A111 – Pulsed Coherent Radar (PCR)

Datasheet v2.8

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^2.

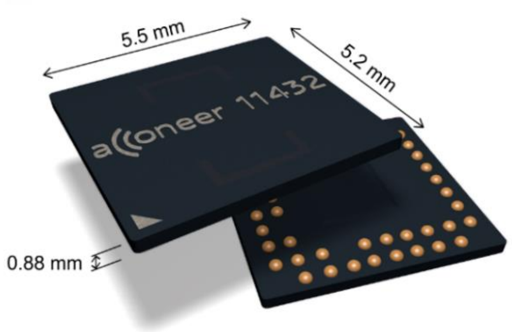
The A111 60 GHz radar system is optimized for high precision and ultra-low power, delivered as a one package solution with integrated Baseband, RF front-end and Antenna in Package (AiP). This will enable easy integration into any portable battery driven device.

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 (1) 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
- Ultra-low power consumption, e.g. average power consumption 0.2 mW at 0.1 Hz update rate, 3 mW at 10 Hz update rate and 20 mW at 100 Hz 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 (1)
    - Absolute accuracy in mm
  - Relative accuracy in µm
  - 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 24 MHz
  - SPI interface for data transfer, up to 50 MHz SPI clock support
  - INTERRUPT support

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

1 Table of Contents

2 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	- EU declaration of conformity added, chapter 9.0. - Pin configuration alphabetically order corrected, chapter 3. - Acconeer Software chapter 7.1 updated including updated software integration info, chapter 7.2.
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	Added clarifications, section 9.2. Added clarification, section 10.1. Added clarification, section 3 (pin A2, B1 must no connect)
V1.9	Updated Table 4.6 footnotes. Updated chapter 7.3. Updated Figure 7.4.
V2.0	Updated with FCC/IC/EN approvals, section 8. Updated A111 marking, section 2.
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 "*Physical layout of the A111 sensor, side view"* with missing figure. Added separate chapter 10.2 "*RoHS and REACH statement*"
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 *Electrical AC conditions*, table 4.6 *Maximum and average current at power terminals*.
V2.5	Maximum number of reflow updated in chapter 10.1. Table 4.4 *Electrical DC conditions* and table 4.5 *Electrical AC conditions* updated
V2.6	Updated RF specification table 4.7. Updated chapter 6.1 with Radar Loop Gain pattern. Updated figures 6.1 and 6.2 to Radar Loop Gain radiation pattern. Updated power consumption characteristics, table 4.6
V2.7	Updated power consumption characteristics, table 4.6 Updated layout recommendations section in chapter 8
V2.8	Update clock input for crystal, 24MHz support only

3 Description

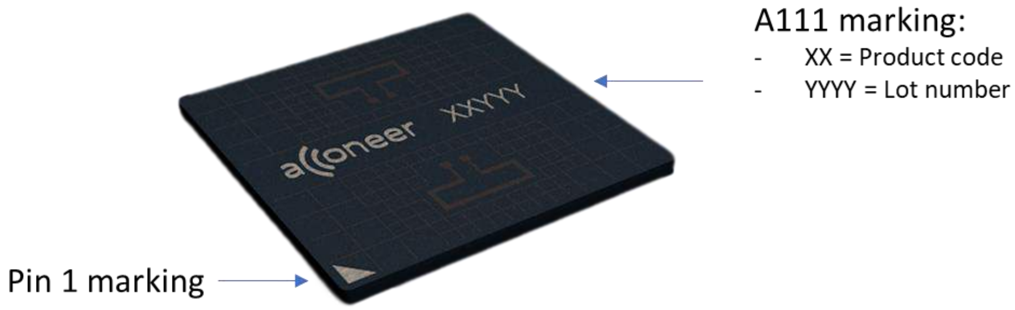
The A111 is an optimized low-power, high-precision, 60 GHz radar sensor with integrated Baseband, an RF front-end and an Antenna in Package (AIP).

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



3.1 Functional Block Diagram

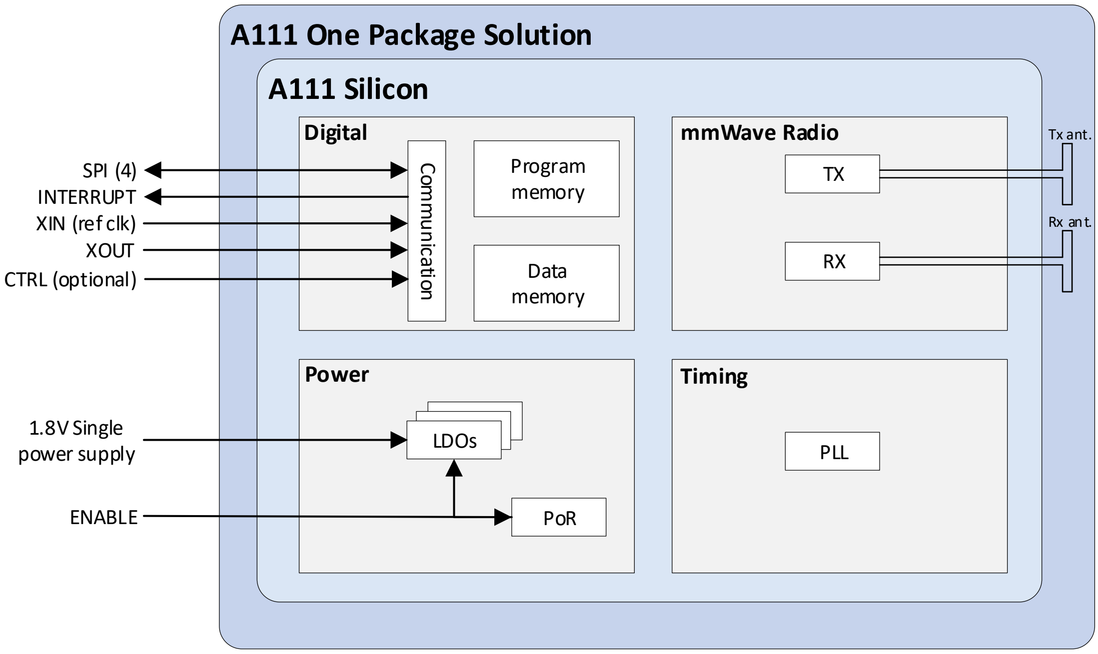


Figure 3.1 The A111 functional block diagram.

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 1.8 V 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 PLL digital clock output is used to drive digital logic and is synthesized from external crystal (XIN/XOUT) . The operational oscillator (XIN) frequency is 24MHz..

The mmWave radio functional block generates and receives radar pulses and includes transmitter (TX), receiver (RX) and interfaces toward the integrated antennas. The A111 operates in the 57-64 GHz band.

4 Pin Configuration and Functions

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

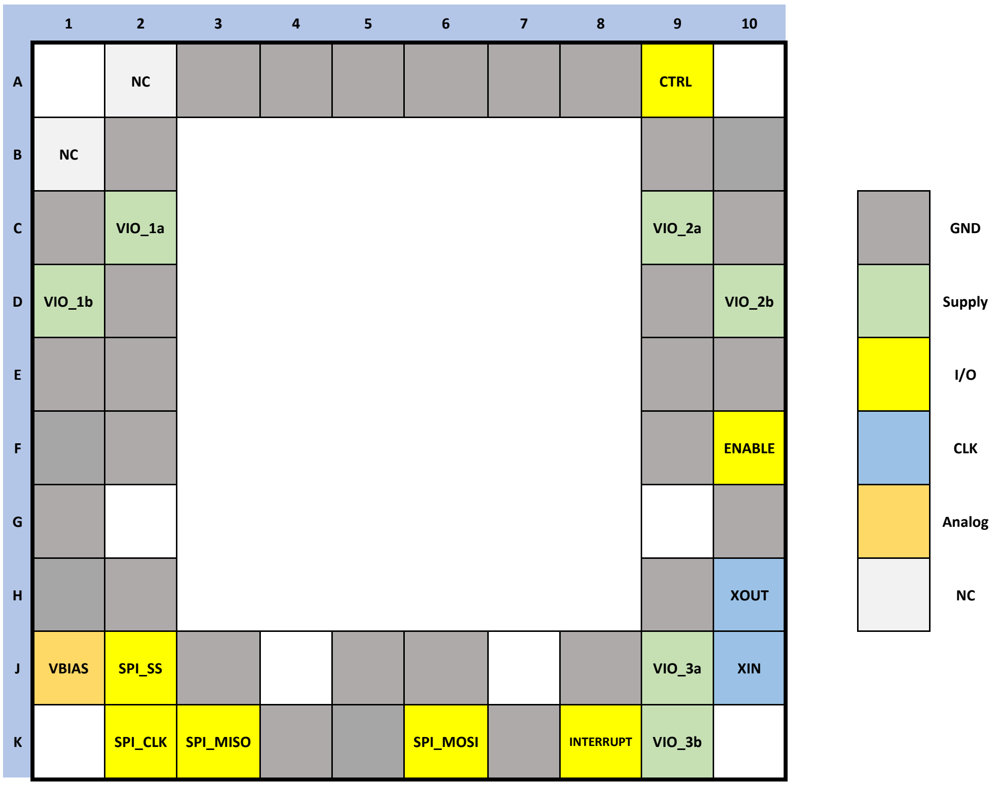


Figure 4.1. Pin configuration of the A111 sensor, top view.

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 (1)	
C9	VIO_2a	Supply voltage	Supply voltage, RF part (1)	
C10	GND	Ground	Must be connected to solid ground plane	
D1	VIO_1b	Supply voltage	Supply voltage, RF part (1)	
D2, D9	GND	Ground	Must be connected to solid ground plane	
D10	VIO_2b	Supply voltage	Supply voltage, RF part (1)	

Pin	Pin name	Pin type	Description	Comment
E1, E2, E9, E10	GND	Ground	Must be connected to solid ground plane	
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 output	
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 (1)	
J10	XIN	CLK	XTAL input	
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, *Description*.	mandatory
K9	VIO_3b	Supply voltage	Supply voltage, digital part (1)	

Table 4.1. 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.

5 Specifications

5.1 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 (1)	1.8 V RF power supply	0	2.0	V
VIO_2 (1)	1.8 V RF power supply	0	2.0	V
VIO_3	1.8 V digital power supply	0	2.0	V
I/O	I/O supply voltage	-0.5	VIO_3+0.5	V
T_{OP}	Operating temperature range	-40	85	°C
T_{STG}	High temperature storage		150	°C

Table 5.1. Absolute maximum ratings.

(1) VIO_1 and VIO_2 must never exceed VIO_3.

Stresses beyond those listed in Table 5.1 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.

5.2 Environmental Sensitivity

The below table shows the A111 environmental sensitivity:

Parameter	Standard	Max.	Unit
Storage temperature	JESD22-A103 (1)	150(1)	ºC
Reflow soldering temperature (1)	J-STD-020 (1)	260	ºC
Moisture Sensitivity Level	JESD22-A113 (1)	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 5.2. Environmental sensitivity.

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

5.3 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
Operating temperature (T_{op})	-40		85	ºC

Table 5.3. Recommended operating conditions.

5.4 Electrical Specification

The below table shows the A111 electrical DC specification conditions, on package, T_{op} = -40ºC to 85ºC:

Parameter	Min.	Typ.	Max.	Unit
Current into any power supply	0		100	mA
I/O V_{IL} Low-level input voltage	-0.3		0.10*VIO_3	V
I/O V_{IH} High-level input voltage	0.90*VIO_3		VIO_3+0.3	V
I/O V_{OL} Low-level output voltage	0		0.4	V
I/O V_{OH} High-level output voltage	1.6		VIO_3	V
I/O I_{OL} (VOL = 0.4V)	4.56	7.8	12.4	mA
I/O I_{OH} (VOH = VIO_3-0.4)	3.42	5.8	9.16	mA
I/O I_{IL} Low-level input current			<1	µA
I/O I_{IH} High-level input current			<1	µA

Table 5.4. Electrical DC conditions.

The below table shows the A111 electrical AC specification conditions, on package, at T_{op} = -40ºC to 85ºC:

Parameter	Min.	Typ.	Max.	Unit
I/O output operating frequency(1)	0		100	MHz
I/O minimum positive and negative pulse	6.25			ns

Table 5.5. Electrical AC conditions.

(1) Load capacitance 2 pF.

5.5 Power Consumption Summary

Table 5.6 summarizes the steady-state current consumption for the sensor states, average current ratings at all power terminals (VIO_1, VIO_2, VIO_3), VIO 1.8 V, at T_{op} = -40ºC to 85ºC:

Parameter		Typ.	Max.	Unit
OFF	VIO_1	29	143	µA
OFF	VIO_2	32	163	µA
OFF	VIO_3	0	22	µA
HIBERNATE	VIO_1	29	143	µA
HIBERNATE	VIO_2	32	164	µA
HIBERNATE	VIO_3	413	2190	µA
SLEEP	VIO_1	765	935	µA
SLEEP	VIO_2	770	942	µA
SLEEP	VIO_3	1.59	3.36	mA
READY(1)	VIO_1	1.32	1.70	mA
READY(1)	VIO_2	768	946	µA
READY(1)	VIO_3	31.0	36.4	mA
READY(2)	VIO_1	1.28	1.64	mA
READY(2)	VIO_2	770	942	µA
READY(2)	VIO_3	1.59	3.36	mA
ACTIVE	VIO_1	2.86	3.58	mA
ACTIVE	VIO_2	1.34	1.72	mA
ACTIVE	VIO_3	60.7	69.7	mA
MEASURE, PROFILE 1	VIO_1	3.89	4.66	mA
MEASURE, PROFILE 1	VIO_2	2.02	2.40	mA
MEASURE, PROFILE 1	VIO_3	67.5	77.0	mA
MEASURE, PROFILE 2	VIO_1	3.96	4.73	mA
MEASURE, PROFILE 2	VIO_2	2.08	2.46	mA
MEASURE, PROFILE 2	VIO_3	67.5	77.0	mA
MEASURE, PROFILE 3	VIO_1	4.23	5.03	mA
MEASURE, PROFILE 3	VIO_2	2.38	2.77	mA
MEASURE, PROFILE 3	VIO_3	68.1	77.6	mA

MEASURE, PROFILE 4	VIO_1	5.09	5.94	mA
MEASURE, PROFILE 4	VIO_2	3.36	3.77	mA
MEASURE, PROFILE 4	VIO_3	68.1	77.6	mA
MEASURE, PROFILE 5	VIO_1	6.21	7.14	mA
MEASURE, PROFILE 5	VIO_2	4.68	5.15	mA
MEASURE, PROFILE 5	VIO_3	68.1	77.6	mA

Table 5.6. Average current ratings at power terminals for the sensor states.

(1) based on non Sparse service configuration

(2) based on Sparse service configuration

5.6 RF Specification

The below table shows the A111 RF specification at T_{op} = -40ºC to 85ºC:

Parameter	Min.	Typ.	Max.	Unit
Operating frequency range	57		64	GHz
EIRP			10	dBm
TX HPBW, elevation plane (1)	42	53	64	degrees
TX HPBW, horizontal plane (1)	52	65	78	degrees

Table 5.7. A111 RF specification.

(1) Based on simulation.

6 Timing Requirements

6.1 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 6.1. The A111 allows several devices to be connected on the same SPI bus, with a dedicated slave-select signal. Daisy-chain is not supported.

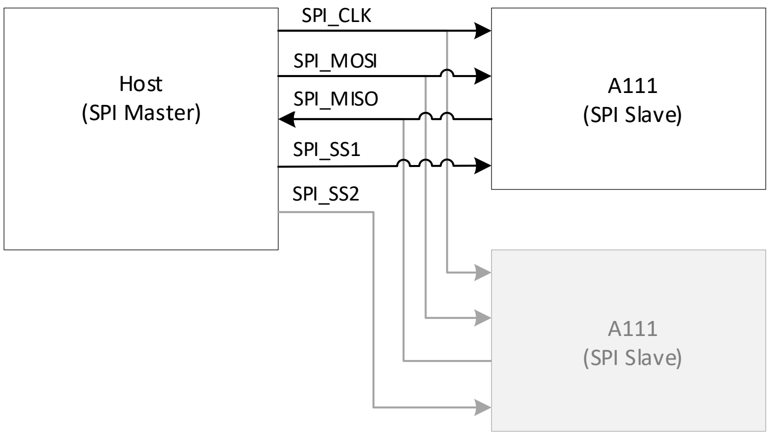


Figure 6.1. SPI master-slave connection.

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 6.2 and Table 6.1 for timing characteristics.

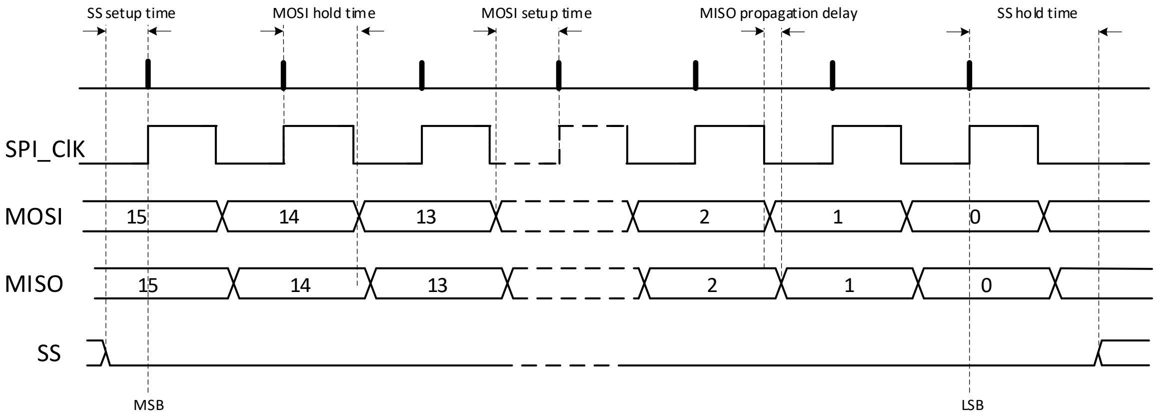


Figure 6.2. Timing diagram of SPI, CPOL=0 and CPHA=0.

Parameter	Min.	Typ.	Max.	Unit
Clock frequency (1)			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 (1)			5.5	ns

Table 6.1. SPI timing characteristics.

(1) 10pF load on SPI_MISO

7 Typical Characteristics

7.1 Radar Loop Gain Pattern

The Radar Loop Gain (RLG) pattern includes the gain in both the TX and RX radar paths and is defined as the angular separation between the two points at which the gain has decreased by 3 dB relative to the maximum main lobe value, when the radar itself is used to measure the reflected power. For details regarding the measurement setup, refer to "Hardware and physical integration guideline", chapter 1.2.

Conditions: T_A = 25 °C, V_{DD} = 1.8 V. Tested on 5 XR112 devices.

Figure 7.1 and Figure *7.2* shows the RLG radiation pattern normalized to free space sensor boresight at elevation plane (E-plane) and azimuth plane (H-plane).

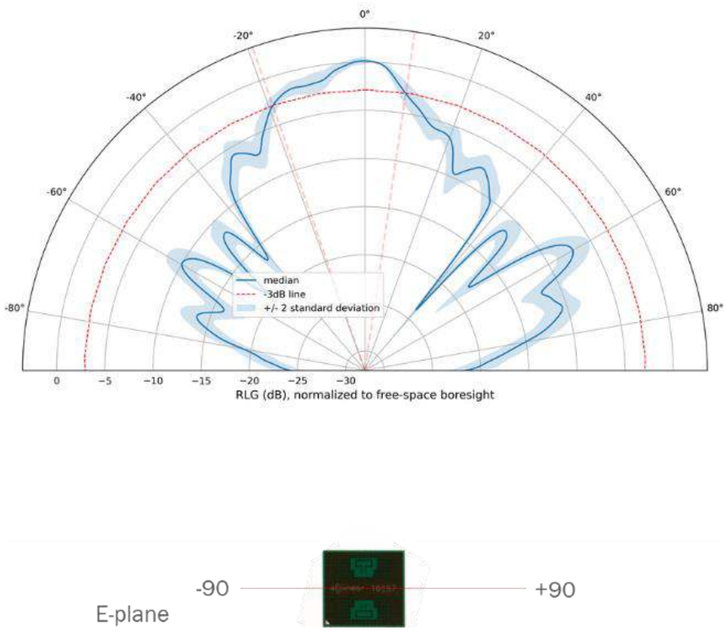


Figure 7.1. Normalized radar loop gain radiation pattern at E-plane.

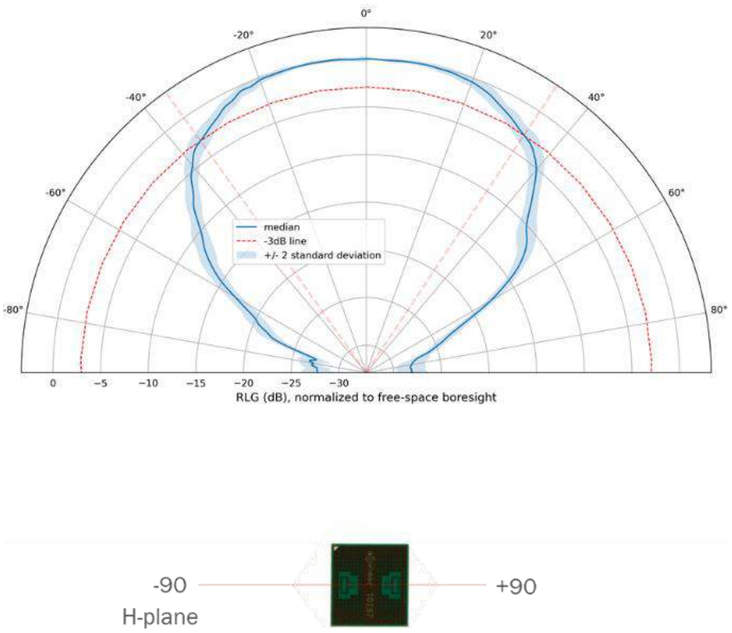


Figure 7.2. Normalized radar loop gain radiation pattern at H-plane.

7.2 Relative Phase Accuracy

Conditions: T_A = 25 °C, V_{DD} = 1.8 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 µm in relative distance accuracy.

8 Functional Description

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

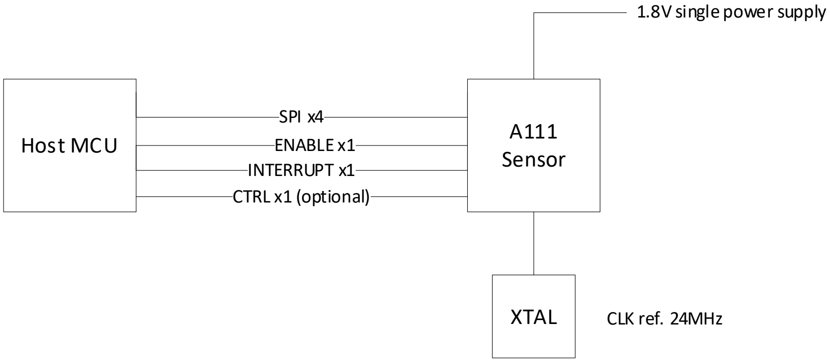


Figure 8.1. System integration.

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.

8.1 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.

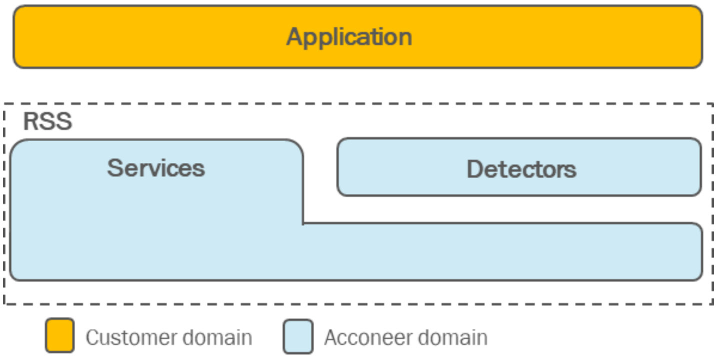


Figure 8.2. Acconeer Software offer.

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.

8.2 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).

8.3 Power Sequences

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

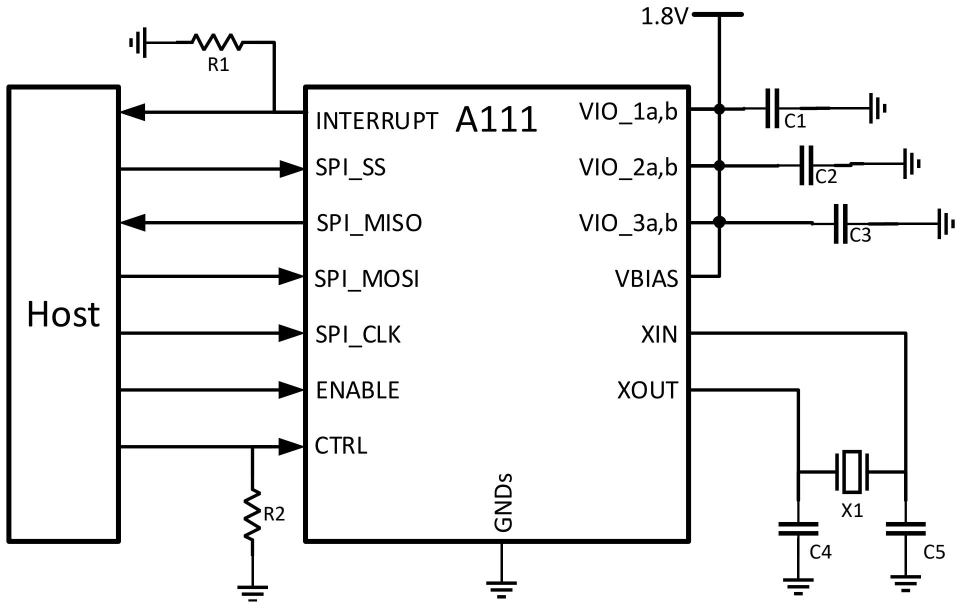


Figure 8.3. Recommended integration of the A111 radar sensor.

The power up sequence is shown in below figure.

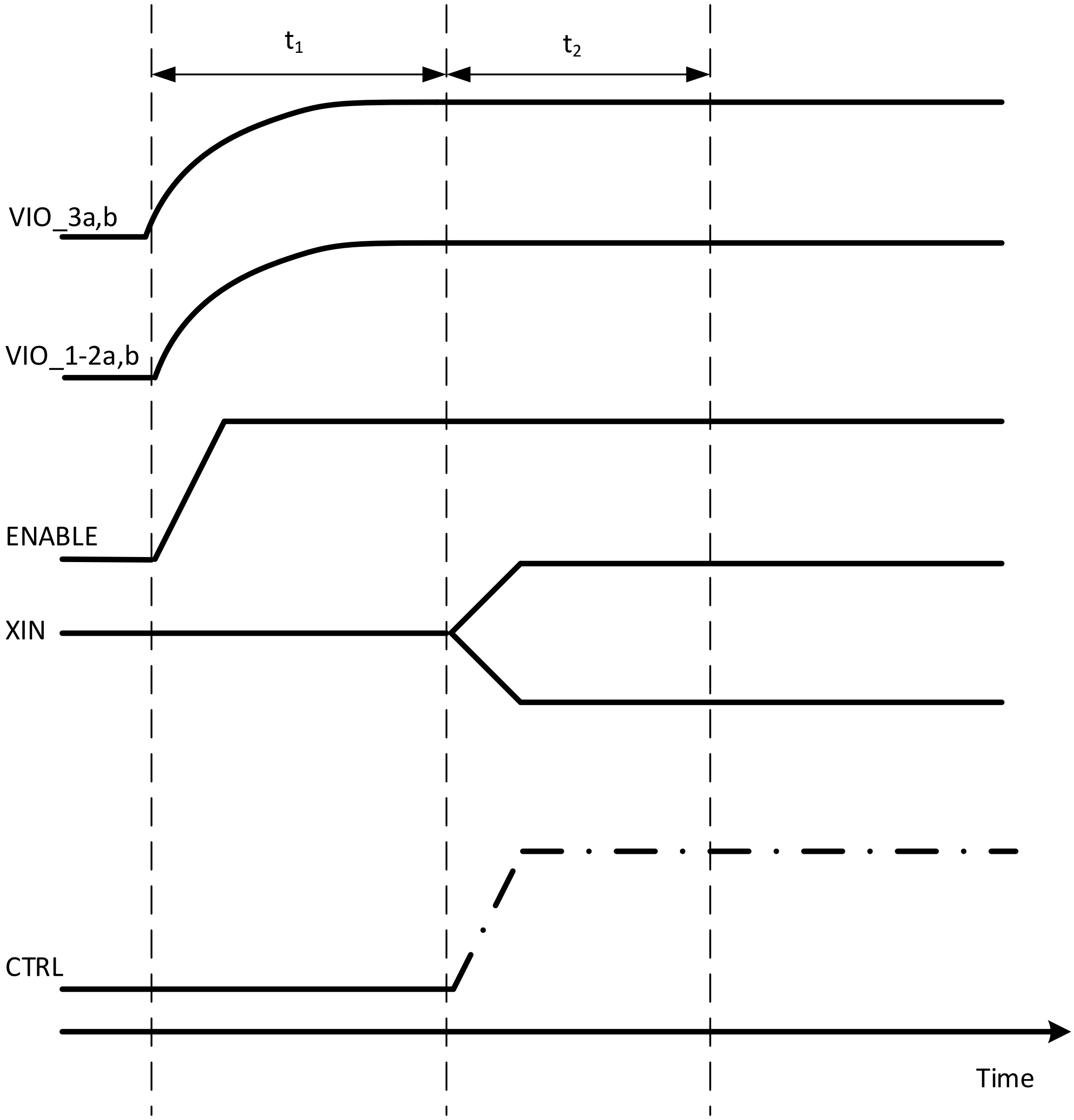


Figure 8.4. Power up sequence.

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 8.4. This may take up to several milliseconds depending on the XTAL performance. 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 8.5.

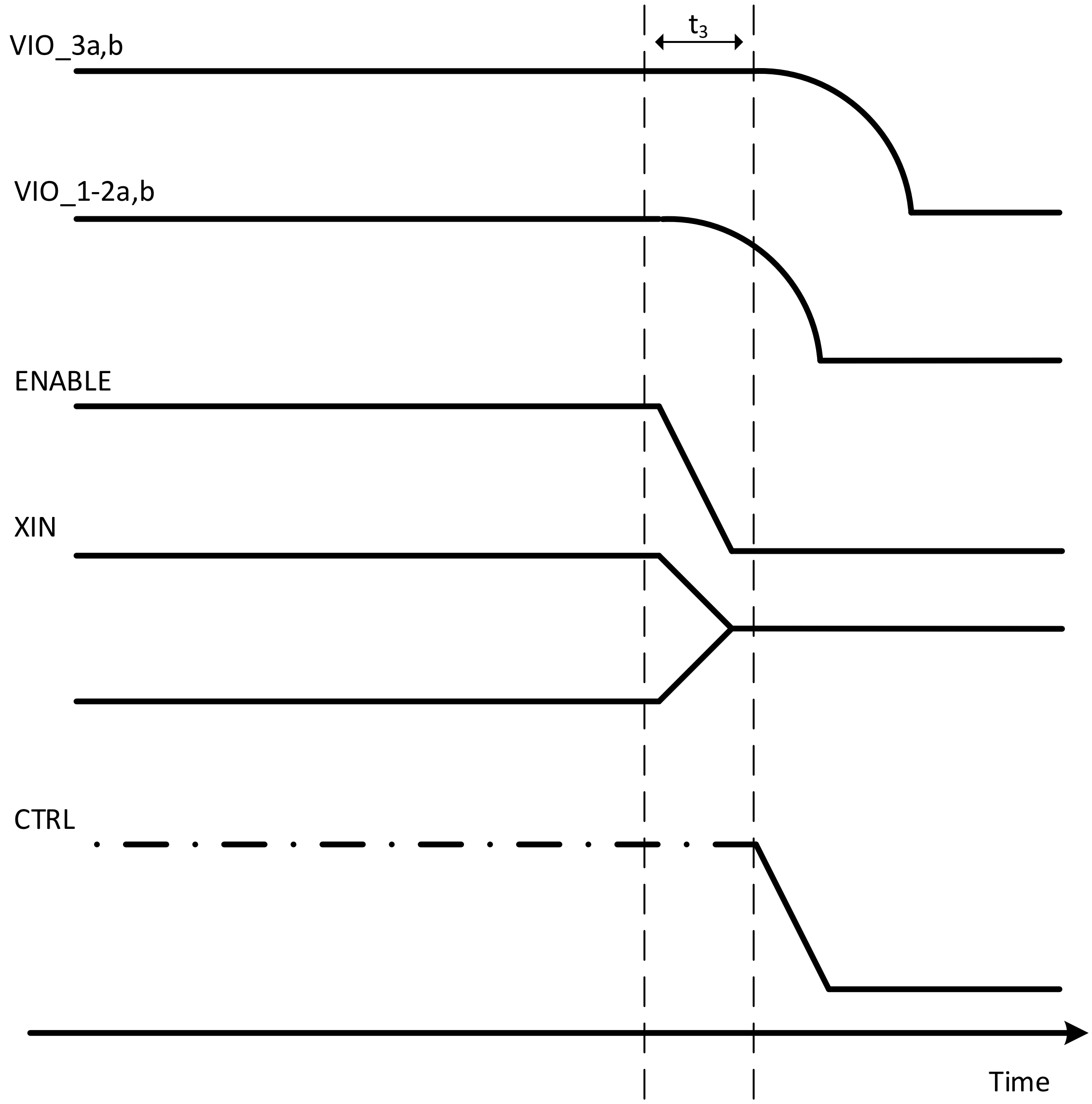


Figure 8.5. The power down sequence.

The power down sequence is initiated by setting "ENABLE" low. The crystal oscillator will be disabled when ENABLE is set low.

After that, VIO_1-2a,b can be turned off. Time constant t_3 (refer to Figure 8.5) later, VIO_3a,b can be disabled. The constant t_3 >=0. The I/O inputs on A111 (including CTRL if it is being used) must be set to 0V before or simultaneously with VIO_3a,b going low, otherwise the internal ESD protection diodes will draw current from the I/O source.

9 Layout Recommendations

The sensor antennas are of a folded dipole type, with its main ground reference being the internal package ground plane, extending below the whole area of the sensor. To further enhance the directivity of the sensor, the package ground plane should be extended by soldering all GND pads to the PCB top layer ground. In terms of regulatory compliance, any openings in the ground plane inside the A111 footprint must be significantly smaller than the wavelength (5 mm in free space) to effectively shield off any disturbance.

Figure 9.1 shows the simulated relative radar loop gain (RLG) as function of ground plane side length, assuming a square ground plane. As the ground plane size increases, the RLG increases because of increased antenna directivity. Constructive and destructive interference results in a non-monotonic increase in RLG.

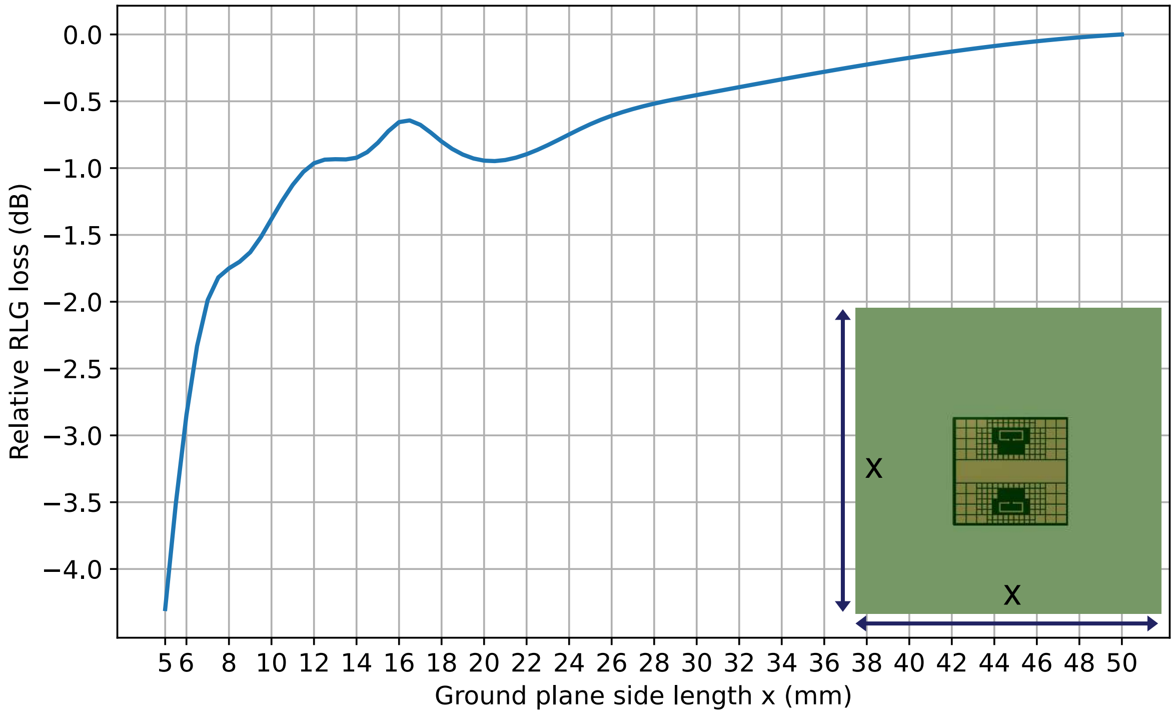


Figure 9.1. Simulated relative radar loop gain as function of ground plane side length (x). Ground plane is a solid square ground plane.

VIO_1a and VIO_1b are internally connected and connecting both on the PCB is recommended as well. Likewise, VIO_2a, VIO_2b and, VIO_3a, VIO_3b are internally connected and connecting both is recommended on the PCB as well. It is recommended to have decoupling capacitors on the supplies placed as close as possible to the supply terminals. A1 µF decoupling capacitance on each supply pin pair is recommended.

More detailed PCB layout guidelines can be found in the “Hardware and physical integration guideline”.

Bill of Material (BoM)

The below table shows BOM for integration of the A111 using a crystal as input clock source:

Component	Value	Description
C1, C2, C3	1 µF	VIO_1, VIO_2, VIO_3 decoupling
R1, R2	100 kΩ	INTERRUPT and CTRL pull down resistor
X1		XTAL 24 MHz, Epson TSX-3225
C4, C5	8 pF (1)	XTAL freq. tuning capacitor

Table 9.1. BOM list.

(1) See details in chapter 9.1 XTAL for C4, C5 value calculation.

9.1 XTAL

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

The A111 sensor has a built-in XTAL oscillator and adding an external XTAL component, as shown in the Figure 9.2.

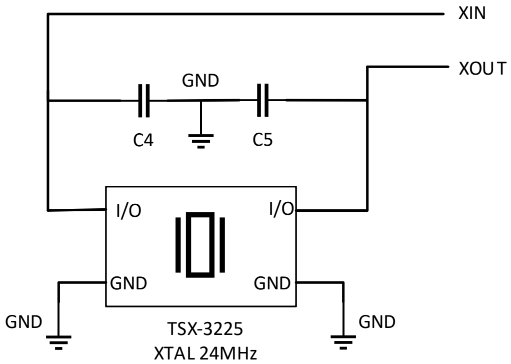


Figure 9.2. External XTAL schematics.

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

$$f * C_{pin}^{0.8} * R_{ESR}^{0.61} < 0.7 \qquad (Equation\ 1)$$

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

$$C_{pin} = C + C_{stray} * 2 \qquad (Equation\ 3)$$

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, that is, the PCB trace capacitance plus package capacitance; 2 to 5 pF is a general estimation.

Example:

- f = 24 MHz
- C_L = 9 pF
- R_{ESR} = 40 ohm

Assuming C_{stray} = 5 pF gives C4, C5 = 8 pF and that the condition is met with the result 0.58 < 0.7.

9.2 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 9.2 provides the required power supply ripple specification for VIO_3.

Frequency (Hz)	Min.	Typ.	Max.	Unit
10 000			18.7	mV_{pp}
100 000			2.6	mV_{pp}
1 000 000			0.26	mV_{pp}
3 000 000			0.09	mV_{pp}
10 000 000			0.23	mV_{pp}
100 000 000			3.0	mV_{pp}

Table 9.2. Required power supply ripple specification for VIO_3.

LC filter solution

When the VIO_3 voltage source is connected to a switching power supply, a post LC filter as displayed in Figure 9.3 can be designed satisfy the ripple specification. The exact values for LC filter depend on switching frequency and ripple amplitude of the supply regulator. Be aware of LC filter peaking at the series resonance frequency $f=1/(2\pi\sqrt{LC})$. A small snubber resistor, 250 mΩ in the example filter, can be inserted to lower the Q factor.

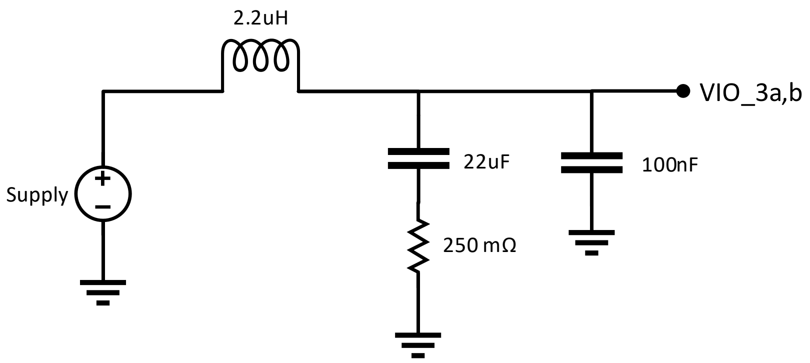


Figure 9.3. LC supply filter.

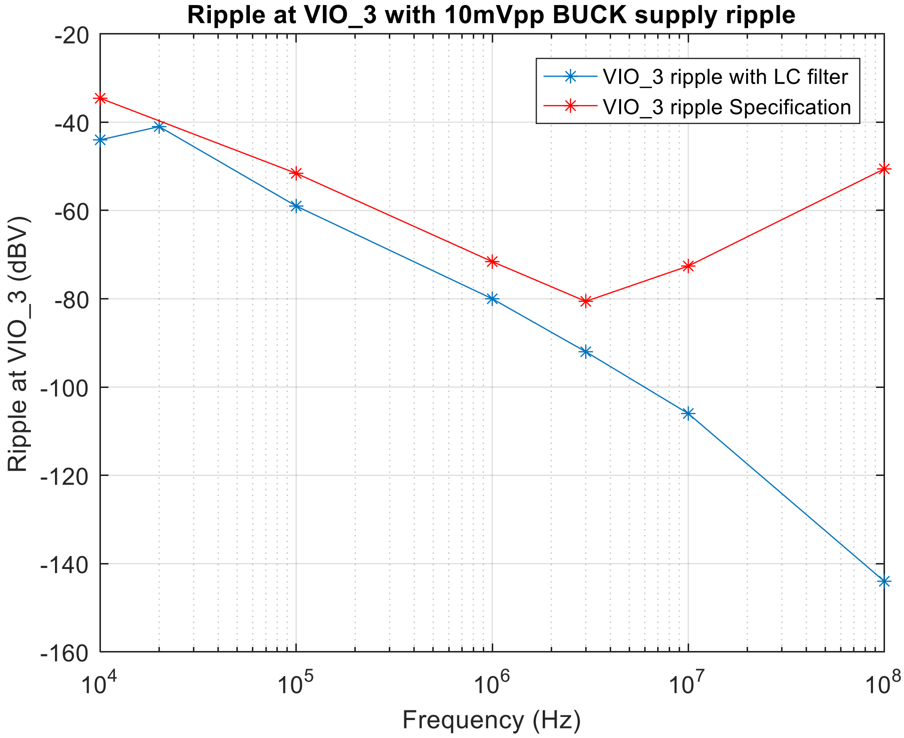


Figure 9.4. Simulated performance with 10 mVpp supply ripple with LC supply filter.

10 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.

10.1 ETSI

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

10.1.1 EU type examination certificate

EU Type Examination Certificate

CTC advanced
member of RWTÜV group

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

Bundesnetzagentur
BNetzA-bS-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.

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 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.

GERMAN NOTIFIED BODY
EUROPEAN ID-NO. 0682

Certificate Registration No.: T818606L-01-TEC

CE 0682

CTC advanced GmbH

Frank Muchitsch
cn=Frank Muchitsch, o=CTC advanced GmbH, ou=CTC-161125, email=frank.muchitsch@ctcadvanced.com, c=DE
2019.11.06 11:12:53 +01'00'

Saarbrücken

Authorized signature / title

CTC advanced GmbH (formerly CETECOM ICT Services GmbH)
Untertuerkheimer Str. 6–10 | 66117 Saarbruecken | Germany | www.ctcadvanced.com

10.2 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.

10.2.1 FCC Regulatory Notes

Modifications

Acconeer has not approved any changes to this device. Any changes or modifications to this device could invalid 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.

MPE RF exposure testing is not needed as the available maximum time-averaged power of the module is no more than 1 mW, according to 47 CFR 1.1307(b)(3)(i)(A).

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

10.2.2 FCC Grant Authorization

TCB

GRANT OF EQUIPMENT
AUTHORIZATION

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

TCB

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

Grant Notes	FCC Rule Parts	Frequency Range (MHZ)	Output Watts	Frequency Tolerance	Emission Designator
	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.

10.3 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

10.3.1 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 etiqueté pour exposer le IC du module précedé par les mots "Contient module émetteur" ou "Contient", ou des termes similaires exprimant le même sense, comme suit:

Contient IC: 24388-A111

10.3.2 Acceptance Certificate - Canada

CETECOM™

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 MRA EU-Canada

Bundesnetzagentur

BNetzA-CAB-13/22-55

TECHNICAL ACCEPTANCE CERTIFICATE - CANADA

Certificate Holder	Acconeer AB Scheelevagen 27 Lund 22370 Sweden
ISED Certification Number	**24388-A111**
Product Description	**Pulsed Coherent Radar**
CETECOM Registration No.	**19-1-0151901T01**
OATS Facility	CETECOM GmbH Im Teelbruch 116 45219 Essen GERMANY Phone: +49 (0) 20 54 / 95 19-0 Fax: +49 (0) 20 54 / 95 19-150 Email: meinolf.glunz@cetecom.com
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'ISDE 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'ISDE. 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 ISDE.

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**

Wenliang Li / FCB

FOREIGN CERTIFICATION BODY

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-sgs.ic.gc.ca/equipmentSearch/searchRadioEquipments?execution=e1s1&lang=en_CA

11 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 11.1. Mechanical data.

The A111 footprint is shown in Figure 11.1.

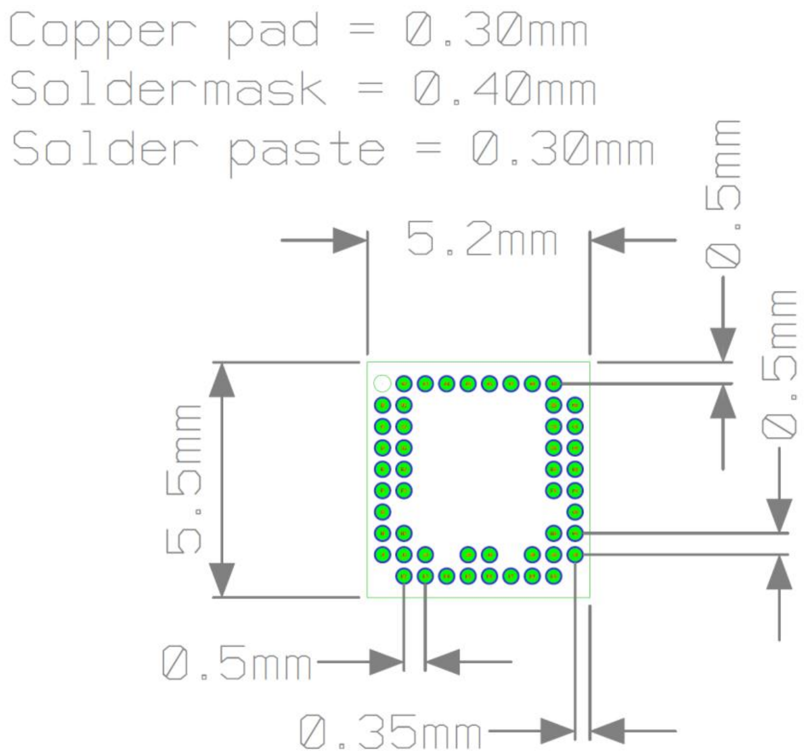


Figure 11.1. A111 footprint.

The physical layout of the A111 sensor is shown in Figure 11.2, 11.3 and 11.4.

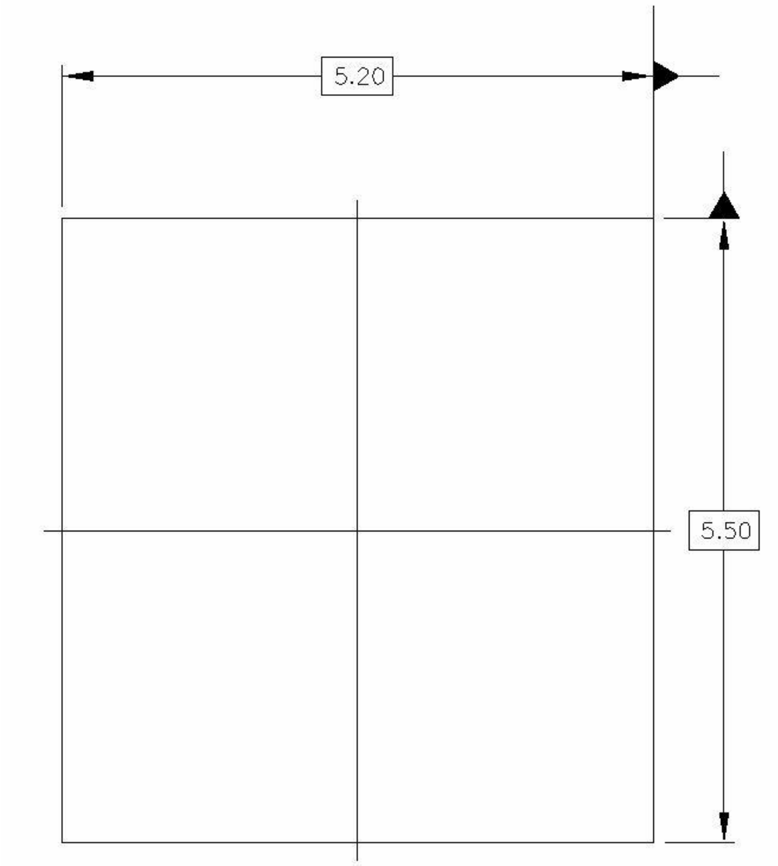


Figure 11.2. Physical layout of the A111 sensor, top view.

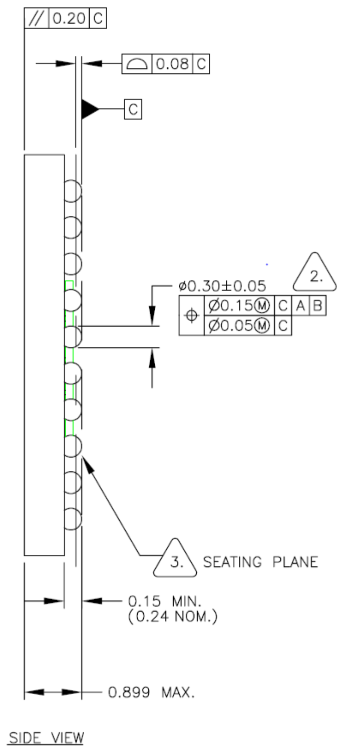


Figure 11.3. Physical layout of the A111 sensor, side view.

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.

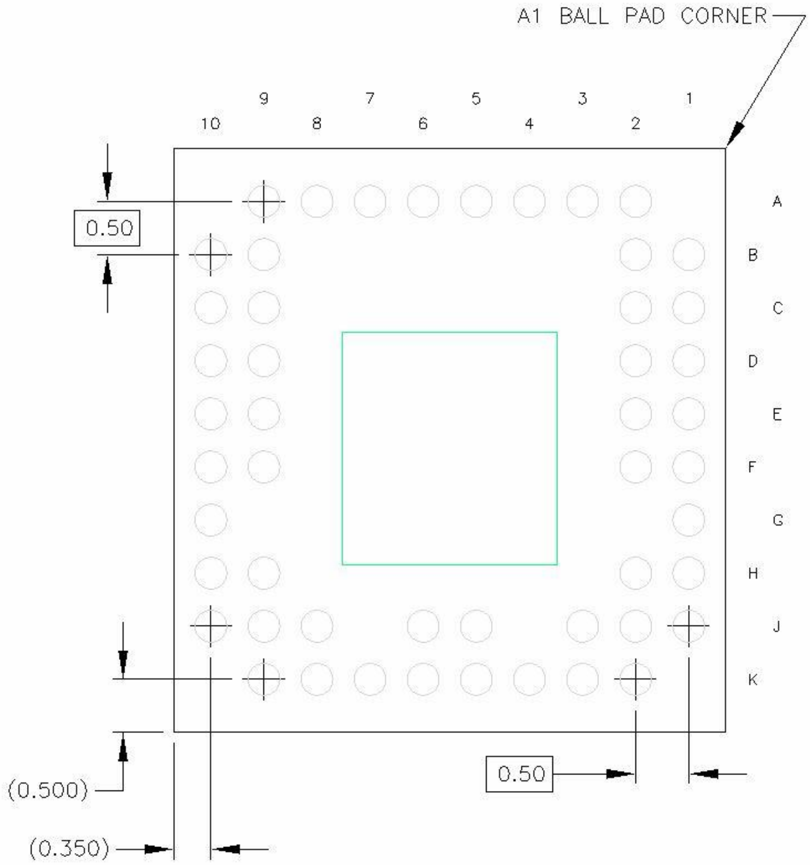


Figure 11.4. Physical layout of the A111 sensor, bottom view.

The bottom view shows 50 solder balls. The pitch of the BGA balls is 500 µm, the ball diameter is 300 µm ±5 µm and the collapsed ball height is 0.244 ± 0.050 mm.

11.1 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.

Maximum number of reflow passes recommended for A111 is 2.

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.

11.2 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.

12 Abbreviations

ADC	Analog digital converter
AiP	Antenna in package
API	Application programming interface
BGA	Ball grid array
BOM	Bill of materials
CE	"Conformité Europèene" (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

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