X4M202 Datasheet

Respiration Sensor

XeThru Datasheet **by Novelda AS**

Rev. A - Preliminary - September 10. 2018

Summary

The XeThru X4M202 Respiration Sensor is an industrialized sensor that complies with worldwide regulations ready for product integration. Based on Novelda's proprietary, highly integrated X4 system-on-chip (SoC), the sensor provides highly accurate measurement of a person's breathing frequency, together with distance and movement information.

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1 List of Features

- Non-contact vital signs monitoring up to 5 meters
    - Measures distance from sensor to person
    - Measures respiration rate of person when person is still
- Radar sensor
    - Baseband data output
    - Pulse Doppler output
- Novelda Ultra Wide Band (UWB) Impulse Radar X4 system on a chip (SoC)
- Built-in TX and RX antennas
- Multiple interface options
    - Serial interface, UART and USRT
    - On-board USB interface
- On-board multi-color LED
- Certifications
    - KCC for Korea
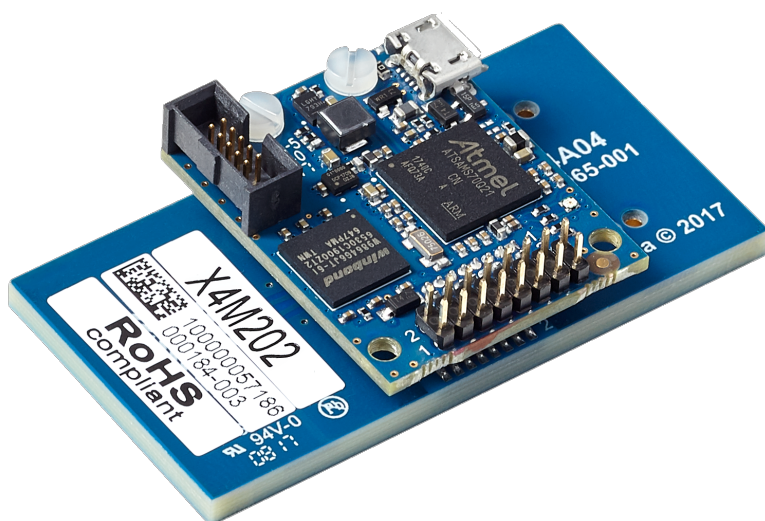
X4M202 Respiration Sensor

1.1 Order information

Order Code	Item Description	MOQ	MPQ	Packaging
X4M202	X4M202 Respiration Sensor KCC version	1	1	1 unit in anti-static bag
X4M202-TR100	X4M220 Respiration Sensor KCC version	100	100	100 units in anti-static tray

MOQ: Minimum Order Quantity

MPQ: Minimum Package Quantity

2 XeThru X4M202 Respiration Sensor

X4M202 senses vital signs data such as respiration rate, breathing pattern and movements on people that are still, typically lying in a bed or sitting still.

X4M202 is able to sense human presence by detecting any motion such as a person walking, hand movements and even a person with no other movements than respiration. The unique ability to sense respiration movement enables products that do not lose track of a person's presence if he/she sits still for a longer time period. Its extreme sensitivity enables it to detect presence up to a distance of 5.0 meters. It is also able to measure the distance between the sensor and the person with centimeter accuracy, and is not susceptible to "dead spots" within the detection zone.

With the XeThru technology's ability to see through light materials it also enables products that detect a person's presence and collects vitals signs data while sleeping with a blanket, duvet or clothes covering the person's body.

3 Sensor Operation

3.1 Power-up and Reset

3.1.1 First Power-Up

At first power-up of the sensor, the default Profile will be loaded and started with its default User Settings. Each Profile has a default message that the sensor will start sending over the serial communication link.

3.1.2 Configuration

Profiles and User Settings can be modified and loaded as described in the Module Connector documentation found on www.xethru.com.

User Settings vary between different Profiles and each Profile has its own default settings. See the Profile description chapters for details.

User Settings can only be changed when the Profile is not running. To change any setting, follow these steps:

1. Stop running Profile (if any Profile is running)
2. Load desired Profile (if not already loaded)
3. Send settings commands
    a. User Settings such as Detection Zone, Sensitivity etc.
    b. Output Control settings that determine which messages will be sent over the serial communication link on X4M202
4. Start running Profile

New settings will be programmed into the sensor when a Profile is started. If new settings are given to the sensor, but power is turned off or lost before a Profile is started, the new settings are lost, and the sensor will remember its old settings at the next power up.

Changing between some Profiles will require the sensor to reset its microcontroller (MCU) to take effect. In this case, when starting to run the new Profile, the sensor will give an error reply, take all changes into affect, and reset. The host should then wait for a couple of seconds to issue new commands to load and start running the Profile. The sensor will then reply OK and start the new Profile. Examples of Profiles that require the sensor to reset its microcontroller are Profiles using only internal MCU memory versus Profiles using external memory on the sensor.

Switching Profile will load the last used User Settings for the new Profile. If the new Profile has not been run earlier, default User Settings for that Profile are used.

3.1.3 Running Sensor Directly from Power-up or Reset

At power-up or reset, the sensor will start with its last used settings.

3.2 IO-pins

Various Profiles may have different uses of IO-pins. Do not connect IO-pins that are not in use. The sensor module will pull up these IO-pins internally. Future FW upgrades of the sensor and any existing or future pin compatible products may use these unused IO-pins for other functionality.

3.3 Firmware Versions

The datasheet may describe features not yet implemented in the current firmware version of the module. The datasheet chapter Firmware Versions explains what features are implemented in which firmware versions.

3.4 Bootloader

The module has a bootloader to allow field firmware upgrades. The bootloader is locked and cannot be reprogrammed, thus it can never be erased, altered or removed from the module over the serial protocol. The bootloader can be entered through the serial protocol, and it is also possible to force the module into bootloader mode using the pin header interface. See datasheet chapter Interface Options for details.
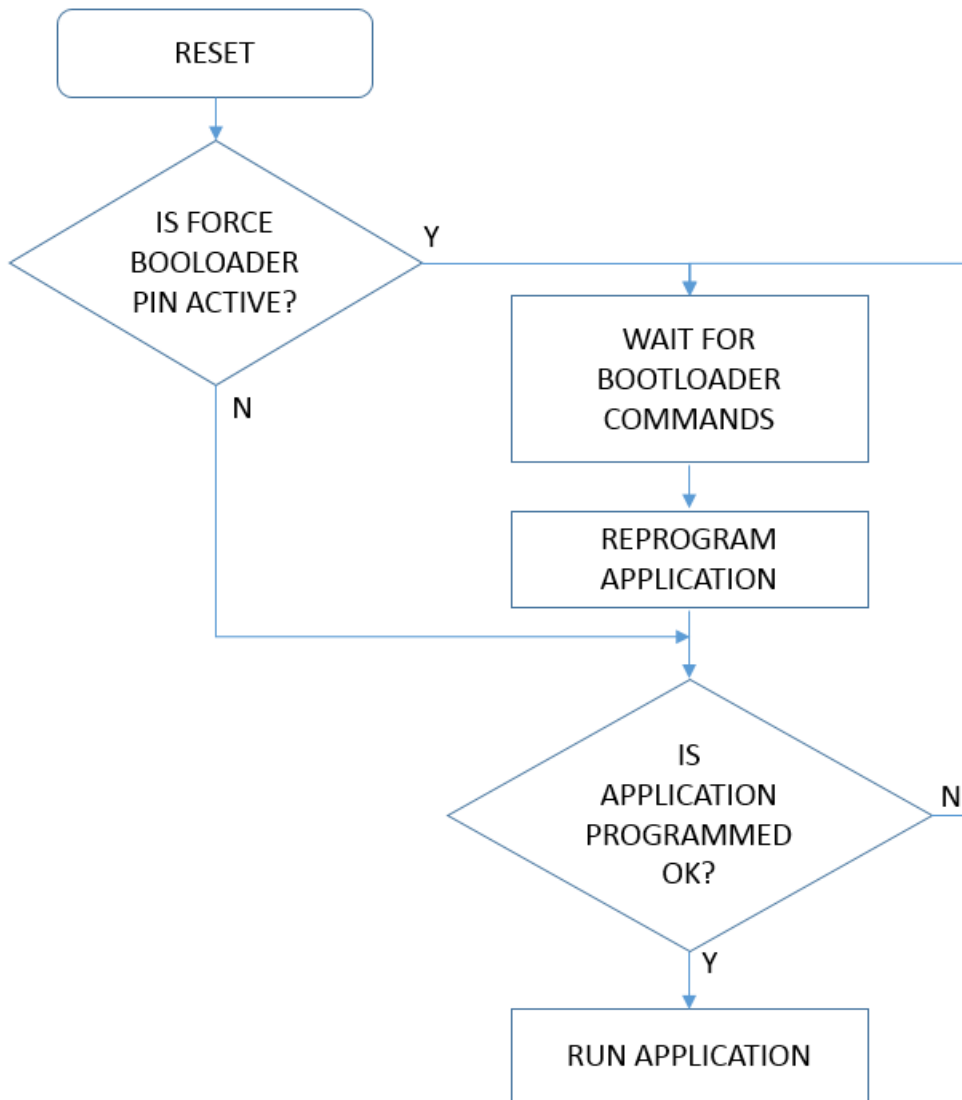
Bootloader flowchart

If a firmware upgrade fails (e.g. power loss) the host providing the firmware upgrade must reinitiate the entire firmware upgrade process. The previous version of the firmware may be lost, but the bootloader will still operate as described even after a failed firmware upgrade attempt.

If the Flash on the microcontroller is erased using an external programmer or debugger, the unit cannot be reprogrammed to default functionality by the user.

3.5 Fail Safe Mode

To contain possible issues that could unintentionally block communication and new firmware upgrades of X4M202, a Fail Safe Mode is implemented.

X4M202 will count the number of resets caused by issues in the firmware and enter Fail Safe Mode after ten such consecutive resets. In Fail Safe Mode, the LED of X4M202 will be white. In Fail Safe Mode, X4M202 will only respond to commands from the XEP interface, and a module reset or firmware upgrade command can be issued. A reset command or power toggle will make X4M202 resume normal operation.

4 X4M202 Respiration Profiles

A Profile is defined as a specific configuration of the sensor that covers a specific use case. New profiles might be included based on market demand.

4.1 Overview

The XeThru Respiration Profiles work by measuring the minute periodic movements of the human body while breathing. All respiration profiles can be used to measure respiration both for a sleeping person in a bed with the sensor placed on a night stand, on the wall or in the ceiling, and for an awake person sitting still with the sensor placed at the height of the chest or abdomen, or pointing towards the chest or abdomen.

The body part generating the best signal will vary from person to person. Some breathe shallowly, drawing air into the chest area and thus the largest movement will come from the chest. Others breathe deeper, expanding the abdomen rather than the chest. In this case, the abdomen will give the largest movement.

X4M202 supports different profiles optimized for respiration monitoring of adults and babies.

Profile Settings

Name	Intended use	Detection Zone	Fast	Slow	RPM range	Optimizations
Respiration_2	Adults and children	0.40 - 5.00 m	6 sec	20 sec	8 - 30 RPM	
Respiration_3	Babies and children	0.40 - 5.00 m	6 sec	15 sec	15 - 65 RPM	
Respiration_4	Adults and children	0.40 - 3.00 m	6 sec	20 sec	8 - 30 RPM	Using internal MCU memory only
Respiration_5	Babies and children	0.40 - 3.50 m	6 sec	15 sec	15 - 65 RPM	Using internal MCU memory only

Typically, a Profile measuring respiration rates above 30 RPM is needed for children under three (3) years of age. Typically, a Profile measuring respiration rates below 15 RPM is needed for children over ten (10) years of age. See https://en.wikipedia.org/wiki/Respiratory_rate or medical publications for more detailed explanations on how resting respiration rate varies with age and between people.

X4M202 has been designed to measure respiration of people, but can be used to measure respiration rate of some animals. For this use case, check what resting respiration rate the target animal has, select the Profile that fits best, and validate performance against the animal in question.

The values for Slow and Fast in the table above shows the length of the Slow and Fast Pulse-Doppler algorithms running in the Profile. See Firmware Algorithms section below for a description on how these are used.

Profiles using only internal MCU memory will have lower electromagnetic interference (EMI) than the other profiles, which uses the external memory on X4M202.

4.2 User Settings

4.2.1 Set Detection Zone

The Detection Zone is set by specifying the start and end of the Detection Zone. The end of the detection zone sets the maximum distance for presence and respiration detection, while the start of the detection zone sets the minimum distance.

Detection zone limits	Respiration_2	Respiration_3	Respiration_4	Respiration_5
Minimum start of detection zone	0.40m	0.40m	0.40m	0.40m
Maximum end of detection zone	5.00m	5.00m	3.00m	3.50m
Minimum size of detection zone	0.20m	0.20m	0.20m	0.20m
Maximum size of detection zone	4.60m	4.60m	2.60m	3.10m

Step size between possible range settings is 5.14 cm. The desired detection zone can be set with 1 cm resolution. The actual detection zone will be set at the closest possible range setting before the lower range desired and the closest possible range setting after the upper range desired. The actual lower and upper range to be used by the sensor can be read back after setting the detection zone.

Movements closer to the sensor than the Detection Zone may trigger detection because of indirect reflection paths. Movements beyond the end of the detection zone will never trigger detection.

4.2.2 Sensitivity

Sensitivity settings	
Minimum sensitivity	0
Maximum sensitivity	9
Sensitivity step size	1

Higher sensitivity setting gives better sensing of small targets. Lower sensitivity makes the sensor more robust against false detections.

4.2.3 LED

The module has 1 multi-color RGB LED. The module LED can be configured between "Full" state indication, a "Simple" indication or "Off", which is convenient for sleep monitoring use.

Full

Initializing: Green (0.2sec) -> Orange (0.2sec) -> Red (0.3sec) -> Orange (0.2sec) -> Green (0.2 sec) -> Off (0.3sec)
Breathing: Blue On/Off flashing 50% duty cycle. Period = RPM (not breathing pattern, RPM =15 means LED flashes 15 times/minute)
Movement tracking: Green (0.5sec) -> Blue (0.5sec)
Movement: Green (0.5sec) -> Orange (0.5sec)
No movement: Red (0.3sec) -> Off (4.7sec)

Simple

Initializing: Green (0.2sec) -> Orange (0.2sec) -> Red (0.3sec) -> Orange (0.2sec) -> Green (0.2 sec) -> Off (0.3sec)
Breathing: Blue On
Movement tracking: Green On
Movement: Orange On
No movement: Red (0.3sec)-Off (4.7sec)

Off

Always: Off

4.2.4 Frequency Band

Low

In the low frequency band, X4M202 will operate within the 6.0 - 8.5 GHz band.

High

In the high frequency band, X4M202 will operate within the 7.25 - 10.20 GHz band.

4.2.5 Noise Map Control

See Firmware Algorithms section below for a description on how Noise Maps are used. There are three User Settings for Noise Map Control: Use Stored Noise Map, Use Default Noise Map, and Adaptive Noise Map. There are two Noise Maps used in all Respiration Profiles, one for the Slow Range-Doppler matrix and one for the Fast Range-Doppler Matrix. When User Settings for Noise Map Control describe functions to control Noise Map, this control is valid for both Noise Maps used in the signal processing algorithms. When creating a new Noise Map, the X4M202 sensor must be still and there must be no people within the Detection Zone.

4.2.6 Use Stored Noise Map

On

If a valid Stored Noise Map exists this will be used at reset or when the Profile is started.

If no valid Stored Noise Map exists and Use Default Noise Map is off, a new Noise Map will be created during Initialization state. The newly created Noise Map will be stored in the sensor when Initialization is done. A noise map created with a different Detection Zone is not valid.

If no valid Stored Noise Map exists and Use Default Noise Map is on, the Default Noise Map will be used at reset or when the Profile is started.

Off

If Use Default Noise Map is off, a new Noise Map will always be created at reset or when the Profile is started. Sensor will be in Initialization state during Noise Map creation. A previously Stored Noise Map in the sensor will be ignored, but not overwritten, when the Profile starts.

If Use Default Noise Map is on, the Default Noise Map will be used at reset or when the Profile is started.

4.2.7 Use Default Noise Map

On

If Use Store Noise Map is on and a valid Stored Noise Map exists, Default Noise Map will not be used.

If Use Stored Noise Map is on and no valid Stored Noise Map exists, the Default Noise Map will be used at reset or when the Profile is started.

If Use Stored Noise Map is off, the Default Noise Map will be used at reset or when the Profile is started.

Off

The Default Noise Map will not be used.

4.2.8 Adaptive Noise Map

On

Enables Noise Map adaptation. Noise Map will still not adapt in certain conditions as described in Firmware Algorithms section below.

Off

Disables Noise Map adaptation.

4.2.9 Default User Settings

Default User Settings for the Supported Profiles

User Setting	Respiration_2	Respiration_3	Respiration_4	Respiration_5
Detection Zone	0.40 - 5.00m	0.40 - 5.00m	0.40 - 3.00m	0.40 - 3.50m
Sensitivity	5	5	5	5
LED	Full	Full	Full	Full
Frequency Band	Low	Low	Low	Low
Use Stored Noise Map	Off	Off	Off	Off
Use Default Noise Map	Off	Off	Off	Off
Adaptive Noise Map	On	On	On	On

4.3 Sensor Operation in X4M202 Respiration Profiles

4.3.1 Detect Presence and Breathing

The X4M202 sensor detects presence within its detection zone by detecting movement and processing the data. Once the module detects movement, it will attempt to identify a breathing movement. The target person needs to be still in order to identify breathing movement.

If more than one person is present in the detection zone, the X4M202 sensor will measure the one who is closest to the sensor. If the intention is to not measure the closest person, the detection zone can be set to a minimum distance that excludes the closest person, but because of indirect reflection paths that could lead to the closer person being read at a longer distance. This specific scenario is unlikely to work reliably in real-life scenarios as soon as the closest person has any significant movement.

There are six states in the Respiration Profile:

- **No Movement** No presence detected
- **Movement:** Presence, but no identifiable breathing movement
- **Movement Tracking:** Presence and possible breathing movement detected
- **Breathing:** Valid breathing movement detected
- **Initializing:** The sensor initializes after the Respiration Profile is executed
- **Error:** The sensor is in an error state and requires a Profile and User Settings to be loaded

4.3.2 Measure Respiration Data

When running, the following data is reported:

- **State**

In all states except Initializing and Error states, the following data is measured:

- **Movement Slow:** Movements for the previous Slow period
- **Movement Fast:** Movements for the previous Fast period
- **Normalized Movement Slow:** Normalized Movements for the previous Slow period
- **Normalized Movement Fast:** Normalized Movements for the previous Fast period

Movement Slow and Movement Fast show the degree of movement as a relative number from 0 to 100 both for 5.14 cm intervals in the Detection Zone and for the entire Detection Zone. 0 means no Doppler cells above the detection threshold, while 100 means that all Doppler cells in the range interval are above the detection threshold.

Normalized Movement Slow and Normalized Movement Fast also show the degree of movement, but are adjusted for distance to give approximately the same value for the same size of movement at different distances. Outputs shows a logarithmic value of the size of the movement and typically varies from -20, which means no movement, and 30 or above, which means very large movements. Normalized Movement Slow and Normalized Movement Fast is provided for 5.14 cm intervals in the Detection Zone.

When in Movement, Movement Tracking, or Breathing states, the following additional data is measured:

- **Distance to closest target:** Distance in meters to target closest to the sensor

- **RCS of closest target:** Radar Cross Section in dB(m^2) as seen from X4M202
- **Signal Quality:** A relative number from 0 to 10 where 10 is best

When in Breathing state, the following additional data is measured:

- **RPM of closest breathing target:** Respirations per Minute
- **Distance to breathing target:** Distance in meters to target RPM is measured from
- **Breathing pattern of closest breathing target:** Detected respiratory movement in mm perpendicular to the X4M202
- **Normalized Movement Interval Slow:** Normalized Movements for the previous Slow period for an approximately 1 meter zone around the distance to breathing target
- **Normalized Movement Interval Fast:** Normalized Movements for the previous Fast period for an approximately 1 meter zone around the distance to breathing target

Distance to closest target and breathing target may be different even when only one target person is present in the Detection Zone. Distance to closest target measures the distance to the closest movements the sensor can see. Distance to breathing target measures the distance to where the respiration motion is seen. As an example, if the target person's hands are closer to the sensor than the chest or abdomen and have some minimal movement, distance to closest target will measure the distance to the hands and distance to breathing target will measure the distance to the chest or abdomen where the respiration motion is.

With two or more targets in the Detection Zone, different distance to closest target and distance to breathing target can also be experienced. As an example, if a still person is still at a longer distance than a second moving person closer to the sensor, the sensor may lock on the breathing of the person further away. In this case distance to closest target will be to the person moving closer to the sensor and distance to breathing target will be on the still person further away. Achieving breathing lock on a still person may be difficult if a moving person is closer to the sensor due to multiple direct path and multi path reflections from the closest moving person.

Normalized Movement Interval Slow and Normalized Movement Interval Fast are intended to show how much movement a sleeping or still person has, without having to identify where in the Detection Zone the target person is.

4.3.3 IO-pin Functionality

All units are shipped with IO-pin functionality off (inputs with pull-up).

When enabling IO-pins, the default functionality is:

Default IO-pin functions when enabled

IO-pin	Name	Direction	Functionality
IO1	MOVEMENT	Output	Low: Movement, Movement Tracking and Breathing states (Driven low) High: No Movement, Initializing and Unknown states (Tri-state with internal pull-up)
IO2	BREATHING	Output	Low: Breathing state (Driven low) High: All other states than Breathing (Tri-state with internal pull-up)
IO3		Input	Not in use. Do not connect

IO-pin	Name	Direction	Functionality
IO4		Input	Not in use. Do not connect
IO5		Input	Not in use. Do not connect
IO6		Input	Not in use. Do not connect

Each IO-pin has the following Pin Setup options:

- Input or output
- Open drain or push-pull
- Active high or active low
- Pull-up enable or disable

Each IO-pin can have one of these Pin Features:

- Disable all IO-pins. Using this feature overrides Pin Setup. Disabling all IO-pins means all IO-pins are input with pull-up.
- According to default functionality shown above. Using this feature overrides Pin Setup. Default IO-pin functionality also specifies which pins are inputs and outputs.
- Passive. Set and get IO-pin level over communication interface.
- Movement. Function as described in table above, but can be set to any pin.
- Breathing. Function as described in table above, but can be set to any pin.

4.4 Detection Range

Detection range varies with the size of the target person and the angle between the sensor and the target person. The detection range varies with the size of the target person, the movement type of the target person and the angle between the sensor and the target person.

Detection range should not be confused with the user setting Detection Zone. Detection Zone defines at what range X4M202 is doing measurements. Detection range describes what can be detected inside the Detection Zone.

Characterization of detection range for various targets will be included here when available.

4.5 Detection Time

Typical detection time for this Profile is:

- From No Movement to Movement state: 3.5 - 9 seconds
- From Movement to No Movement state: 5 seconds + length of Slow Pulse-Doppler algorithm.
- From Movement to Breathing state: 5 seconds + length of Slow Pulse-Doppler algorithm.

Detection time is given by the length of the range-Doppler matrices and the M/N detection logic described in the Firmware Algorithm section below.

4.6 Firmware Algorithms
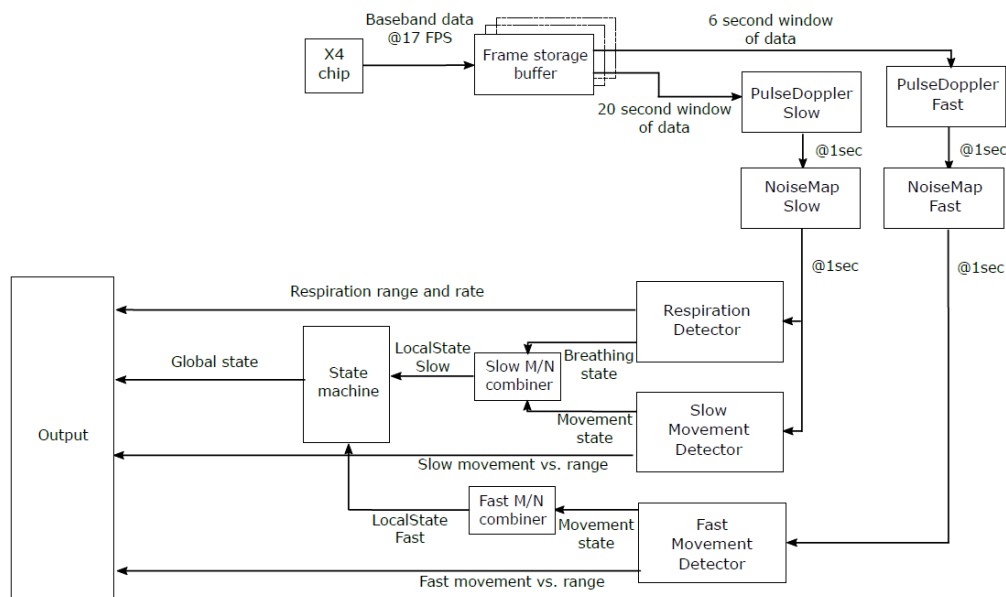
Adult Respiration Profile signal processing block diagram

All firmware algorithms for movement detection and respiration measurements are running in the X4M202. The X4 UWB radar SoC is set up to provide 17 baseband data frames per second. The radar data frames are stored in a buffer. Two Range-Doppler matrices are running in parallel. The Slow and Fast Range-Doppler matrices are using data from different periods of radar frames. Length of Slow and Fast periods may vary between Profiles and are shown above in the table Profile Settings.

Both Range-Doppler matrices have individual Noise Maps to determine if a reflection at a certain distance and frequency is above a threshold. Creating and enabling a Noise Map will give different threshold values at different distances and frequencies.

The Noise Maps will adapt to changes in the environment unless User Setting Noise Map Adaptation is off. Noise Map Adaptation works continuously and will over time remove presence detection of reflectors with small movement at a fixed distance. The Noise Map will not adapt if a still person with breathing frequency matching the RPM Range specified in the Profile Settings table above is detected.

The Fast Range-Doppler matrix with its Fast Movement Detector will detect presence quickly, typically when a person enters the Detection Zone. The Fast Movement Detector has two states, Movement or No Movement. The Fast M/N Combiner uses these states to determine the LocalStateFast. An M/N Combiner determines that M out of N detections need to be a certain value for the output to change.

All detection algorithms are run once per second, meaning all outputs like State, Distance, RPM etc. are updated once per second.

Logic for Fast M/N Combiner

LocalStateFast	M/N
No Movement -> Movement	3/3
Movement -> No Movement	5/5

The Slow Range-Doppler matrix with its Slow Movement Detector and Respiration Detector will detect presence of stationary people and measure respiration rate and distance to the breathing target when the target person is still. The Slow Movement Detector and Respiration Detector have three states, Breathing, Movement and No Movement. The Slow M/N Combiner uses these states to determine the LocalStateSlow. An M/N Combiner determines that M out of N detections need to be a certain value for the output to change.

Logic for Slow M/N Combiner

LocalStateSlow	M/N
No Movement -> Movement	3/3
No Movement -> Breathing	3/3
Movement -> No Movement	5/5
Movement -> Breathing	6/7
Breathing -> No Movement	5/5
Breathing -> Movement	4/4

The State Machine determines the (global) State using the following logic.

Global state machine logic

LocalState Fast	LocalState Slow	Global state
Movement	Breathing	Breathing
No Movement	Breathing	Breathing
Movement	Movement	Movement
No Movement	Movement	Movement
Movement	No Movement	Movement
No Movement	No Movement	No Movement

4.6.1 Default Noise Map

A Default Noise Map is provided with the sensor to achieve fast start-up even when no Noise Map has been created in the sensor earlier. The Default Noise Map represents a typical Noise Map for the sensor placed in an environment without reflections.

4.6.2 Stored Noise Map

The Active Noise Map, which is the Noise Map in use by the firmware algorithms, can be stored locally in the sensor as a Stored Noise Map. If a valid Stored Noise Map exists and the User Setting Use Stored Noise Map is on, the Stored Noise Map will be used when the Profile is started.

The Active Noise Map can become different than the Stored Noise Map due to Noise Map adaption. The Active Noise Map can be stored as the new Stored Noise Map, and the Stored Noise Map can be loaded as the Active Noise Map during operation of the sensor without stopping the Profile or disrupting operation of the sensor. The Stored Noise Map can be deleted without disrupting operation of the sensor. If the Noise Map is stored or deleted during sensor operation, X4M202 is not able to measure radar frames during the store or delete operation. The missing radar frames will be replaced with the next valid radar frame. For signal processing algoithms running in X4M202, these missing radar frames will have insignificant effect of the sensor performance.

To initialize a new Noise Map, delete the Stored Noise Map, and then stop and start the Profile with User Setting Use Store Noise Map on. A new Noise Map will then be created during Initialization, unless User Setting Use Default Noise Map is on, which dictates use of the Default Noise Map.

Only one Stored Noise Map can be saved in the sensor.

The Stored Noise Map can be read and stored by the host and a new Stored Noise Map can be loaded over the serial interface.

4.6.3 Start-up Time

The Range-Doppler matrices are filled with radar data during Initialization state. This takes 15-20 seconds for the Slow Range-Doppler matrix, depending on which Profile is used. See Profile Settings table above for details. Total start-up time is 120 seconds when a Noise Map needs to be created and equals the length of the Slow Range-Doppler matrix if a Default Noise Map or Stored Noise Map is used.
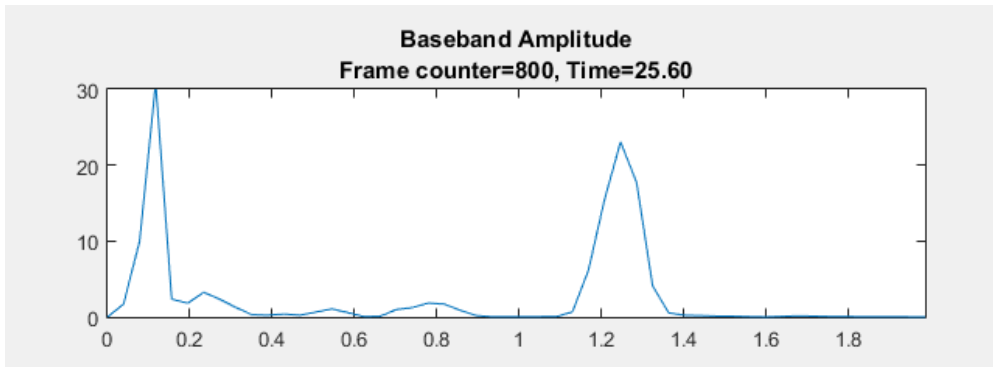
4.7 Baseband Data Output

Baseband data is generated approximately 17 times per second and shows reflection at all distances in the Radar Frames used in 5.14 cm intervals.

The length and position of Radar Frames is controlled by the actual lower and upper range determined by the Detection Zone User Setting. The Radar Frame starts 5.14 cm before the actual lower range and ends 5.14 cm after the actual upper range.

Baseband data is available as an option on the communication port.

Baseband data outputs either amplitude and phase information of reflections, or the same data represented with I and Q values.

A Frame Counter is supplied with the Baseband Data. The Frame Counter increases by 1 for each radar frame that is output from the X4 UWB radar SoC. Stopping and starting a Profile does not reset the frame counter. Size of frame counter is 2^{32}. The frame counter wraps to 0 when it reaches the maximum. With 17 frames per second, the max value is reached in approximately 8 years. A reset of the X4 UWB radar SoC or a power toggle of the sensor module will reset the frame counter.

Example of baseband data output.

The example above shows the amplitude of reflections plotted for a 2 meter Radar Frame. This particular measurement shows two reflections; the first reflection is about 0.1 meter into the Radar Frame, which is the directly coupled energy from the TX to the RX antenna, and the second reflection is about 1.2 meter into the Radar Frame.

Refer to application notes on www.xethru.com for more detailed descriptions on how to use baseband data output.

4.8 Pulse-Doppler Processing and Range-Doppler Data Output

X4M202 uses Pulse-Doppler processing as described in more detail here: https://en.wikipedia.org /wiki/Pulse-Doppler_signal_processing.

Pulse-Doppler processing results in Range-Doppler data, which can be output from X4M202. The data is represented as Range-Doppler matrices that show all reflections at different distances and frequencies over the last time period as specified in the Firmware Algorithm section for each Profile. All reflections with Doppler frequency 0 (static reflectors) are removed before the Pulse-Doppler processing.

5 Certification Mode

5.1 Overview

X4M202 can be set in Certification Mode to test compliance with regulations.
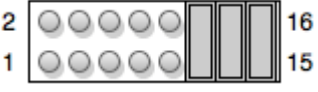
5.2 Certification Modes

Various certification modes can be set either using the communication interface or by using jumpers or similar to short pins on the 16-pin XeThru Interface Connector.

Certification Mode	Jumper Setting	Description

Certification Mode	Jumper Setting	Description
Tx Only	2 [○○○○○ ▊ ○○] 16 1 [○○○○○ ▊ ○○] 15	Enables continuous UWB transmission, with all other activities disabled. Meaning that only the digital circuitry needed for operating the UWB transmitter, and the UWB transmitter is enabled. This mode is used to demonstrate the isolated emissions from the UWB transmitter, and the emissions generated by the digital circuitry needed to enable UWB transmission. The UWB transmitter must be set to continuous worst case transmission, i.e. that a pulse is sent at every PRI interval for the given chip setting, to maximize the average energy emitted from the module. LED is off in this mode to minimize noise.
Tx Only Digital	2 [○○○○○○ ▊ ○] 16 1 [○○○○○○ ▊ ○] 15	Enables only the digital part used for continuous UWB transmitting, with all other activities disabled. The exact same settings as Tx only mode is used, but with the UWB transmitter disabled. This mode demonstrates radiated emissions from digital circuitry used to enable operation of the UWB transmitter. These emissions should comply with FCC 15.521, § 15.209. LED is off in this mode to minimize noise.
Stream Tx Off	2 [○○○○○ ▊▊ ○] 16 1 [○○○○○ ▊▊ ○] 15	Disables continuous UWB transmitting, while associated digital devices used to control additional functions or capabilities on module is operating. This mode is used to demonstrate emissions from unintentional radiators not needed for, or generated by, UWB transmission. LED is orange in this mode.
Stream	2 [○○○○○ ▊ ○ ▊] 16 1 [○○○○○ ▊ ○ ▊] 15	Normal operation of the module with both UWB transmitter and associated digital devices, used to control additional functions or capabilities on module, activated. This mode is used to demonstrate typical emissions from a module during normal operation. LED is orange in this mode.

Certification Mode	Jumper Setting	Description
Rx Fail Detection		In normal operation, the FW monitors the sampler outputs to ensure acknowledgement of reception. If no such acknowledgement is received, the EUT will shut down the transmitter within 10 seconds. During certification test, this situation can be provoked / emulated by forcing the receiver to not provide an acknowledgement of reception. The procedure is as follows: 1. Power off the device. 2. Set the EUT in Stream mode by the appropriate jumpers (11/12 and 15/16). 3. Power up the device by connecting the USB cable. The EUT should now emulate normal operation. 4. Set RX Fail emulation jumper (13/14), this will emulate a missing acknowledgement within 3 seconds. 5. TX should now be shut down by the standard FW. Alternatively, all three jumpers may be set in step 2 and then power up and omit step 4. The EUT will start transmitting and within maximum 10 seconds shut down. LED is orange in this mode.
End Certification Test		Setting this jumper setting while the device is powered will return the module to normal operation after the execution of a power cycle. The module will then respond to the normal API over USB. Note that the EUT may be brought back to any other test mode by the appropriate jumper setting. LED is orange in this mode.

6 Firmware versions

The firmware version can be read over the serial interface. All firmware versions support upgrading to a different firmware version.

In addition to the firmware versions described in this section, additional firmware versions with potential error corrections and stability improvements should be expected.

6.1 X4M202 Version 1.5.10

Initial release

6.2 X4M202 Version 1.6.6

The User Setting "Initialize Noise Map at Reset" has been renamed to "Use Stored Noise Map". Communication protocol is not affected by this change, thus any software controlling this User Setting for previous FW version will behave exactly the same with this and future FW versions.

Added features from previous version:

- Respiration_4 and Respiration_5 Profiles added
- Use Default Noise Map added
- Delete Noise Map protocol command added (delete_noisemap)
- Normalized Movement added

See errata section for bug fixes.

6.3 Future versions of X4M202

The additional functions may be introduced in existing Profiles:

- Enable / disable Noise Map adaption (Previous versions always enable Noise Map adaption)
- Load a Stored Noise Map into Active Noise Map in sensor
- Load and Store Stored Noise Map to host

Some of these features may be introduced as a new Profile not yet documented in this datasheet.

- Detection list for all moving targets in detection zone
- RPM for multiple targets in detection zone
- Radar Cross Section for all moving targets in detection zone

7 X4M202 HW revisions

7.1 Identifying HW revision
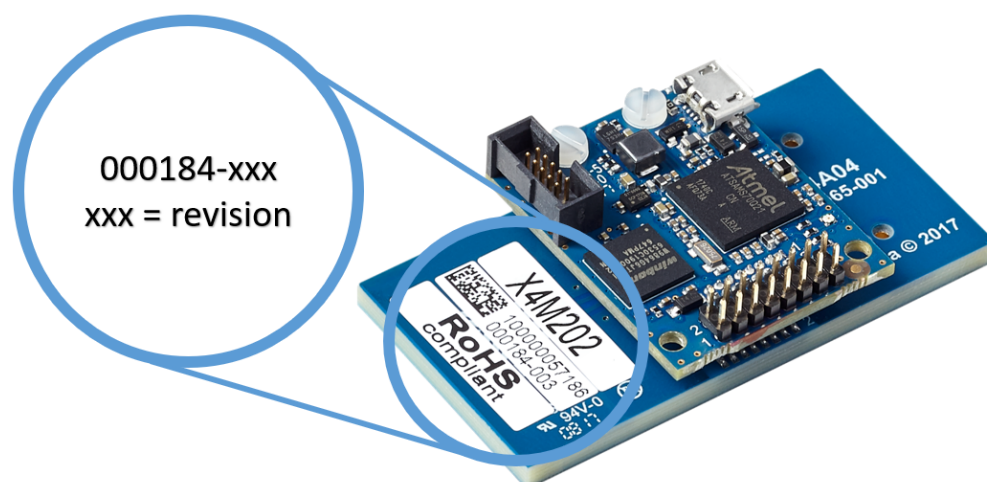
How to identify HW revision of X4M202

For detailed descriptions of X4A02 and XTMCU02 hardware, see their respective datasheets.

7.2 X4M202 Revision 1

Uses the following boards:

- X4M07 Revision 2
  - X4A04 Revision 1
  - X4SIP02 Revision 4
- XTMCU02 Revision 4

8 Software Resources

8.1 XeThru Explorer

The XeThru Explorer application is a visual presentation of the protocol and data output from the sensor. It also allows for storing the measured data into a log file.

Firmware upgrades of X4M202 are deployed with new versions of XeThru Explorer.

XeThru Explorer can be downloaded from www.xethru.com.

8.2 XeThru Module Connector

The XeThru Module Connector is a software used to communicate with all XeThru radar sensor modules from a host computer through a serial interface. XeThru Module Connector makes a complete API of the modules available in host environments such as MATLAB, Python, C++ and C. This makes it easy to start streaming and analyzing radar data on multiple levels (raw radar data, baseband data, pulse doppler data, detection lists, respiration and presence) and directly to an environment ideally suited for development of new algorithms.

XeThru Module Connector includes a SW API that implements the serial protocol of X4M202.

XeThru Module Connector can be downloaded from www.xethru.com.

8.3 Module Communication Protocol Wrapper (MCP Wrapper)

Module Communication Protocol (MCP) is the lowest level communication protocol implementation for the XeThru modules, used on the module FW and XeThru host components, e. g. Module Connector. The MCP Wrapper goes one step further for embedded host implementation adding a wrapper with convenience methods around the MCP. Compared to Module Connector, which is a more feature rich component with logging and buffering capabilities, MCP Wrapper offers a similar interface with only the basic transport methods wrapped in a more easy-to-use interface.

Typical use for the MCP Wrapper is when implementing a host application communicating with a XeThru module on an embedded target that does not need or have the Module Connector available .

MCP Wrapper is implemented in C. Example code is available in C and C++.

MCP Wrapper can be downloaded from www.xethru.com.

8.4 X4M202 Firmware Binary

Firmware upgrades of X4M202 can be done by using Module Connector, MCP Wrapper or any other custom implementation of the serial protocol in a scenario where the modules are deployed. In this case, the module firmware file that is used during firmware upgrade is needed.

X4M202 firmware binary (Annapurna) can be downloaded from www.xethru.com.

9 Mechanical Data

For dimension details and mechanical drawings see the X4M07 datasheet and XTMCU02 datasheet, available at www.xethru.com .

10 Electrical Specification

Parameter	Value	Comment
Supply Voltage VDD_EXT	3.3 - 5.5V	
Supply Voltage USB	4.5 - 5.5V	
IO-voltage range, nominal	-0.3 - 3.3V	
V_{IH} min	2.0V	Minimum input high threshold voltage
V_{IL} max	0.8V	Maximum input low threshold voltage
Typical power consumption	TBD mW	Expected around 600 mW
Operating Temperature range	0°C to +85°C	

11 X4M202 Interface Options

11.1 16-pin XeThru Interface Connector

The X4M202 has a 16-pin connector intended for interfacing a host board.

11.1.1 Pin Descriptions

Pin descriptions

Pin no	Description	Name	Type	Usage
1	Power, 3.3-5.5V	VDD_EXT	Power	Module power input
2	Power, GND	GND	Power	Module power input
3	USART RX / Force Bootloader	RX / BOOT	Input	USART receive / Holding pin 3 low during reset or power-up will force the unit into bootloader mode
4	USART TX	TX	Output	USART transmit

Pin no	Description	Name	Type	Usage
5	MODE SELECT 1 / USART SCK	MODESEL1	Input with pull-up	Mode select pin 1, ref table below for details / USART serial clock (USRT mode only)
6	MODE SELECT 2	MODESEL2	Input with pull-up	Mode select pin 2, ref table below for details
7	Reset	nRESET	Input with pull-up	Active low module MCU reset
8	No Connect	N.C	N/A	Leave unconnected
9	No Connect	N.C	N/A	Leave unconnected
10	No Connect	N.C	N/A	Leave unconnected
11	IO1	IO1	I/O	Functionality is Profile specific
12	IO2	IO2	I/O	Functionality is Profile specific
13	IO3	IO3	I/O	Functionality is Profile specific
14	IO4	IO4	I/O	Functionality is Profile specific
15	IO5	IO5	I/O	Functionality is Profile specific
16	IO6	IO6	I/O	Functionality is Profile specific

The connector is a 2x8 2.00mm pitch male pin header.

11.2 USB Connector

The X4M202 is fitted with a USB micro type B connector type supporting USB 2.0 High Speed.

11.3 Communication Modes

The sensor module will always use USB communication if USB power is present.

Additional communication modes can be selected at power-up or reset. The procedure is as follows seen from the host system outside the sensor:

1. Assert nRESET (set low for at least 1ms)
2. Set communication mode according to table below on pin 5 and 6.
3. Release nRESET (set high)
4. Hold communication mode level for minimum 2 seconds.
5. Set IO configuration of pins 3, 4, 5 and 6 to comply with the selected communication mode.
6. Selected communication is now activated on the sensor module

When USB is used this takes precedence over the table below. The use of USB is detected by the presence of power at the USB 5V power wire at startup. To change communication mode X4M202 need to be reset.

Mode	MODESEL1 (Pin 5)	MODESEL2 (Pin 6)	Comments
Reserved	Low	Low	Not supported
Reserved	Low	High	Not supported
USRT	High	Low	X4M202 is USRT slave
UART	High/Open (*)	High/Open (*)	Default UART settings are 115200 baud rate, 8 data bits, 1 stop bit, no parity This is the default mode. Enabled when pin 5 and pin 6 are left open.

(*) MODESEL1 and MODESEL2 has pull-up resistors and can be left open if a "High" is required.

Not supported modes should not be selected. Future firmware versions may use these modes.

11.4 Power System

There are 2 possible ways to power the sensor: Through pins 1 and 2 on the 16-pin interface connector or via USB. Both power sources may be connected at the same time. When powering via the USB connector this will always take precedence over the 16-pin connector.

12 Schematics and Bill of Material

Schematics and Bill of Material for X4M07, X4SIP02, X4A04 and XTMCU02 are available from www.xethru.com.

13 Module User Guide

13.1 Placing the Sensor Module

The sensor module should be protected from environmental surroundings such as moisture. Most firmware algorithms assume the sensor to be still with no movement or vibrations during operation.

When placing the sensor, pay attention to the following:

- Point the sensor in the direction of the object or zone to monitor
- Be aware of indirect reflections. An object 1 meter away may also give additional reflections via the floor, the ceiling or walls at longer distances
- Nearby metallic objects should be avoided, especially in the signal path to the sensor's observation area

- The sensor can be placed on static (non-moving) surfaces such as:
  - On a desk
  - On a wall
  - Behind a wall (*)
  - In the ceiling
  - Behind the ceiling (*)

Firmware algorithms in the sensor module are sensitive to vibrations. If vibrations occur, the sensor may report movement in an empty detection zone.

If a sensor casing is required, the material should be of a kind that does not attenuate the high frequency signals in the sensor´s main direction. Recommended materials are ABS and other types of non-conductive plastics (*).

(*): Different materials will attenuate the signal. Application note regarding this topic is found at www.xethru.com.

13.2 Connecting the X4M202 to a host system

The X4M202 can be connected to a host system in several ways:

1. Via USB
2. Via the interface connector using the UART interface
3. Via the interface connector using the USRT interface. X4M202 will be a USRT slave.

Some Profiles have GPIO interface that can be enabled and operate as the only control interface for a sensor module. The GPIO interface is described in the Profile chapters of this datasheet.
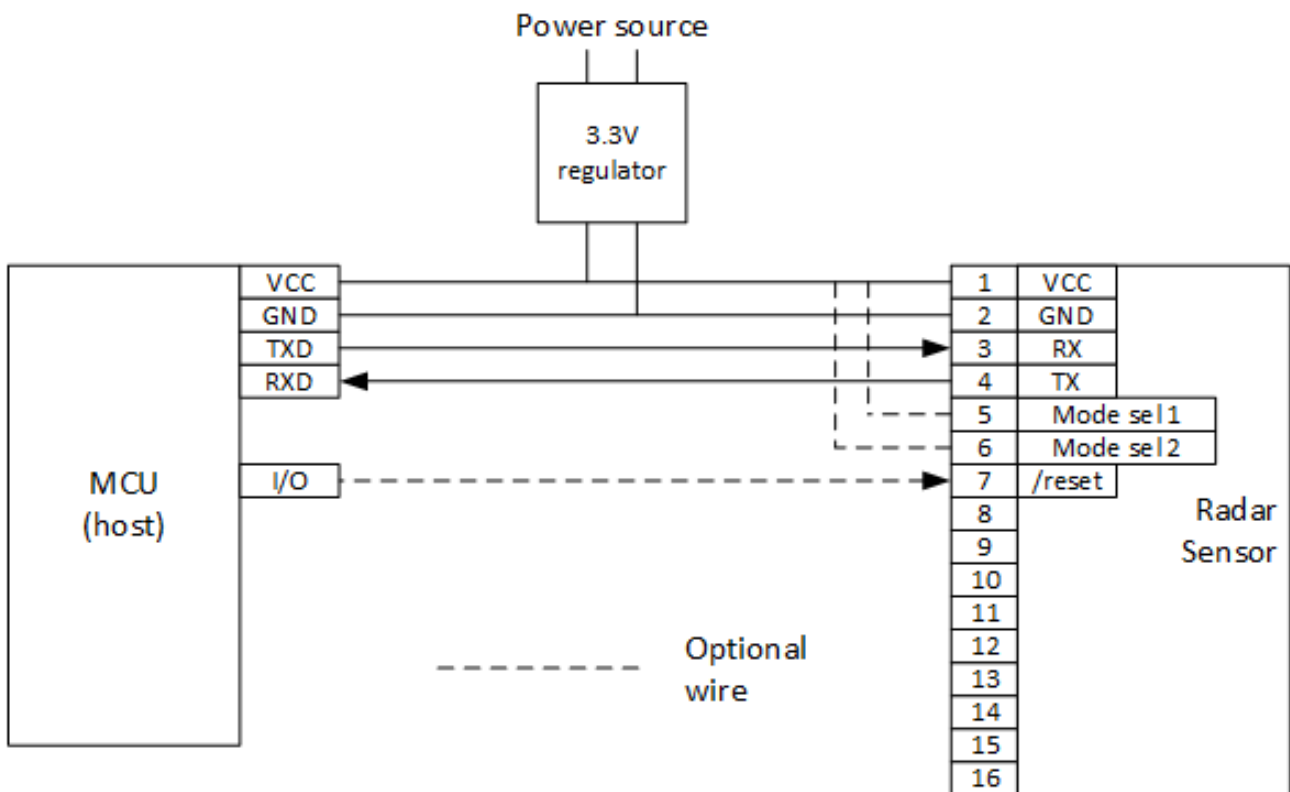
Bootloader for firmware updates only supports USB and UART.

13.2.1 Interfacing via USB

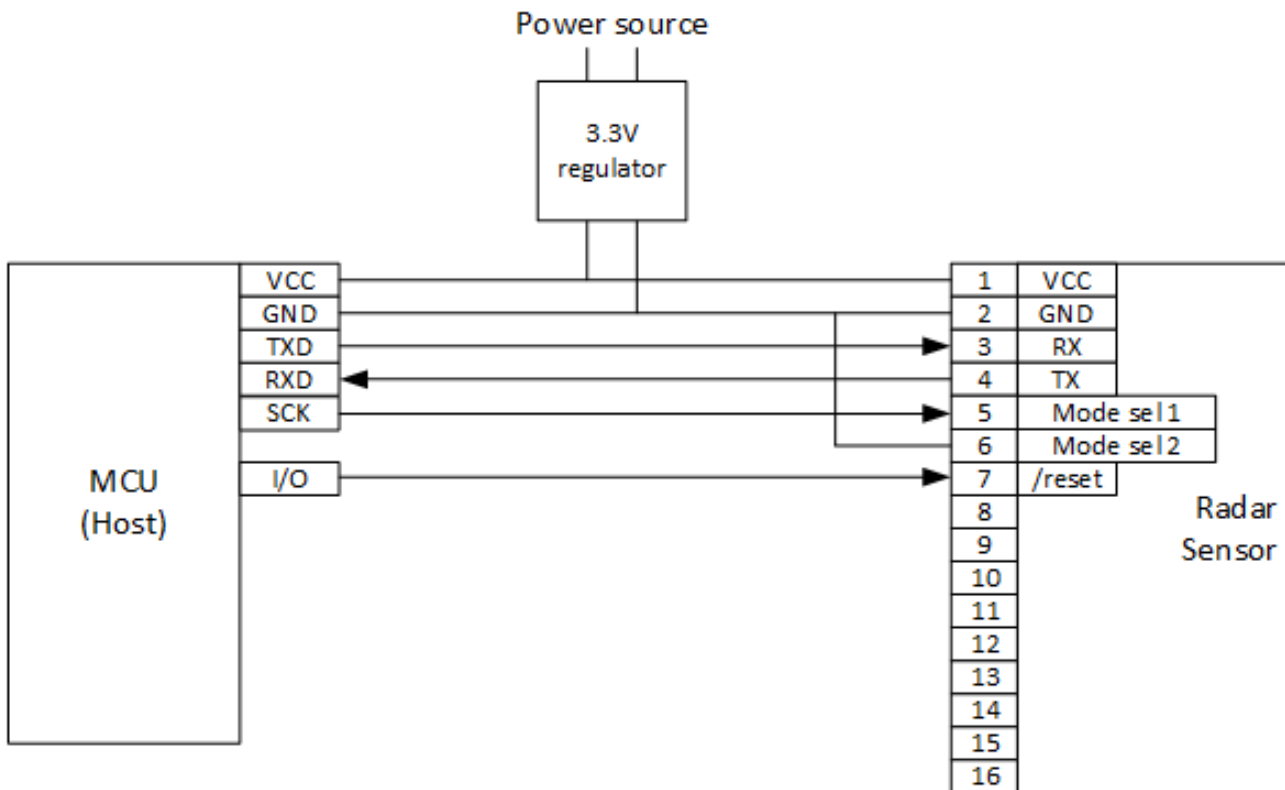When interfacing via USB this interface will take presence over other interfaces.

13.2.2 Interfacing via UART

Simplified schematics of host MCU using UART mode

13.2.3 Interfacing via USRT

The USRT mode is using a clock line in addition to RX and TX lines.

Simplified schematics of host MCU using USRT mode

13.2.4 Reset control of X4M202

Reset control from host is required for:

- Force bootloader function
- Exit from certain certification modes
- Selecting communication mode. UART is used if communication mode is not selected.

13.3 Upgrading the Firmware Using the Bootloader

The module´s firmware may be updated over USB or UART.

LED will be purple during firmware upgrades.

14 Regulatory Approval

X4M202 is designed to meet UWB RF specifications of KCC (Korea).

Some regulatory specifications also specify how the sensor is used. Users of X4M202 must check regulatory requirements for their own use case and determine whether the regulatory approvals obtained from Novelda are sufficient for their product.

14.1 KCC Approval

X4M202 has KCC approval. KCC certification number is R-CRM-N1A-X4M07.

Mean output power and frequency of the X4M202 depends on the Pulse Repetition Frequency (PRF), tx_power and Transmitter (TX) center frequency settings in the X4 radar chip. PRF must be set to 15.1875 MHz, tx_power must be set to High (3), and the TX center frequency must be set to 8.748 GHz by the host system to be in compliance with KCC regulations. For further description of the X4 radar chip, please refer to the X4 datasheet.

B679-3EEC-473D-4D64

방송통신기자재등의 적합인증서
Certificate of Broadcasting and Communication Equipments

상호 또는 성명 *Trade Name or Applicant*	NOVELDA AS
기자재명칭(명칭) *Equipment Name*	UWB 및 용도미지정기기(UWB 기술을 사용하는 기기)
기본모델명 *Basic Model Number*	X4M07
파생모델명 *Series Model Number*	
인증번호 *Certification No.*	R-CRM-N1A-X4M07
제조자/제조국가 *Manufacturer/ Country of Origin*	NOVELDA AS / 노르웨이
인증연월일 *Date of Certification*	2018-01-17
기타 *Others*	

위 기자재는 「전파법」 제58조의2 제2항에 따라 인증되었음을 증명합니다.

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2018년(Year) 01월(Month) 17일(Day)

국립전파연구원장

Director General of National Radio Research Agency

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X4M07 KCC approval document

15 Errata

15.1 Errata in Firmware Version xxx

- ### 15.1.1 Errata in Firmware Version 1.5.10

  - RPM may lock on second harmonic frequency of the respiration frequency. Future FW upgrades are planned to improve this.
  - RPM frequencies higher than maximum for a Profile (30 for Adult Respiration Profile and 65 for Baby Respiration Profile) may report as a frequency below the maximum value. Future FW upgrades are planned to improve this.
  - RPM frequencies lower than minimum for a Profile (8 for Adult Respiration Profile and 15 for Baby Respiration Profile) may report as a frequency above the minimum value. Future FW upgrades are planned to improve this.
  - Distance to breathing target may occasionally report a longer distance due to lock on multi path reflections. Future FW upgrades are planned to improve this.

- ### 15.1.2 Errata in Firmware Version 1.6.6

  - RPM may lock on second harmonic frequency of the respiration frequency. Future FW upgrades are planned to improve this.
  - RPM frequencies higher than maximum for a Profile (30 or 65 depending on Profile) may report as a frequency below the maximum value. Future FW upgrades are planned to improve this.
  - RPM frequencies lower than minimum for a Profile (8 or 15 depending on Profile) may report as a frequency above the minimum value. Future FW upgrades are planned to improve this.
  - Distance to breathing target may occasionally report a longer distance due to lock on multi path reflections. Future FW upgrades are planned to improve this.

16 Support and Resources

Development support, resources, links to development partners and resellers can be found on Novelda's web site www.xethru.com.

17 Disclaimer

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