documentation including test report | conform |

**EU Type Examination Certificate:**  
 In accordance with Annex III of the European Council Directive 2014/53/EU on radio equipment, our opinion is that this equipment type complies with the essential requirements stated above.

**Marking:**  
 The product shall be marked with the CE marking as required in the Council Directive 2014/53/EU.

**Annexes:**  
 The certificate is only valid in conjunction with the following number of annexes: 1

**Validity:**  
 Conformity is provided unless changes/modifications have been done to the standard and/or assessed type of equipment.

**Certificate Registration No.:** T818606L-01-TEC

**CTC advanced GmbH**  
 Frank Muchitsch  
 c/o=Frank Muchitsch, o=CTC advanced GmbH,  
 ou=CTC-161125,  
 email=frank.muchitsch@ctcadv.  
 advanced.com, c=DE  
 2019.11.06 11:12:53 +0100'

**Authorized signature / title**



Bundesnetzagentur  
 BNetzA-b5-02/51-52  
 authorized by the German Government to act as Notified Body in accordance with the RE Directive 2014/53/EU of 16 April 2014.




Saarbrücken

CTC advanced GmbH (formerly CETECOM ICT Services GmbH)  
 Untertürkheimer Str. 6-10 | 66117 Saarbrücken | Germany | www.ctcadvanced.com



## 9.2 FCC Approval

Hereby, Acconeer declares that the A111 sensor has modular approval granted by FCC.

Testing for the modular approval of the A111 has been performed using a binary file which represents highest Tx emission configuration. This test binary is available in the software provided by Acconeer and can be used for certification purposes.

The A111 sensor meets the title 47 of the Code of Federal Regulations, part 15 section 15.255 for intentional radiators operating in the 57-71 GHz band for the following type of applications.

- Field disturbance sensor employed for fixed operations.
- Short range device for interactive motion sensing.

Warning: The end user needs to maintain 20 cm distance to radiating parts of the device.

FCC ID: 2AQ6KA1001

The host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification.

### 9.2.1 FCC Regulatory Notes

#### Modifications

Acconeer has not approved any changes to this device. Any changes or modifications to this device could invalidate the FCC approval.

#### Interference statement

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

#### RF exposure

This device complies with the FCC radiation exposure limits set forth for an uncontrolled environment. Co-location of this module with other transmitters that operate simultaneously are required to be evaluated using the FCC multi-transmitter procedures.

The RF exposure has been calculated with a 20 cm separation distance I.e. Mobile devices.

#### Labelling requirements for the host device

The host device shall be labelled to identify the modules within the host device, which means that the host device shall be labelled to display the FCC ID of the module preceded by words "Contains transmitter module" or "Contains", E.g.

*Contains FCC ID: 2AQ6KA1001*



## 9.2.2 FCC Grant Authorization

**TCB**

**GRANT OF EQUIPMENT  
AUTHORIZATION**

**TCB**

Certification  
Issued Under the Authority of the  
Federal Communications Commission  
By:

CETECOM GmbH  
Im Teelbruch 116  
45219 Essen,  
Germany

Date of Grant: 11/08/2019  
Application Dated: 11/08/2019

Acconeer AB  
mikael.rosenhed@acconeer.com  
mikael.egard@acconeer.com  
Lund, 22370  
Sweden

Attention: Mikael Rosenhed , Product Manager

**NOT TRANSFERABLE**

EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.

FCC IDENTIFIER: 2AQ6KA1001  
Name of Grantee: Acconeer AB  
Equipment Class: Part 15 Low Power Transceiver, Rx Verified  
Notes: Pulsed Coherent Radar  
Modular Type: Single Modular

| <u>Grant Notes</u> | <u>FCC Rule Parts</u> | <u>Frequency Range (MHZ)</u> | <u>Output Watts</u> | <u>Frequency Tolerance</u> | <u>Emission Designator</u> |
|--------------------|-----------------------|------------------------------|---------------------|----------------------------|----------------------------|
|                    | 15C                   | 57000.0 - 71000.0            | 0.0058              |                            |                            |

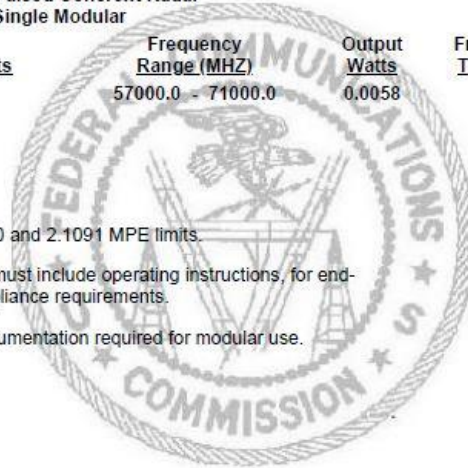
Single modular transmitter.

Output Power is EIRP.

RF exposure compliance is addressed for 1.1310 and 2.1091 MPE limits.

The final product operating with this transmitter must include operating instructions, for end-users and installers to satisfy RF exposure compliance requirements.

The Grantee is responsible for providing the documentation required for modular use.





## 9.3 Industry Canada Approval

The A111 sensor module meets the radio requirements for the 57-64 GHz band for the following type of applications:

- field disturbance sensor employed for fixed operations

IC certification number: 24388-A111

*L'approbation finale Industry Canada (IC) reste en instance.*

*Le module du capteur A111 répond aux conditions de la bande 57-64 GHz pour le genre suivant d'applications:*

- capteur des champs de perturbation employé pour des activités fixées

*Numéro d'identification IC: 24388-A111*

### 9.3.1 Regulatory Information Canada

Acconeer has not approved any changes to this device. Any changes or modifications to this device could invalid the usage of the module.

*Acconeer n'a pas approuvé aucun changement de ce dispositif. Tout changement ou toute modification de ce dispositif pourrait invalider l'usage du module.*

This device complies with Industry Canada's licence-exempt RSSs. Operation is subject to the following two conditions: (1) This device may not cause interference; and (2) This device must accept any interference, including interference that may cause undesired operation of the device.

*Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.*

#### RF Exposure

Radiation Exposure Statement This equipment complies with Canada radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20cm between the radiator & your body.

#### Déclaration d'exposition aux radiations

Cet équipement est conforme Canada limites d'exposition aux radiations dans un environnement non contrôlé. Cet équipement doit être installé et utilisé à distance minimum de 20cm entre le radiateur et votre corps.



Labelling requirements for the host device

The host device should be labelled to identify the modules within the host device, which means that the host device shall be labelled to display the IC of the module preceded by words "Contains transmitter module" or "Contains", or similar wording expressing the same meaning, as follows

*Contains IC: 24388-A111*

*Le dispositif hôte doit être étiqueté afin d'identifier les modules du dispositif hôte, ce qui veut dire que le dispositif hôte doit être étiqueté pour exposer le IC du module précédé par les mots "Contient module émetteur" ou "Contient", ou des termes similaires exprimant le même sens, comme suit:*

*Contient IC: 24388-A111*

9.3.2 Acceptance Certificate - Canada



CETECOM GmbH  
 CAB Identifier DE0005

authorized by the German Federal  
 Regulatory Body (BNetzA) to act as a  
 CAB (Conformity Assessment Body) in  
 accordance with the MFA E3-Canada

BNetzA-CAB-13/22-55

TECHNICAL ACCEPTANCE CERTIFICATE - CANADA

|                           |   |
|---------------------------|---|
| Certificate Holder        | Acconeer AB<br>Scheelevagen 27<br>Lund 22370<br>Sweden  |
| ISED Certification Number | 24388-A111  |
| Product Description       | Pulsed Coherent Radar   |
| CETECOM Registration No.  | 19-1-0151901T01   |
| OATS Facility             | CETECOM GmbH<br>Im Teelbruch 116<br>45219 Essen<br>GERMANY  |
|                           | Phone: +49 (0) 20 54 / 95 19-0<br>Fax: +49 (0) 20 54 / 95 19-150<br>Email: <a href="mailto:meinolf.glanz@cetecom.com">meinolf.glanz@cetecom.com</a> |
| OATS Facility ID          | 3462D   |

Certification of equipment means only that the equipment has met the requirements of the above-noted specification. License applications, where applicable to use certified equipment, are acted on accordingly by the ISED issuing office and will depend on the existing radio environment, service and location of operation. This certificate is issued on condition that the holder complies and will continue to comply with the requirements and procedures issued by ISED. The equipment for which this certificate is issued shall not be manufactured, imported, distributed, leased, offered for sale or sold unless the equipment complies with the applicable technical specifications and procedures issued by ISED.

La certification du matériel signifie seulement que le matériel a satisfait aux exigences de la norme indiquée ci-dessus. Les demandes de licences nécessaires pour l'utilisation du matériel certifié sont traitées en conséquence par le bureau de délivrance d'ISED et dépendent des conditions radio ambiantes, du service et de l'emplacement d'exploitation. Le présent certificat est délivré à la condition que le titulaire satisfasse et continue de satisfaire aux exigences et aux procédures d'ISED. Le matériel à l'égard duquel le présent certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins d'être conforme aux procédures et aux spécifications techniques applicables publiées par ISED.

I hereby attest that the subject equipment was tested and found in compliance with the above-noted specification.  
 J'atteste par la présente que le matériel a fait l'objet d'essai et jugé conforme à la spécification ci-dessus.

Place, date of issue

Essen, 2019-11-08

CETECOM GmbH

Digitally signed  
 by Wenliang  
 Li, DN:  
 cn=Wenliang  
 ou=CETECOM  
 GmbH, ou=IT,  
 email=meinolf.glanz@cetecom.com,  
 c=DE  
 Date: 2019.11.08  
 16:12:10 +0900'

Wenliang Li / FCB



CETECOM GmbH - Im Teelbruch 116  
 DE-45219 Essen - TCB@cetecom.com - www.cetecom.com

This certificate becomes valid when published in REL at:  
 Le présent certificat n'entre en vigueur qu'après être publié en REL sur:  
[https://sms-sqs.ic.gc.ca/equipmentSearch/searchRadioEquipments?execution=e1s1&lang=en\\_CA](https://sms-sqs.ic.gc.ca/equipmentSearch/searchRadioEquipments?execution=e1s1&lang=en_CA)



## 10 Mechanical Data

The A111 is available in fcCSP package for mounting on a substrate. The below table shows mechanical data:

| Parameter       | Min. | Typ.  | Max   | Unit |
|-----------------|------|-------|-------|------|
| Body X          | 5.15 | 5.20  | 5.25  | mm   |
| Body Y          | 5.45 | 5.50  | 5.55  | mm   |
| Body Z (height) |      | 0.821 | 0.899 | mm   |
| Ball pitch      | 0.45 | 0.50  | 0.55  | mm   |
| Ball diameter   | 0.25 | 0.30  | 0.35  | mm   |
| Ball height     | 0.15 | 0.24  |       | mm   |
| Ball count      |      | 50    |       | #    |

Table 10.1. Mechanical data

The A111 footprint is shown in Figure 10.1.

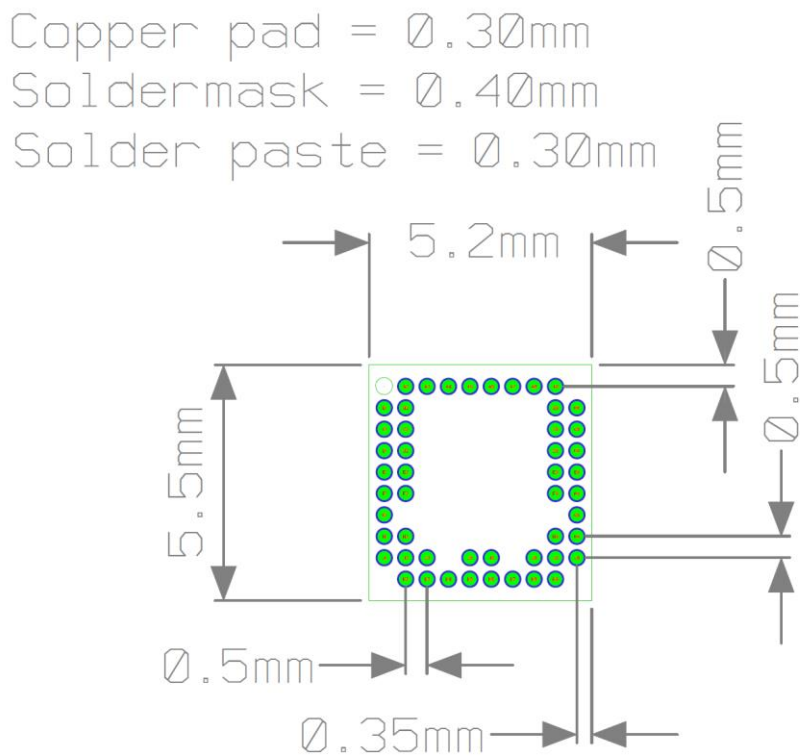


Figure 10.1. A111 footprint



The physical layout of the A111 sensor is shown in Figure 10.2, 10.3 and 10.4.

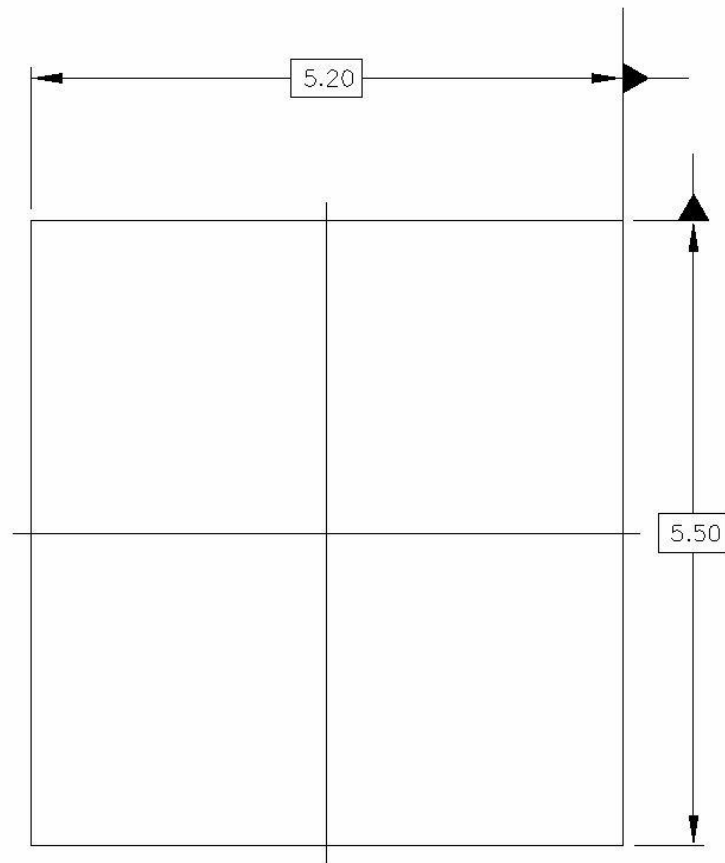


Figure 10.2. Physical layout of the A111 sensor, top view.

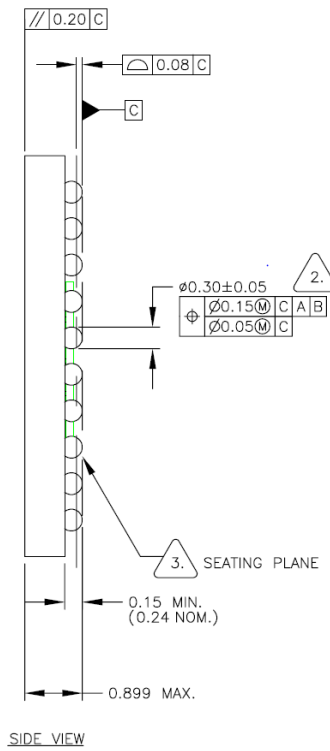


Figure 10.3. Physical layout of the A111 sensor, side view.





Primary datum C and seating plane are defined by the spherical crowns of the solder balls. Dimension is measured at the maximum solder ball diameter, parallel to primary datum C. All dimensions and tolerances conform to ASME Y14.5 – 2009.

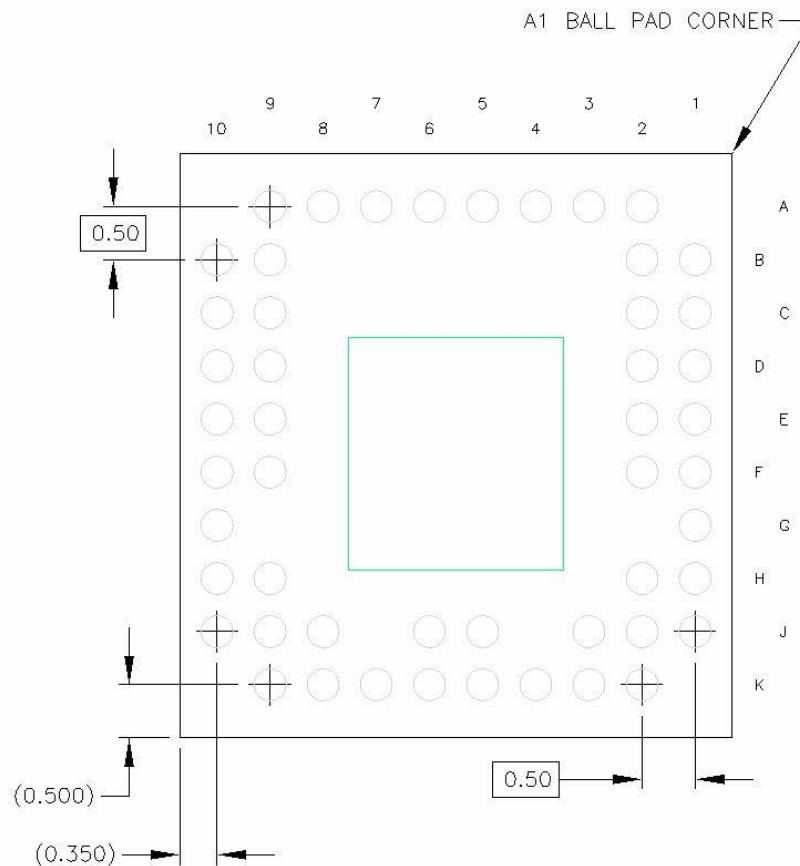


Figure 10.4. Physical layout of the A111 sensor, bottom view.

The bottom view shows 50 solder balls. The pitch of the BGA balls is 500  $\mu\text{m}$ , the ball diameter is 300  $\mu\text{m} \pm 5 \mu\text{m}$  and the collapsed ball height is  $0.244 \pm 0.050 \text{ mm}$ .

## 10.1 Moisture Sensitivity Level and Recommended Reflow Profile

Acconeer A111 sensor is a Moisture Sensitive Devices (MSD) in accordance to the IPC/JEDEC specification. The Moisture Sensitivity Level (MSL) relates to the packaging and handling precautions required. A111 sensor is rated at MSL level 3.

Soldering process qualified during qualification with “Preconditioning MSL 3: 30°C. 60%r.h., 192h, according to JEDEC JSTD20”, and qualified for soldering heat resistance according to JEDEC J-STD-020.

## 10.2 RoHS and REACH Statement

Acconeer A111 sensor meet the requirements of Directive 2011/65/EC of the European Parliament and of the Council on the Restriction of Hazardous Substances (RoHS) and the requirements of the REACH regulation (EC 1907/2006) on Registration, Evaluation, Authorization and Restriction of Chemicals.



## 11 Abbreviations

|       |  |
|-------|--|
| ADC   | Analog digital converter   |
| AiP   | Antenna in package   |
| API   | Application programming interface                                    |
| BGA   | Ball grid array  |
| BOM   | Bill of materials  |
| CE    | "Conformité Européene" (which literally means "European Conformity") |
| CPHA  | Clock phase  |
| CPOL  | Clock polarity   |
| EIRP  | Equivalent isotropically radiated power                              |
| ESD   | Electrostatic discharge  |
| ETSI  | European Telecommunications Standards Institute                      |
| FCC   | Federal Communications Commission                                    |
| fcCSP | Flip-chip chip-scale package   |
| GND   | Ground   |
| HAL   | Hardware abstraction layer   |
| HPBW  | Half power beamwidth   |
| LDO   | Low-dropout regulator  |
| MCU   | Microcontroller unit   |
| MISO  | Master input, slave output   |
| MOSI  | Master output, slave input   |
| NC    | No connect   |
| PCR   | Pulse coherent radar   |
| PLL   | Phase locked loop  |
| PoR   | Power on reset   |
| RCS   | Radar cross section  |
| RF    | Radio frequency  |
| RX    | Receiver   |
| SPI   | Serial peripheral interface  |
| SS    | Slave select   |
| STD   | Standard deviation   |
| TCXO  | Temperature compensated crystal oscillator                           |
| TX    | Transceiver  |
| XTAL  | Crystal  |



## Disclaimer

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