X4F103 - Datasheet

Ultra Wideband (UWB) Impulse Radar Sensor

Rev. A - 03-Jun-2024

Key Features

- Complete Ultra Wideband (UWB) impulse radar sensor module.
- Operates at 7.58 GHz.
- Advanced power management enabling low power duty cycle controlled operation.
- Industrial operating temperature range, -40°C to +85°C.
- Designed for ETSI and FCC modular compliance.
- Built-in antenna, no external circuitry required.
- SPI or I2C serial interface support.
- Wide supply voltage range, 1.8V - 3.3V.

Product Description

The X4F103 is an Ultra Wideband (UWB) short-range impulse radar sensor module, designed for unlicensed operation in world-wide markets.The X4F103 contains all required circuitry, such as antennas, clocks and de-couploing capacitors and can be connected directly to existing systems through a standard I2C or SPI interface. The X4F103 sensor is extremly sensitive and can detect human presence based on respiration motion alone. The sensor accurately detects presence within the detection zone and has configurable range limits and sensitivity settings.

Applications

- Proximity detection for display control, appliances, etc. to extend product lifetime and improve human-machine interaction.
- Occupancy detection for light control applications such as luminaire control etc.

Table of Contents

1. Electrical Characteristics

1.1. Absolute Maximum Ratings

Parameter		Min	Typ	Max	Unit
VDD	Supply voltage, all domains	-0.3		3.6	V
VDD_{IO}	Input voltage, digital I/O	-0.3		VDD + 0.3	V
JESD22-A103C	Storage temperature			150	°C
J-STD-020	Reflow soldering temperature			260	°C
J-STD-020	Moisture Sensitivy Level		3		
JEDEC JS-002	ESD, CDM			500	V
JEDEC JS-001	ESD, HBM			1000	V

Table 1.1. Absolute maximum ratings

1.2. General Operating Conditions

Parameter		Min	Typ	Max	Unit
VDD	Supply voltage, all domains	1.8		3.3	V
T_A	Ambient operating temperature	-40		85	°C

Table 1.2. General operating conditions

1.3. TX Parameters

Tc = 25°C, VDD = 1.8 V, unless otherwise noted.

Parameter		Min	Typ	Max	Unit
TX center frequency			7.58		GHz
TX bandwidth (-10 dB)	EIRP on X4F103		900		MHz
Power Spectral Density [1]	EIRP on X4F103		-43		dBm/MHz

[1] X4 configuration and instrument setup as used during regulatory compliance testing. PL = 3, CPP = 14, duty cycle = 100%

Table 1.3. TX parameters

1.4. Current Consumption

Tc = 25°C, VDD = 1.8 V, unless otherwise noted.

Parameter		Min	Typ	Max	Unit
VDD = 1.8V					
Power-down current	Enable pin low [1]		20		µA
Idle	CPU Idle, reduced system clock, LPOSC		300		µA
Active	CPU active, full clock rate, LPOSC		1.7		mA
Active	CPU active, full clock rate, XOSC		1.8		mA
Active, radar ready	All LDOs and PLLs on		50		mA
Radar Acquisition	During sweep [2] [3]		70		mA
VDD = 3.3V					
Power-down current	Enable pin low [1]		35		µA
Idle	CPU Idle, reduced system clock, LPOSC		500		µA

Parameter		Min	Typ	Max	Unit
Active	CPU active, full clock rate, LPOSC		1.9		mA
Active	CPU active, full clock rate, XOSC		2.1		mA
Active, radar ready	All LDOs and PLLs on		50		mA
Radar Acquisition	During sweep [2] [3]		70		mA

[1] 100kohm pull-up on Enable signal.

[2] Actual acquisition current is dependent on sweep length and FPS. Refer to product specific information for details.

[3] Settings used: TxPower = 3, Iterations = 128, PulsesPerStep = 7, DACRange = {963, 1087}, DACStep = 1, PRFDivisor = 16.

Table 1.4. Current consumption

1.5. Specification of Clock Sources

1.5.1. Internal Low Power Oscillator (LPOSC)

Parameter		Min	Typ	Max	Unit
F_{tol}	Absolute frequency accuracy		5		%
F_{LPOSC}	Output frequency		27		MHz

Table 1.5. Low power oscillator (LPOSC) specification

1.5.2. Crystal Oscillator (XOSC)

Parameter		Min	Typ	Max	Unit
$F_{fundamental}$	Crystal frequency		27		MHz
F_{tol}	Frequency accuracy		±40		ppm

Table 1.6. Crystal oscillator specification

1.5.3. Digital I/O characteristics

Tc = 25°C, unless otherwise noted.

Parameter		Min	Typ	Max	Unit
DVDD_IO = 1.8V					
V_{IL}	Logic '0' input voltage			0.6	V
V_{IH}	Logic '1' input voltage	1.2			V
V_{OL}	Logic '0' output voltage			0.5	V
V_{OH}	Logic '1' output voltage	1.3			V
R_{PU}	Internal pull-up resistor		111		kohm
I_{OL}	GPIO current at V_{OL} max		4		mA
I_{OH}	GPIO current at V_{OH} min		4		mA
DVDD_IO = 2.5V					
V_{IL}	Logic '0' input voltage			0.7	V
V_{IH}	Logic '1' input voltage	1.7			V
V_{OL}	Logic '0' output voltage			0.7	V
V_{OH}	Logic '1' output voltage	1.7			V
R_{PU}	Internal pull-up resistor		73		kohm
I_{OL}	GPIO current at V_{OL} max		9		mA
I_{OH}	GPIO current at V_{OH} min		9		mA

Parameter		Min	Typ	Max	Unit
DVDD_IO = 3.3V					
V_{IL}	Logic '0' voltage input voltage			0.8	V
V_{IH}	Logic '1' voltage input voltage	2			V
V_{OL}	Logic '0' voltage output voltage			0.4	V
V_{OH}	Logic '1' voltage output voltage	2.4			V
R_{PU}	Internal pull-up resistor		54		kohm
I_{OL}	GPIO current at V_{OL} max		7		mA
I_{OH}	GPIO current at V_{OH} min		13		mA

Table 1.7. Digital I/O characteristics

2. Inter-Integrated Circuit (I2C)

This section specifies the I2C interface and the I2C bootloader which enables communication between the X4 and an external host for transfer of radar and configuration data. The X4 I2C interface supports a maximum clock frequency of 400 kHz and the default device 7-bit slave address is 0x5A.

2.1. I2C Specification

Parameter	Min	Max	Unit
Maximum I2C clock frequency		400	kHz
7-bit I2C slave address	0x5A		

Table 2.1. I2C Specification

2.2. I2C Operation

After boot (power-on-reset, or pin reset), the X4 will by default enable the I2C bootloader. This bootloader can be used to upload program data to the internal memory of the X4. Typically, this program will be a sensor profile provided by Novelda which configures the sensor and enables signal processing. When the host has completed the transfer of the program to the X4's internal memory, it must initiate a soft reset to start executing the uploaded program. The profile may implement its own I2C commands in addition to the ones supported by the boot loader.

Note that the memory in the X4 is not retained through a power cycle or when the Enable pin is pulled low. After such events, the host must upload the program data through the bootloader again.

Novelda will provide all the software that handles the firmware loading protocol and the communication with the X4. Only the low level I2C read and write transactions, using the local host's appropriate serial peripheral unit, must be implemented by the user.

3. Serial Peripheral Interface (SPI)

This section specifies the Serial Peripheral Interface (SPI) between the X4F103 and an external host for transfer of radar and configuration data.

The SPI interface has been tested at clock frequencies up to of 32 MHz.

3.1. SPI Protocol

All SPI communication between external host and the X4F103 take place as units called commands. A command starts with an 8-bit instruction and may be followed by a payload.

During SPI communication data is transferred from the host to the X4F103 on the COPI pin and from the X4F103 to the host on the CIPO pin.

The SPI can be driven by a host in either of the two following clocking modes:

- **Mode 0** with Clock Polarity (CPOL) = 0 and, Clock Phase (CPHA) = 0.
- **Mode 3** with CPOL = 1 and, CPHA = 1.

In both of these modes the X4F103 samples the input on the rising edge of the SPI clock signal (SCLK) and changes the output following a falling edge. The difference is in the polarity of the clock between transfers:

- SCLK will stay at logic low state with CPOL = 0, CPHA = 0.
- SCLK will stay at logic high state with CPOL = 1, CPHA = 1.

All transfers begin with the most significant bit and ends with the least significant bit.

When Chip Select (CS) is inactive (high) the CIPO pin must be in high impedance mode to allow multiple peripherals to operate against a single controller. The SPI module therefore disables the output enable signal on the CIPO pin when CS is high.

Novelda will provide all the software that handles the firmware loading protocol and the communication with the X4F103. Only the low level SPI read and write transactions, using the local host's appropriate serial peripheral unit, must be implemented by the user.

3.2. SPI Commands

The commands are structured as follows:

- A command begins when CS is pulled low by the host.
- All commands start with an eight bit instruction transferred from the host to the X4F103.
- The most significant bit is always high for write instructions and low for read instructions.
- The length of all transfers following the instruction are determined by the instruction.
- The commands end when CS is pulled high by the host.

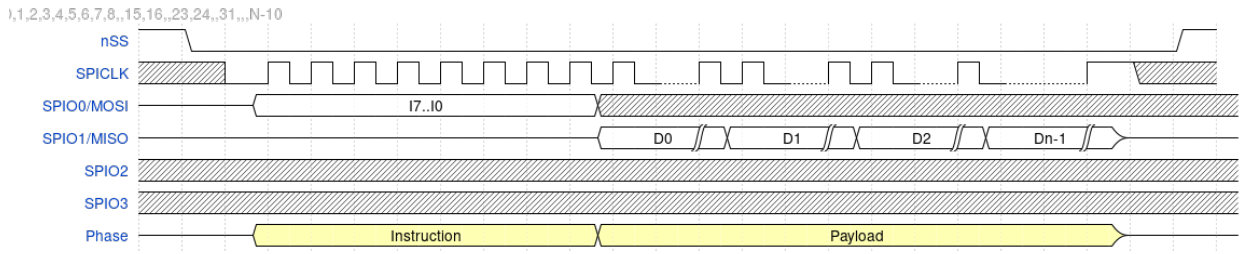

Figure 3.1. SPI read sequence.

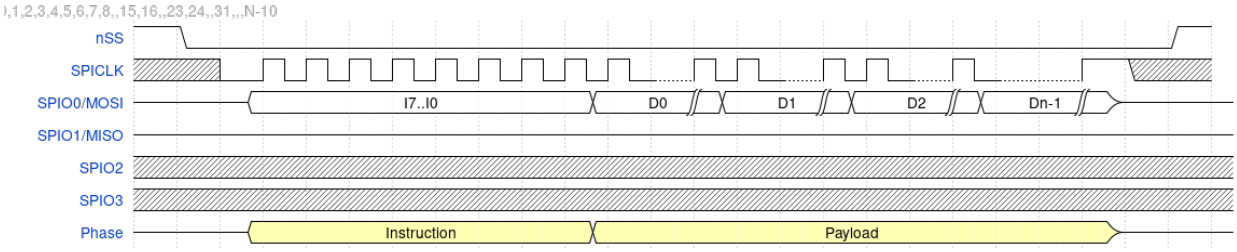

Figure 3.2. SPI write sequence.

4. Implementation and Layout

The X4F103 is mechanically and electrically connected to a carrier PCB through 16 solder balls. The balls are non-collapsable to ensure proper clearance for the components on the bottom side of the module.

Figure 4.1 shows the front- and back side of the of sensor module.

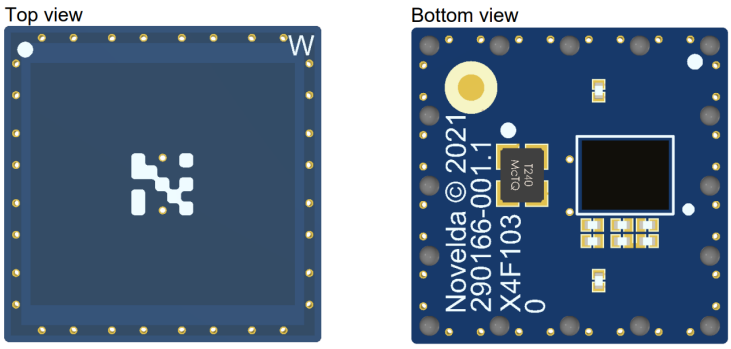

Figure 4.1. X4F103

4.1. Module Pinout

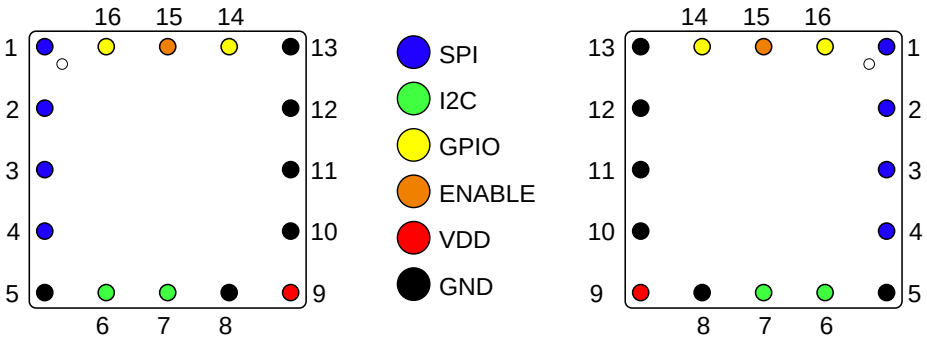

Figure 4.2. Pinout - top view (left) - bottom view (right)

Connector Pad	Signal Name	Function
1	CIPO	SPI - Controller In Peripheral Out
2	COPI	SPI - Controller Out Peripheral In
3	SCLK	SPI Clock
4	CS	Chip Select
5	GND	Ground
6	SDA	I2C Data
7	SCL	I2C Clock
8	GND	Ground
9	VDD	Power supply
10	GND	Ground
11	GND	Ground
12	GND	Ground
13	GND	Ground
14	GPIO4	GPIO (typically used as IRQ signal from X4)

Connector Pad	Signal Name	Function
15	ENABLE	Enable pin, active high
16	GPIO3	GPIO (function depending on SW profile)

Table 4.1. Pinout

4.2. Typical Application Circuit

The following figures show the X4F103 in typical application circuits using I2C and SPI as the communication interface.

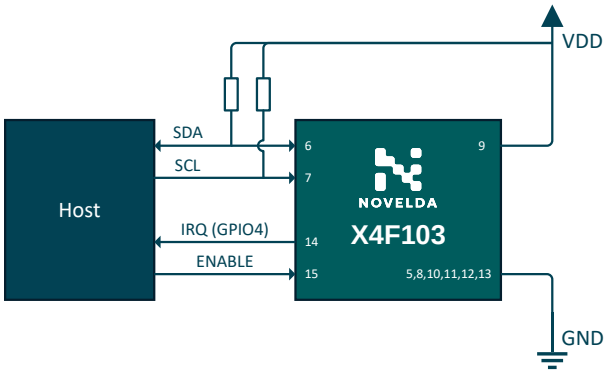

Figure 4.3. Application Circuit - I2C

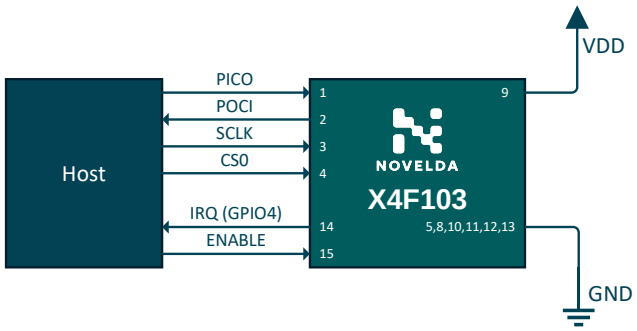

Figure 4.4. Application Circuit - SPI

- Unused GPIO should be left not connected. Do NOT tie unused GPIO to ground. This would prevent the I2C interface from working as expected.
- When the ENABLE signal is set low, the module goes into an ultra low power shutdown state. When the ENABLE signal is set high, the device goes out of the shutdown state and goes through a full reset sequence.
- The ENABLE signal can be connected to VDD to avoid using an additional pin on the host controller to assert and deassert this signal. However, it is highly recommended to control the ENABLE pin from the host, as this makes it possible to reset the module in a controlled manner.

- The IRQ signal (GPIO4) is typically used to indicate to the host that there is data available on X4, or that the radar has detected presence. This will depend on the firmware running on the X4 and the overall software profile in use. The signal is not strictly required, as the host can poll X4 to read out status periodically. However, in order to save overall system power, using the interrupt mechanism is recommended.

4.3. Mechanical Specifications

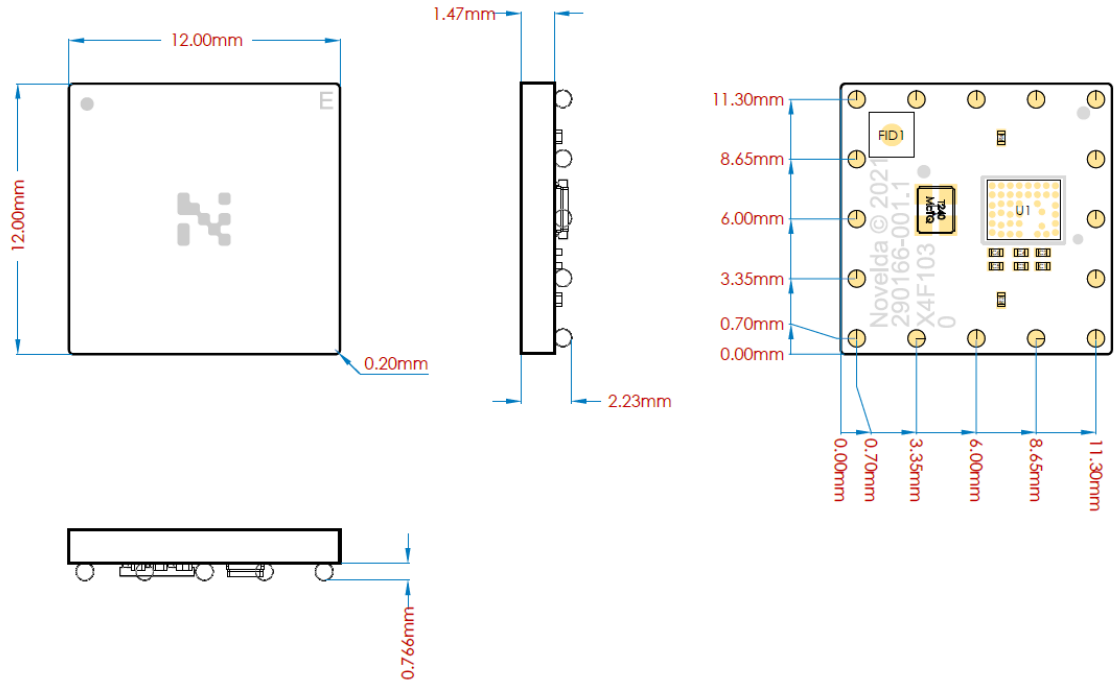

Figure 4.5. Physical Dimensions

4.4. Recommended footprint

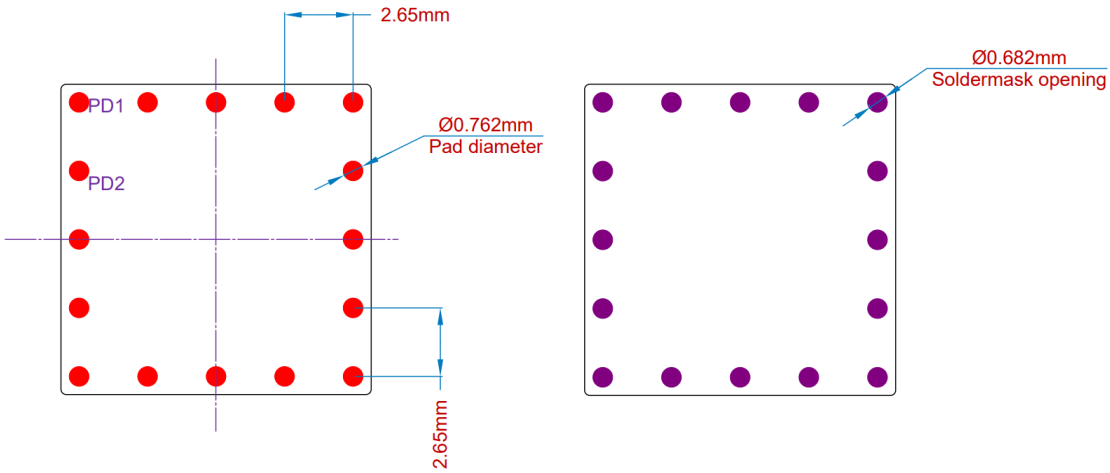

Figure 4.6. Recommended Footprint

Solderpads are recommended to be "solder mask defined", i.e. the soldermask opening is smaller than the pad size.

4.5. Layout

For regulatory compliance the layout must follow these requirements:

- A solid continuous ground plane, connected to all the sensor´s ground pins, is required on the uppermost PCB layer underneath the sensor. The ground plane must be at least 12 mm x 12 mm to include all the ground pins. The ground plane can be of any electrically conductive material and any thickness.
- No signal routing on the top layer underneath the sensor is allowed. All signals must be fanned out away from the module.

Additional guidelines:

- Signal routing on other PCB layers underneath the sensor and the ground plane is allowed.
- The sensor can be placed directly on PCBs with solid ground planes, including aluminium PCBs.

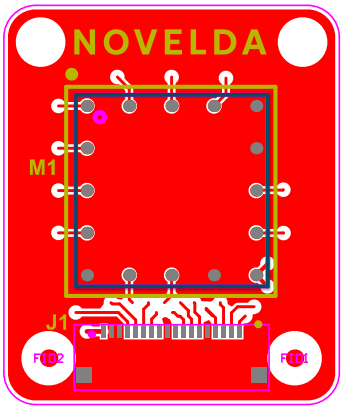

Figure 4.7. Layout Example

The dark blue square is the outline of the sensor module and the grey circles inside the square are the solder pads for the sensor module. All signals are routed outwards and away from the module. There is a solid continuous ground plane, connected to all the module ground pads, underneath the module.

4.6. General Mechanical Integration Guidelines

For more detailed integration guidelines refer to separate documentation available on Novelda´s web pages.

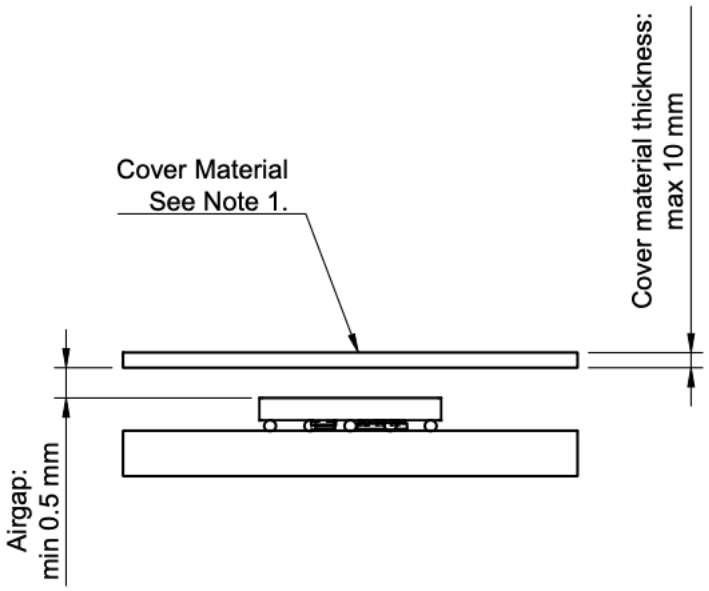

Figure 4.8. Material In Front of Sensor

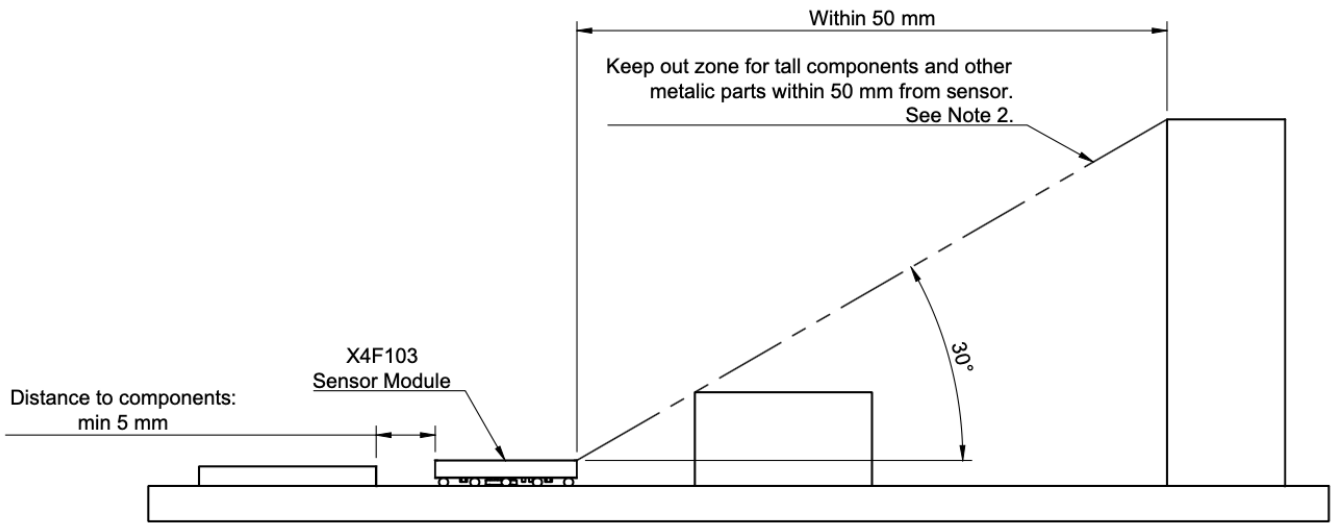

Figure 4.9. Objects Next to Sensor

Notes:

1. Non-Metallic and non-conductive materials only. Typically plastic or glass.
2. Placement closer to the sensor might affect performance. Ask Novelda for advice.
3. PCB layout guidelines can be found further up in this document.

5. Regulatory Compliance

The X4F103 module is certified under the European Radio Equipment Directive (2014/53/EU,ETSI/CE) and Canadian IC/ISED as listed in Table 5.1. The EU Declaration of Conformity and the EU Type Examination Certificate can be found on Novelda´s web pages.

Host manufacturers can build their certification on Novelda´s testing provided the integration guidelines listed in Section 4.5 are followed.

In other territories, not listed here, it is the host manufactureres responsibility to obtain necessary certification for the host product.

Region	Requirement	Specification
Europe	Electrical safety	EN 62368-1:2014 + AC:2015 + AC:2017 + A11:2017
	EMF exposure	EN 62479:2010
	EMC	EN 301 489-1 v2.2.3 EN 301 489-33 v2.2.1
	Radio spectrum use	EN 302 065-1 v2.2.1
Canada	RF Exposure	RSS-102 Issue 5 (2015-03) Amd 1 (2021-02)

Table 5.1. Certifications

5.1. Canada (ISED) Regulatory Notices

5.1.1. Modification Statement

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Les changements ou modifications non expressément approuvés par la partie responsable de la conformité pourraient annuler l'autorisation de l'utilisateur d'utiliser l'équipement.

5.1.2. Interference Statement

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s). 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.

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique 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;
2. L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

5.1.3. RF Exposure

This device complies with the ISED RF exposure limits and has been evaluated in compliance with portable exposure condition.

There is no limitation as to which distance can be used from the human body.

Cet appareil est conforme aux limites d'exposition RF d'ISDE et a été évalué conformément aux conditions d'exposition portable.

Il n'y a aucune limitation quant à la distance qui peut être utilisée par rapport au corps humain.

5.1.4. Labelling Requirements for the Host Device

The host device shall be properly labelled to identify the modules within the host device. The certification label of the module shall be clearly visible at all times when installed in the host device, otherwise the host device must be labelled to display the IC of the module, preceded by the words "Contains transmitter module", or the word "Contains", or similar wording expressing the same meaning, as follows:

Contains IC:22782-X4F103

L’équipement hôte doit être correctement étiqueté pour identifier les modules dans l’équipement. L'étiquette de certification du module doit être clairement visible en tout temps lorsqu'il est installé dans l'hôte, l’équipement hôte doit être étiqueté pour afficher l'IC du module, précédé des mots "Contient le module émetteur", ou le mot "Contient", ou un libellé similaire exprimant la même signification, comme suit:

Contient IC:22782-X4F103

5.1.5. CAN ICES-003(B)

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de Classe B est conforme à la norme NMB-003 du Canada.

6. Disclaimer

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Document History

Rev.	Release date	Change description
A	03-Jun-2024	First release.