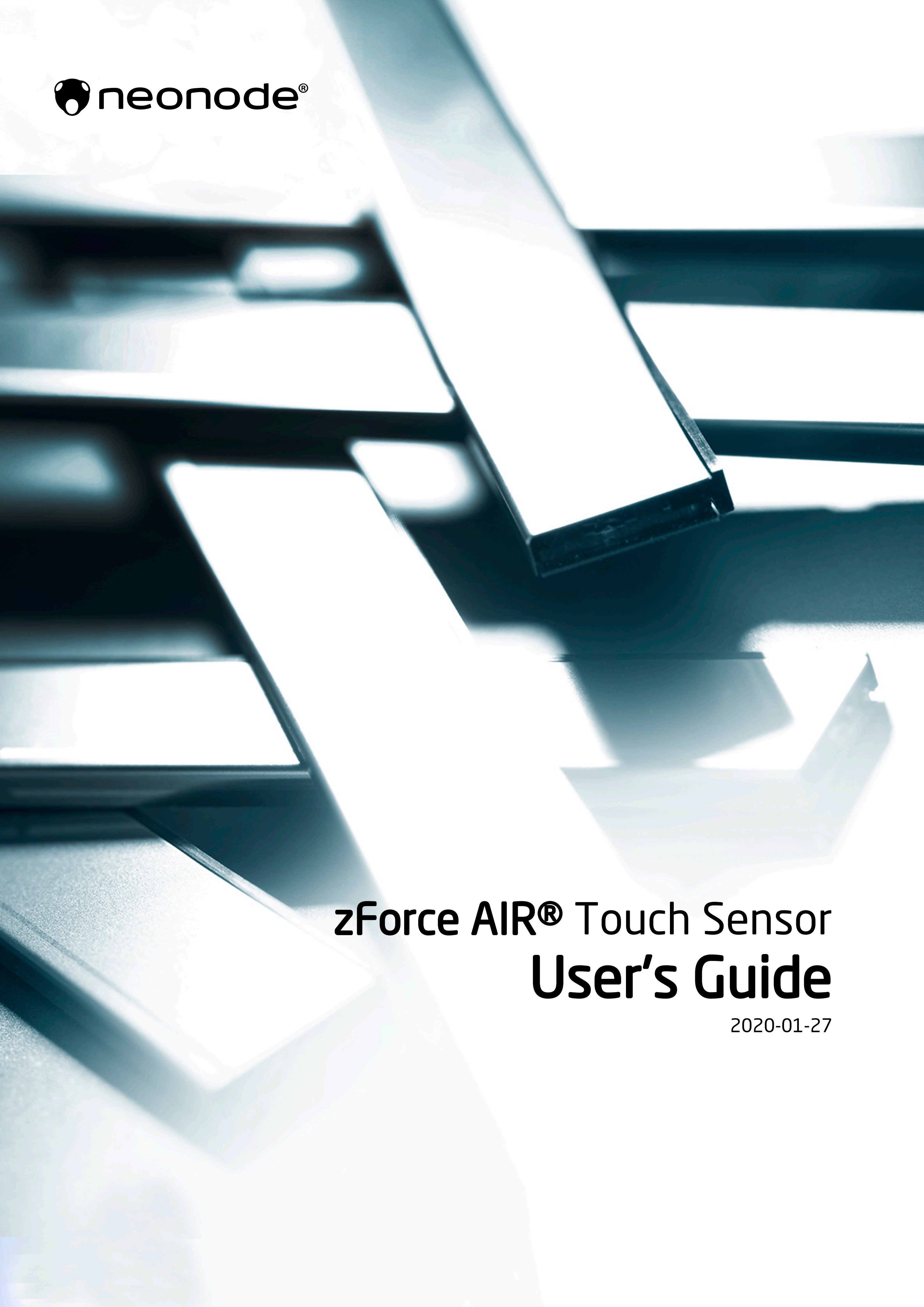


zForce AIR® Touch Sensor User's Guide

2020-01-27

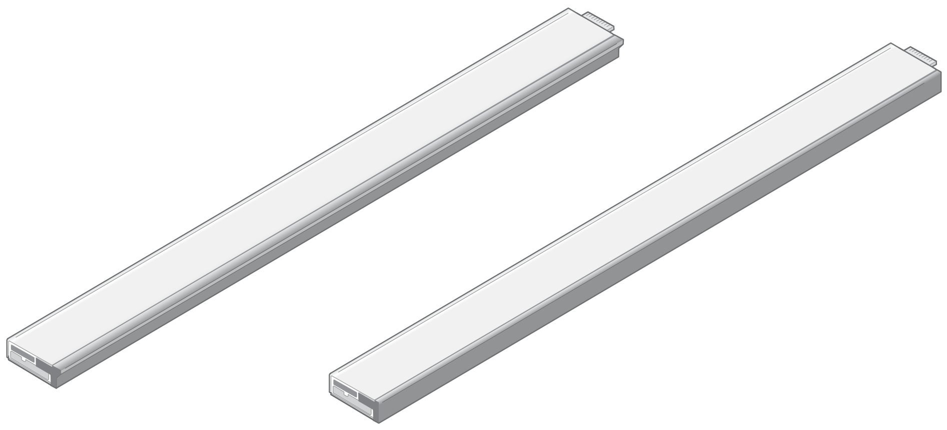
Legal Notice

1 Table of Contents

2 Introduction

2.1 Product Overview

The zForce AIR Touch Sensor is a laser light based touch sensor that can be integrated and used in various applications. The sensor characteristics are high scanning frequency, low latency, good touch accuracy and it can be used on any surface or even in mid air. zForce AIR Touch Sensor can be connected to the host system through a standard connector and communicate through a standard I2C or USB interface.



2.1.1 Main Features

- Enables touch on any surface or in mid air
- Dual touch support
- High scanning frequency – up to 200Hz or more depending on sensor length
- Low touch latency
- High touch accuracy
- Idle mode for reduced current power consumption
- Configurable touch active area
- I2C and USB interface
- Standard 5V power supply

2.2 Product Variants

In order to fit in a wide range of applications, the zForce AIR Touch Sensor exists in two types, one for horizontal and one for vertical integration, and a number of different lengths.

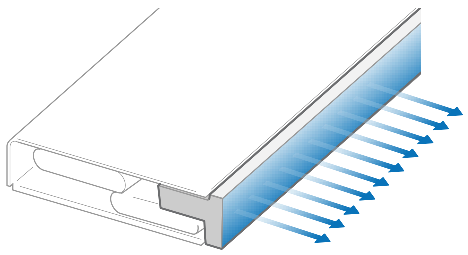
⚠ If the variant you are interested in is not available for purchase from your distributor, please contact the distributor or a Neonode sales representative (refer to www.neonode.com[1]) for more information.

1 http://www.neonode.com/

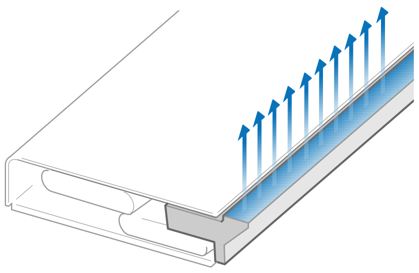
2.2.1 Sensor Orientation

The zForce AIR Touch Sensor is available in two types, one where the active area emerges straight out from the sensor (0° type) and one where it emerges out from the sensor at a 90° angle (90° type). This enables both vertical and horizontal integration.

0° Type



90° Type



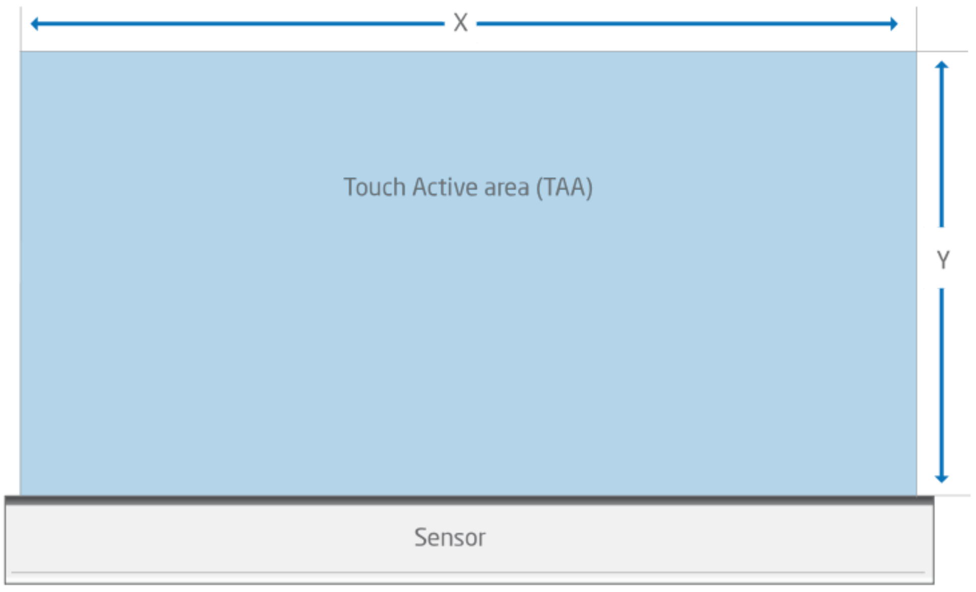
2.2.2 Sensor Length

The Touch Sensor is available in 43 different lengths. The length affects the Touch Active Area (TAA) in both X and Y directions.

2.2.3 Touch Active Area

The tables list all product variants, the product number, the TAA, and, if applicable, the TAA with Extended Range for each variant. See also Mechanical Data (see page 109).

Sensors with X ≥ 237.6 mm are long enough to use a scanning pattern that extends the active area in the Y-direction. The use of the Extended Range scanning pattern is supported from different firmware versions for different product variants, see the following tables.. Extended Range can affect the power consumption and the accuracy.



Product Number		**TAA (mm)**	
0° Type	**90° Type**	**X**	**Y**
NNAMC0430PC01	NNAMC0431PC01	43.2	14.9
NNAMC0500PC01	NNAMC0501PC01	50.4	29.8
NNAMC0580PC01	NNAMC0581PC01	57.6	29.8
NNAMC0640PC01	NNAMC0641PC01	64.8	44.7
NNAMC0720PC01	NNAMC0721PC01	72	44.7
NNAMC0790PC01	NNAMC0791PC01	79.2	59.6
NNAMC0860PC01	NNAMC0861PC01	86.4	59.6
NNAMC0940PC01	NNAMC0941PC01	93.6	74.5
NNAMC1010PC01	NNAMC1011PC01	100.8	74.5
NNAMC1080PC01	NNAMC1081PC01	108	89.4
NNAMC1150PC01	NNAMC1151PC01	115.2	89.4
NNAMC1220PC01	NNAMC1221PC01	122.4	104.3
NNAMC1300PC01	NNAMC1301PC01	129.6	104.3

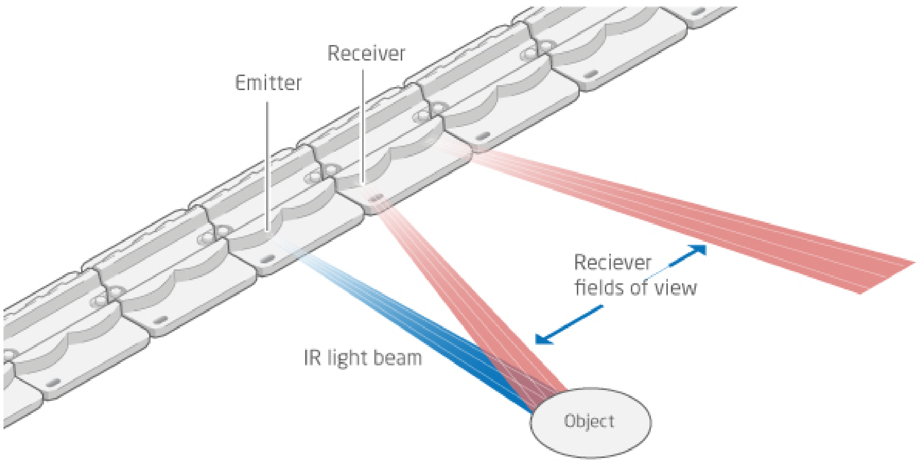
Product Number		TAA (mm)	
0° Type	90° Type	X	Y
NNAMC1370PC01	NNAMC1371PC01	136.8	119.2
NNAMC1440PC01	NNAMC1441PC01	144	119.2
NNAMC1510PC01	NNAMC1511PC01	151.2	134.0
NNAMC1580PC01	NNAMC1581PC01	158.4	134.0
NNAMC1660PC01	NNAMC1661PC01	165.6	148.9
NNAMC1730PC01	NNAMC1731PC01	172.8	148.9
NNAMC1800PC01	NNAMC1801PC01	180	163.8
NNAMC1870PC01	NNAMC1871PC01	187.2	163.8
NNAMC1940PC01	NNAMC1941PC01	194.4	178.7
NNAMC2020PC01	NNAMC2021PC01	201.6	178.7
NNAMC2090PC01	NNAMC2091PC01	208.8	193.6
NNAMC2160PC01	NNAMC2161PC01	216	193.6
NNAMC2230PC01	NNAMC2231PC01	223.2	208.5
NNAMC2300PC01	NNAMC2301PC01	230.4	208.5

Product Number		TAA (mm)		TAA, Extended Range (mm)		
0° Type	90° Type	X	Y	X	Y	From Firmware Version
NNAMC2380PC01	NNAMC2381PC01	237.6	208.5	Available on request		
NNAMC2450PC01	NNAMC2451PC01	244.8	208.5	Available on request		
NNAMC2520PC01	NNAMC2521PC01	252	208.5	Available on request		
NNAMC2590PC01	NNAMC2591PC01	259.2	208.5	Available on request		
NNAMC2660PC01	NNAMC2661PC01	266.4	208.5	Available on request		
NNAMC2740PC01	NNAMC2741PC01	273.6	208.5	Available on request		
NNAMC2810PC01	NNAMC2811PC01	280.8	208.5	Available on request		

Product Number		TAA (mm)		TAA, Extended Range (mm)		
0° Type	90° Type	X	Y	X	Y	From Firmware Version
NNAMC2880PC01	NNAMC2881PC01	288	208.5	Available on request		
NNAMC2950PC01	NNAMC2951PC01	295.2	208.5	Available on request		
NNAMC3020PC01	NNAMC3021PC01	302.4	208.5	Available on request		
NNAMC3100PC01	NNAMC3101PC01	309.6	208.5	Available on request		
NNAMC3170PC01	NNAMC3171PC01	316.8	208.5	Available on request		
NNAMC3240PC01	NNAMC3241PC01	324	208.5	Available on request		
NNAMC3310PC01	NNAMC3311PC01	331.2	208.5	Available on request		
NNAMC3380PC01	NNAMC3381PC01	338.4	208.5	Available on request		
NNAMC3460PC01	NNAMC3461PC01	345.6	208.5	345.6	327.7	v1.49

Basic Principles

zForce AIR Touch Sensors detect and trace objects by detecting diffusely reflected infrared light. The sensor comprises an optical system arranged to combine emitted IR beams and receiver fields of view within the same apertures. IR light beams are emitted perpendicular to the output window, while receivers field of view is centered at a certain angle left and right.

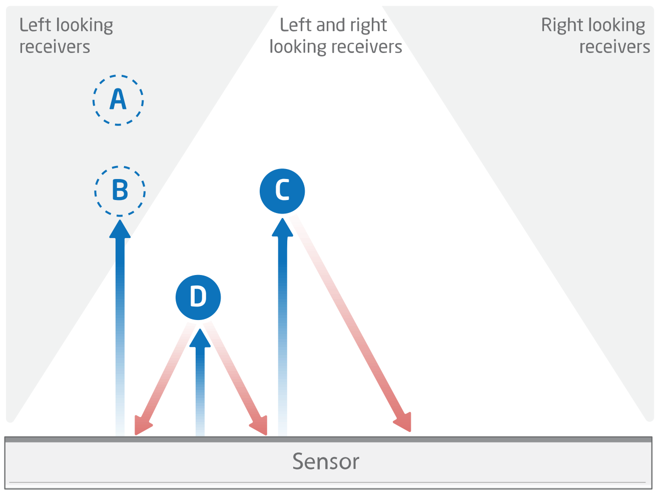


Each emitter-receiver combination covers a narrow region on the active area. An object present in the active area will affect several emitter-receiver channels, and the reported coordinates is the outcome of a center of gravity calculation on these signals.

2.3 Multi-Touch Functionality

zForce AIR Touch Sensor determine an object's position by signals derived from emitter-receiver pairs and have the capacity to detect and track several objects at the same time. Both the hardware and the software have been optimized in order to support standard touch gestures like, pinch-to-zoom, rotate, swipe and tap. However, some combinations of two or more objects might require special consideration, which is described in more detail below.

2.3.1 Shadows



- An object directly behind another object cannot be illuminated. In the figure above, object A will not be detected since illumination is blocked by object B.
- The correct receiver must have a clear field of view. Object B is in a region covered only by left looking receivers. Object B will not be detected because its field of view is blocked by object D.
- Object C may be seen by both left and right looking receivers. Although the right looking field of view is blocked by object D, object C is detected by the left looking receiver.
- Object D is detected by both left and right looking receivers.

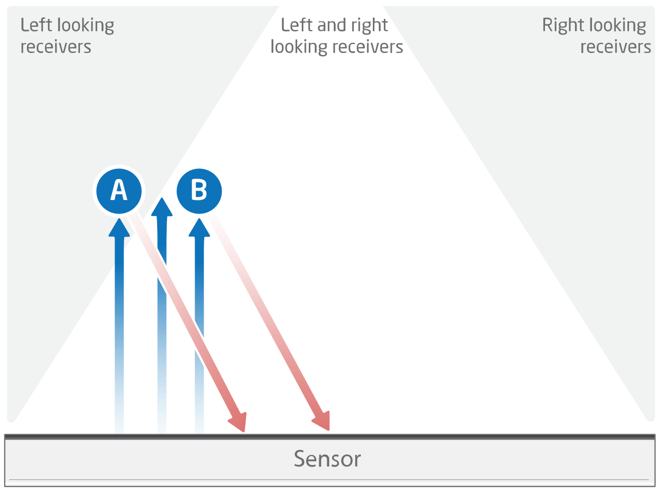
Shadow Trick

Note that in most cases, user experience is not affected by the shadow situations mentioned above. This is because of a functionality implemented in the Touch Sensor firmware called "shadow trick", which e.g. generates a smooth "rotate" feeling despite one touch object being shadowed during the rotate gesture. A previously detected object that can no longer be detected is still reported as present if:

- The object was last seen close to a location where it could be shadowed by another object.
- The potentially shadowing object is still detected and hasn't moved away from a shadowing location.

The shadow trick make multi-touch gestures such as "rotate" and "pinch-to-zoom" work better.

2.3.2 Adjacent Objects



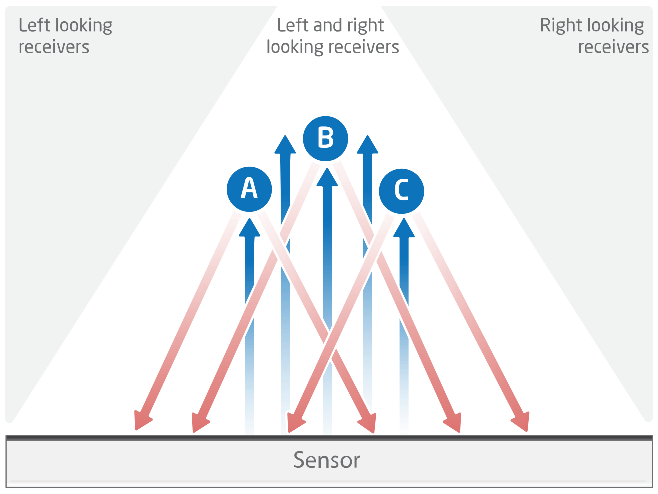
- In order to recognize two objects close to each other (A and B), a separation must allow at least one emitter-receiver channel (~10 mm) to pass freely between them. Otherwise, the two objects will be reported as one large object.

2.3.3 More Than Two Objects

When more than two objects are being tracked the likelihood that an object ends up being in the shadow of another object increases. Therefore, it is only recommended to enable more than two tracked objects if, for example:

- it is not vital to track all detected objects 100% in all possible combinations and locations at all time.

When all objects are likely to be detected by the sensor, for example when it is expected that all objects will be placed along a line that is parallel to the sensor, as in the example below.



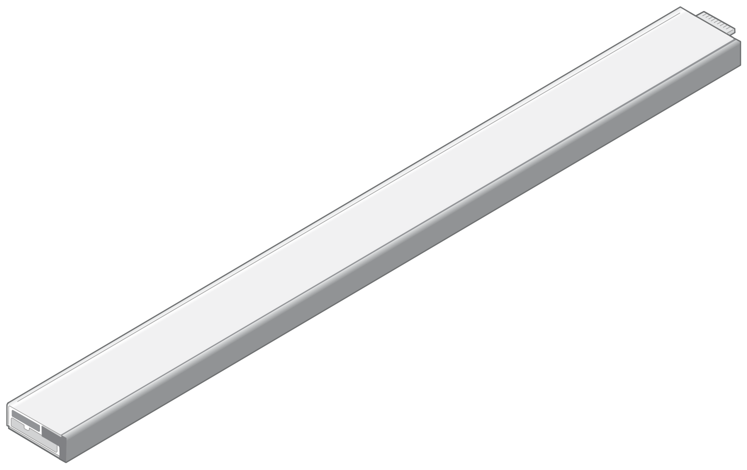
2.4 Applications

zForce AIR Touch Sensors can be integrated for a wide range of applications, such as:

- PCs/Tablets
- TVs/Monitors
- Printers
- Mechanical key replacement
- White goods
- Smart furniture
- Interactive mirrors
- Elevator panels
- eReaders
- Instruments
- Vending Machines
- ATM/POS terminals
- Robotics
- Range finders
- Collision detectors
- ... and much more

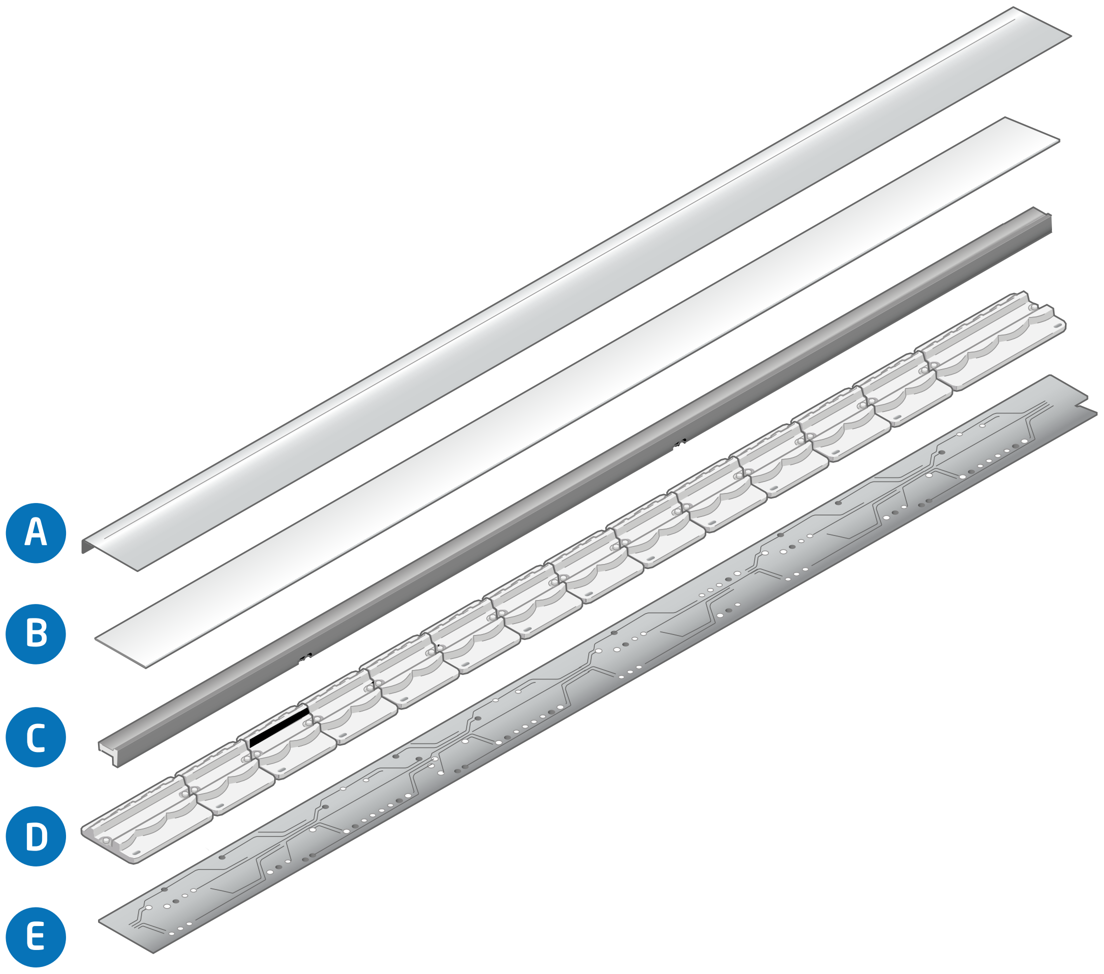
2.5 Sensor Design and Components

The zForce AIR Touch Sensor is a laser light based touch sensor that can be used for various touch and mid-air detection applications. The image below show the sensor design (0° type). The connector is shown to the far right.



2.5.1 Exploded view

The image below shows the sensor (0° type) in an exploded view.



Part	Description
A	Cover
B	Adhesive
C	Front light pipe – straight shooting or 90 degree shooting depending on sensor type
D	Lenses - the amount depends on sensor size
E	PCBA

2.5.2 Sensor Components

The PCBA is equipped with both active and passive components, for example:

- MCU

- Co-processor, a Neonode proprietary scanning IC
- Optical lenses, made out of polycarbonate
- VCSELs
- Photodiodes
- Other passive components

2.6 Product Integration

The zForce AIR Touch Sensor can be integrated into any host system through a physical connector with 8 contact pads. The connector supports both I2C and USB HID.

The sensor communicates with messages that are defined in ASN.1-notation. ASN.1 is a standardized way (ISO/IEC 8824) to describe data regardless of language implementation, hardware system and operation system. The host system can communicate with the sensor using the zForce communication protocol.[2]

To facilitate integration, Neonode has developed function libraries that are available for download.

2 https://support.neonode.com/docs/display/AIRTSUsersGuide/zForce+Communication+Protocol

3 Getting started with zForce AIR Touch Sensor Evaluation

3.1 Getting Started with Sensor Evaluation - Plug and Play with USB

3.1.1 Required Equipment

The following equipment from the evaluation kit is required:

- 1 x zForce AIR Touch Sensor
- 1 x FPC cable with connector
- 1 x Interface board

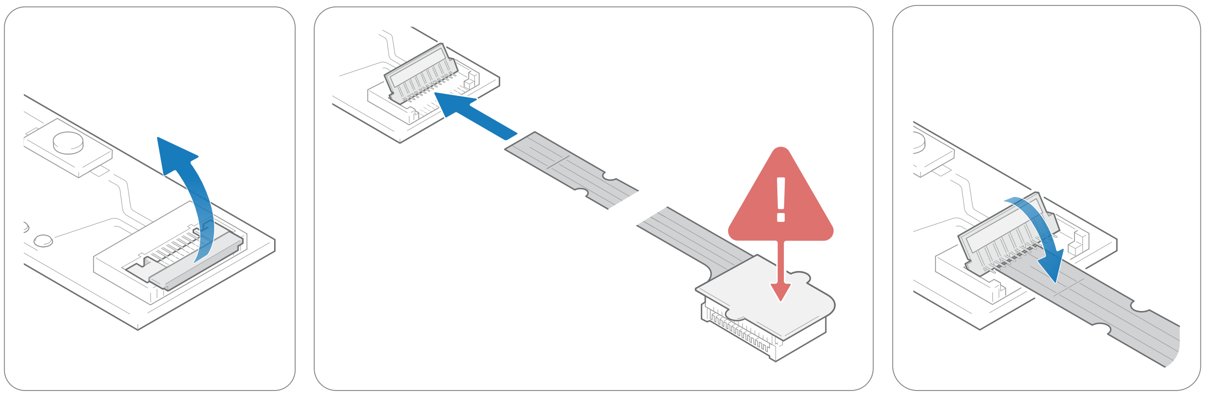
Additional required equipment:

- Computer (Windows or Linux)
- For a sensor of the 90° type: double-sided adhesive tape.
- USB cable with a Micro USB type B connector

Make sure that the USB cable transmits both power and data and not only power.

3.1.2 Connecting Sensor

1. Connect the FPC cable to the interface board:

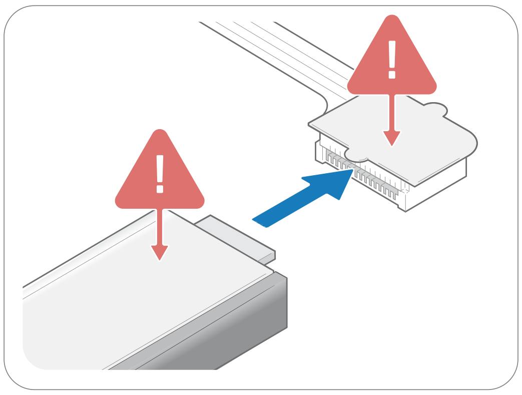


   a. Lift the flip lock on the interface board.
   b. Insert the FPC cable into the end of the connector, with the connector pads facing down, towards interface board. The yellow piece of PCB of the connector on the other side of the cable is facing upwards. Make sure the direction is straight into the connector and the pads have reached the end of the connector.

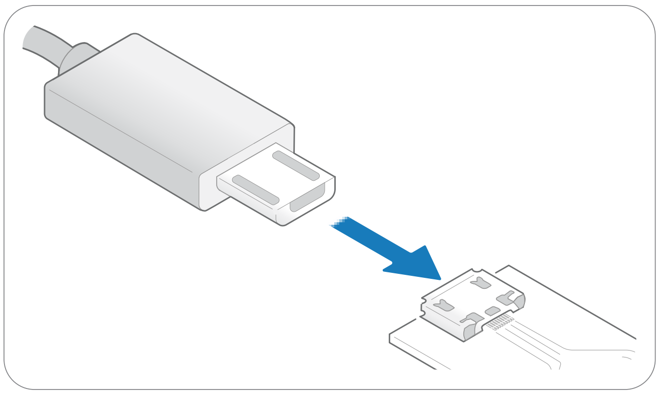
      Make sure the connector pads of the FPC cable are facing downwards, towards interface board. The sensor risks damage if the FPC cable is connected in wrong direction.

   c. Press down the flip lock.

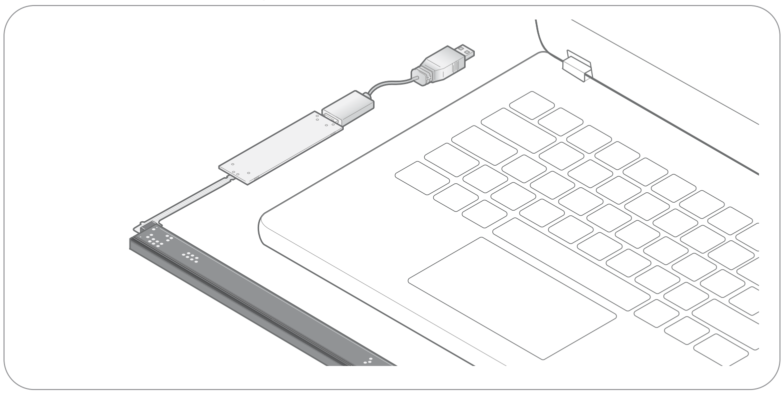
2. Connect the FPC cable to the sensor:



   a. Place the sensor so that the sensor connector pads of the sensor are facing downwards (steel surface upwards).
   b. Insert sensor into the connector on FPC cable (yellow piece of PCB of the FPC connector still facing upwards).
   c. Make sure the direction of the pads is straight into the connector, and the pads have reached the end of the connector.
3. Connect a USB cable with a Micro USB type B connector to the interface board.

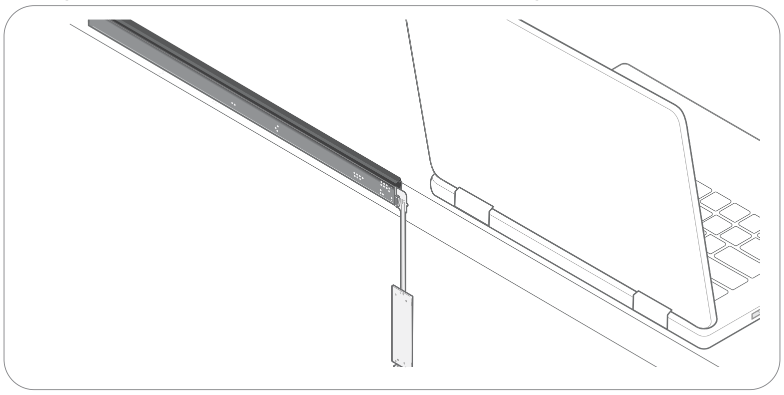


4. If the sensor is of the 0° type**:** Place the sensor on a table with the steel surface facing downwards and with the optical surface facing towards you.

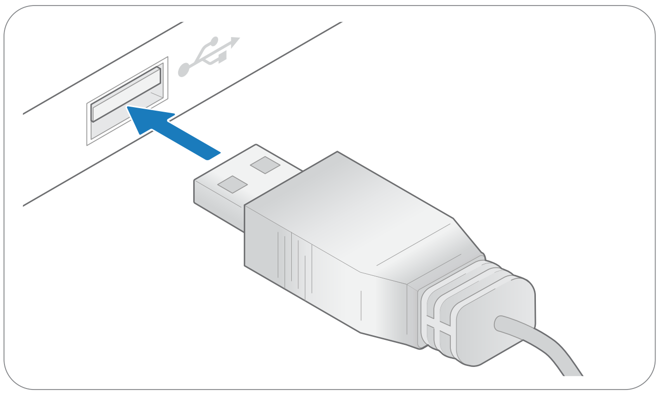


Make sure no object is within the touch active area of the sensor before connecting power to the sensor through USB. The sensor calibrates itself when powered on and an object within the touch active area may interfere with the calibration.

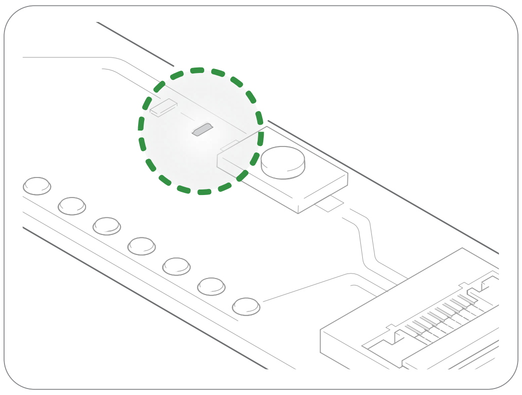
5. If the sensor is of the 90° type**:** Use double-sided adhesive tape to fasten the steel surface of the sensor to the edge of a table, with the optical surface facing towards you.



6. Insert the USB cable into a computer.



7. The green LED on the interface board lights up when connected.



8. When the sensor has enumerated, it will act as a touch screen USB HID device.
9. Put an object in the touch active area, touch HID reports will be sent to your computer.

To visualize touches, you can for for example use Paint (default Windows application) and draw lines by moving you finger in the touch active area.

3.2 Getting Started with Sensor Evaluation - USB and Workbench

3.2.1 Required Equipment

The following equipment from the evaluation kit is required:

- 1 x zForce AIR Touch Sensor
- 1 x FPC cable with connector
- 1 x Interface board

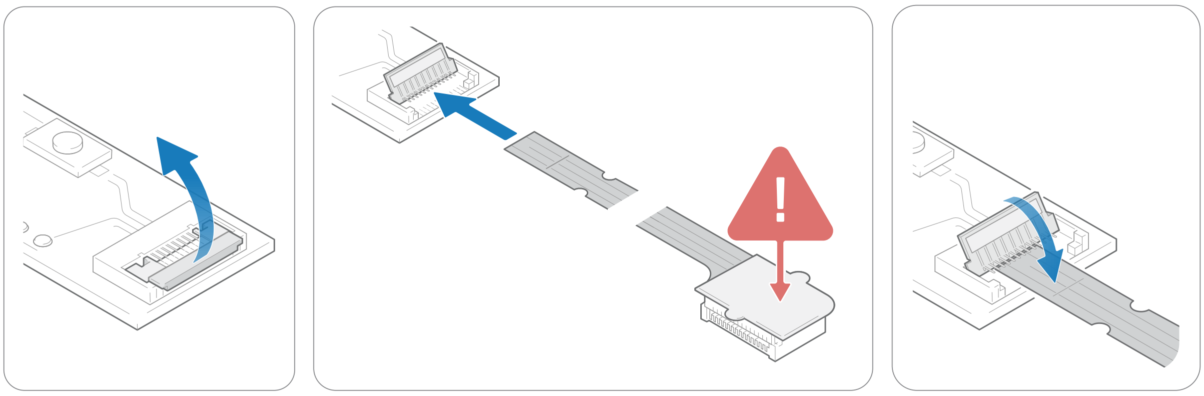
Additional required equipment:

- For a sensor of the 90° type: double-sided adhesive tape.
- Computer
    - Operating system: Windows 8.1 or Windows 10.
    - Software requirements: .NET Framework 4.5 or higher is required and can be downloaded from Microsoft's official website. Windows 8 and higher has this installed by default.
- USB cable with a Micro USB type B connector

Make sure that the USB cable transmits both power and data and not only power.

3.2.2 Connecting Sensor

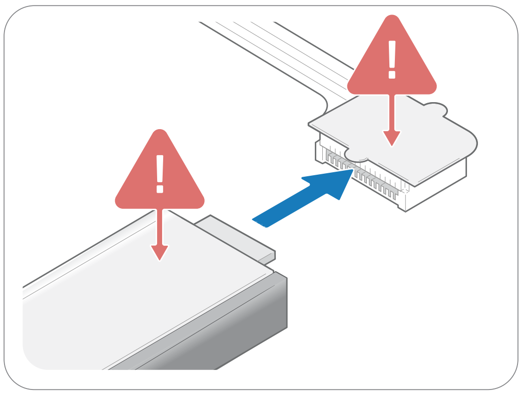
1. Connect the FPC cable to the interface board:



   a. Lift the flip lock on the interface board.
   b. Insert the FPC cable into the end of the connector, with the connector pads facing down, towards interface board. The yellow piece of PCB of the connector on the other side of the cable is facing upwards. Make sure the direction is straight into the connector and the pads have reached the end of the connector.

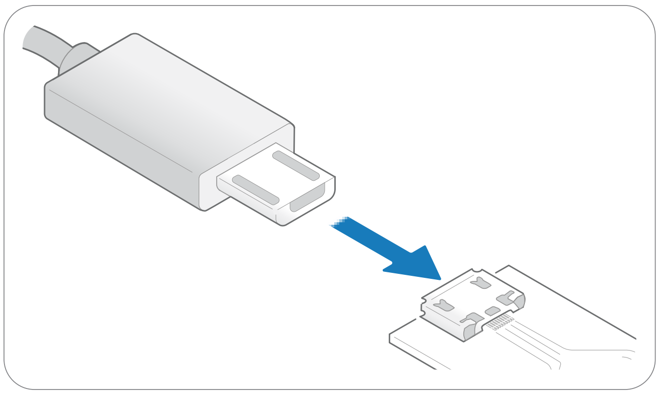
      Make sure the connector pads of the FPC cable are facing downwards, towards interface board. The sensor risks damage if the FPC cable is connected in wrong direction.

   c. Press down the flip lock.
2. Connect the FPC cable to the sensor:

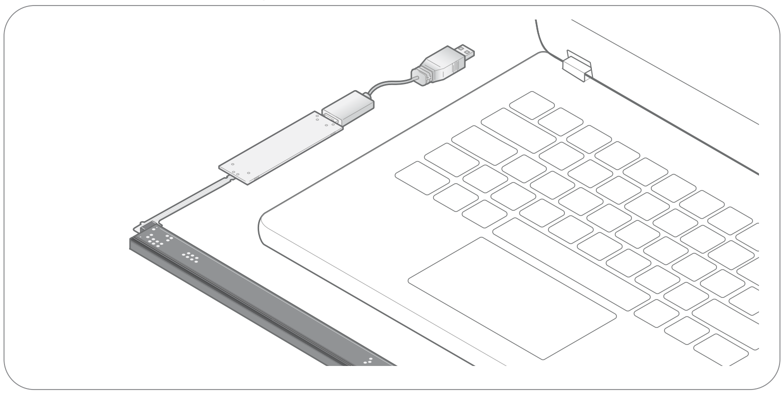


a. Place the sensor so that the sensor connector pads of the sensor are facing downwards (steel surface upwards).
b. Insert sensor into the connector on FPC cable (yellow piece of PCB of the FPC connector still facing upwards).
c. Make sure the direction of the pads is straight into the connector, and the pads have reached the end of the connector.

3. Connect a USB cable with a Micro USB type B connector to the interface board.

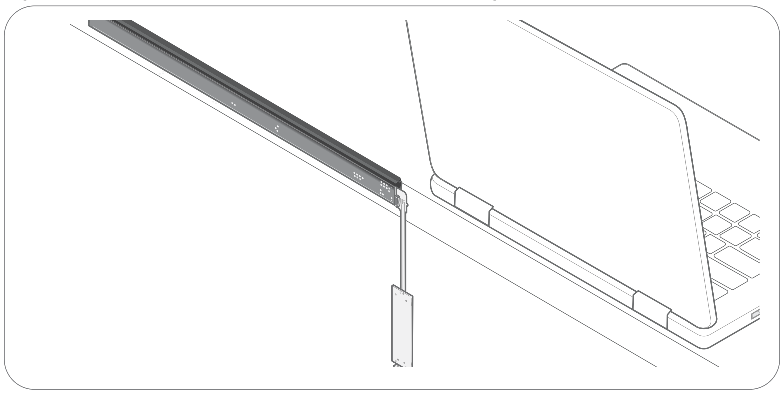


4. If the sensor is of the 0° type: place the sensor on a table with the steel surface facing downwards and with the optical surface facing towards you.

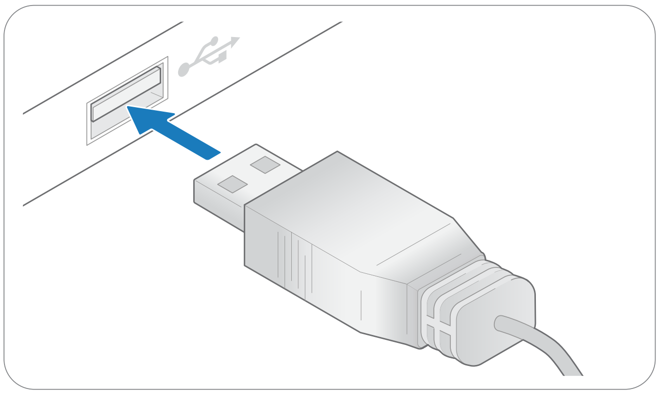


Make sure no object is within the touch active area of the sensor before connecting power to the sensor through USB. The sensor calibrates itself when powered on and an object within the touch active area may interfere with the calibration.

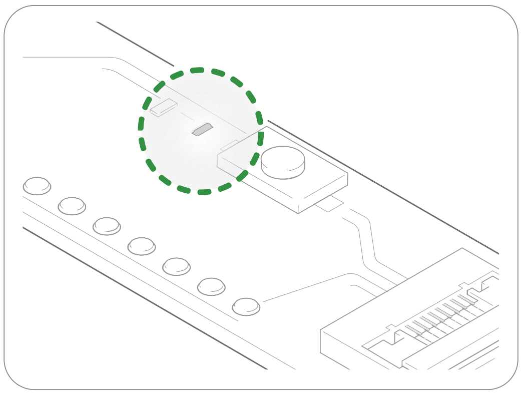
5. If the sensor is of the 90° type: use double-sided adhesive tape to fasten the steel surface of the sensor to the edge of a table, with the optical surface facing towards you.



6. Insert the USB cable into a computer.



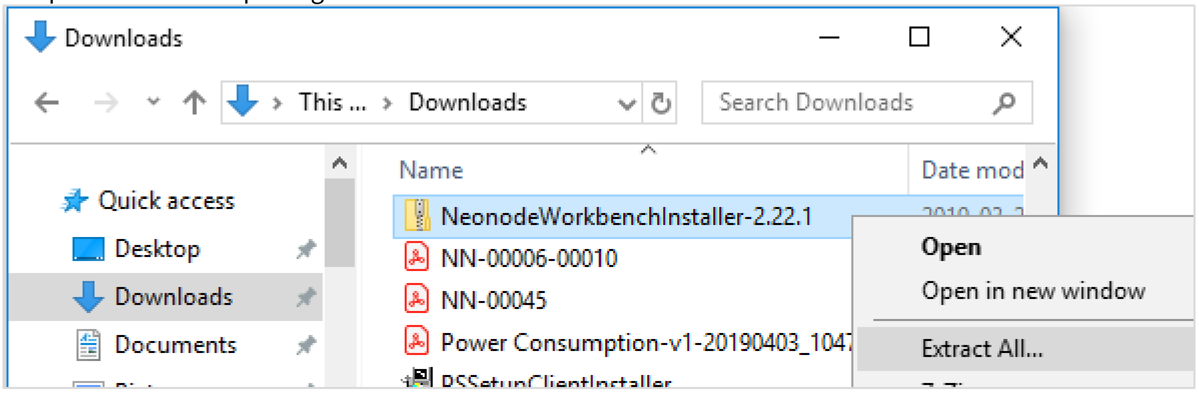
7. The green LED on the interface board lights up when connected.



3.2.3 Installing and Opening Neonode Workbench

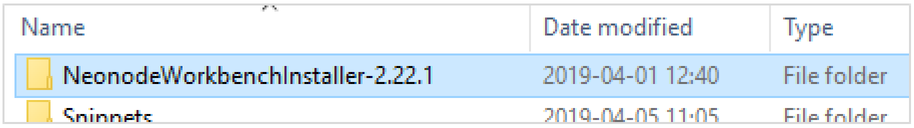
1. Download the latest release of the Workbench installation package from https://support.neonode.com/docs/pages/viewpage.action?pageId=2490816.

2. Unzip the installation package.



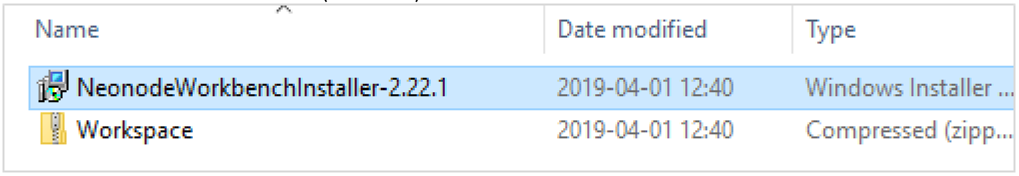
Name	Date mod
NeonodeWorkbenchInstaller-2.22.1	
NN-00006-00010	
NN-00045	
Power Consumption-v1-20190403_104	
PSSetupClientInstaller	

3. Open the installation package folder.



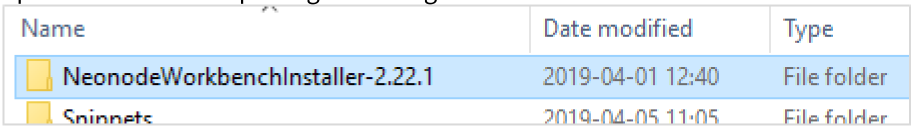
Name	Date modified	Type
NeonodeWorkbenchInstaller-2.22.1	2019-04-01 12:40	File folder
Snippets	2019-04-05 11:05	File folder

4. Run the Workbench installer (.msi file) and follow the instructions.



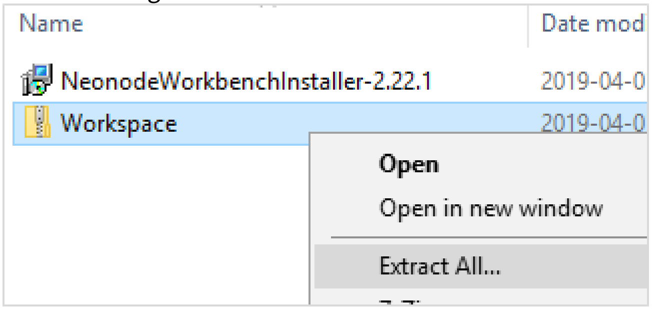
Name	Date modified	Type
NeonodeWorkbenchInstaller-2.22.1	2019-04-01 12:40	Windows Installer ...
Workspace	2019-04-01 12:40	Compressed (zipp...

5. Open the installation package folder again.



Name	Date modified	Type
NeonodeWorkbenchInstaller-2.22.1	2019-04-01 12:40	File folder
Snippets	2019-04-05 11:05	File folder

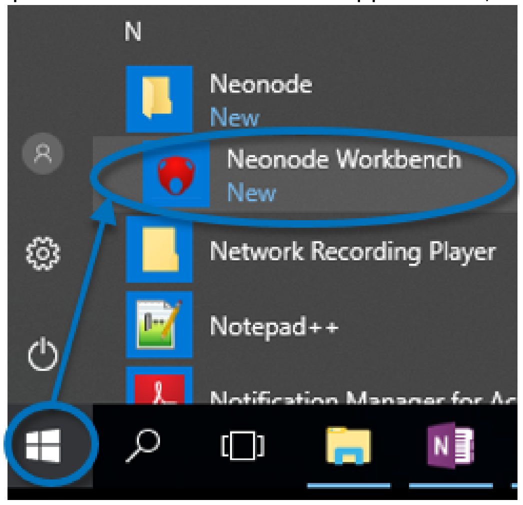
6. Unzip the Workspace folder to a location where you have write permissions. Write permissions are required to save settings and user data.



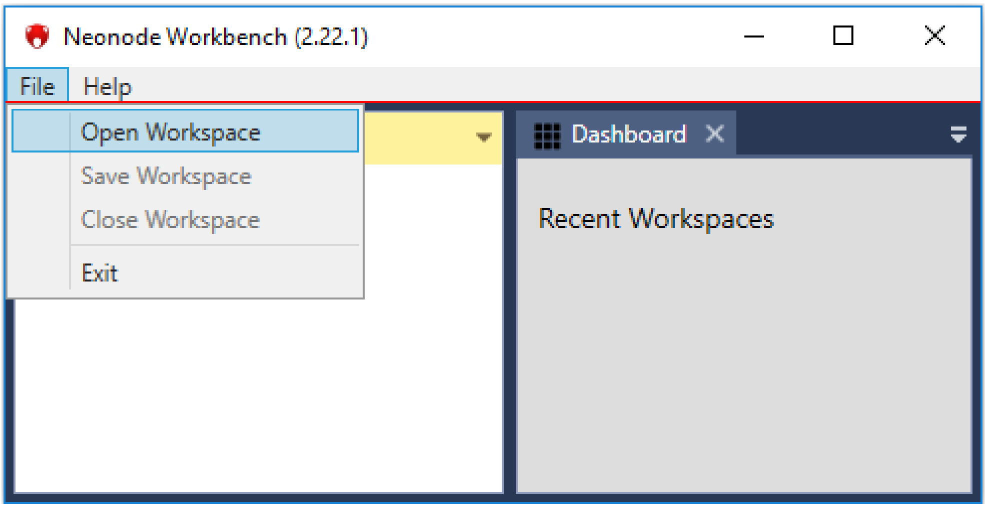
Name	Date mod
NeonodeWorkbenchInstaller-2.22.1	2019-04-0
Workspace	2019-04-0

ⓘ In order for the Workbench application to operate, the files in the Workspace folder must be kept together. Move the entire folder if you want to relocate the workspace file.

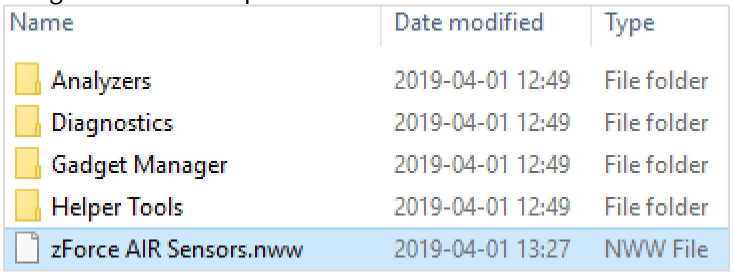
7. Open the Neonode Workbench application. (The illustration is from Windows 10.)



8. From the toolbar, select **File** >> **Open Workspace**.



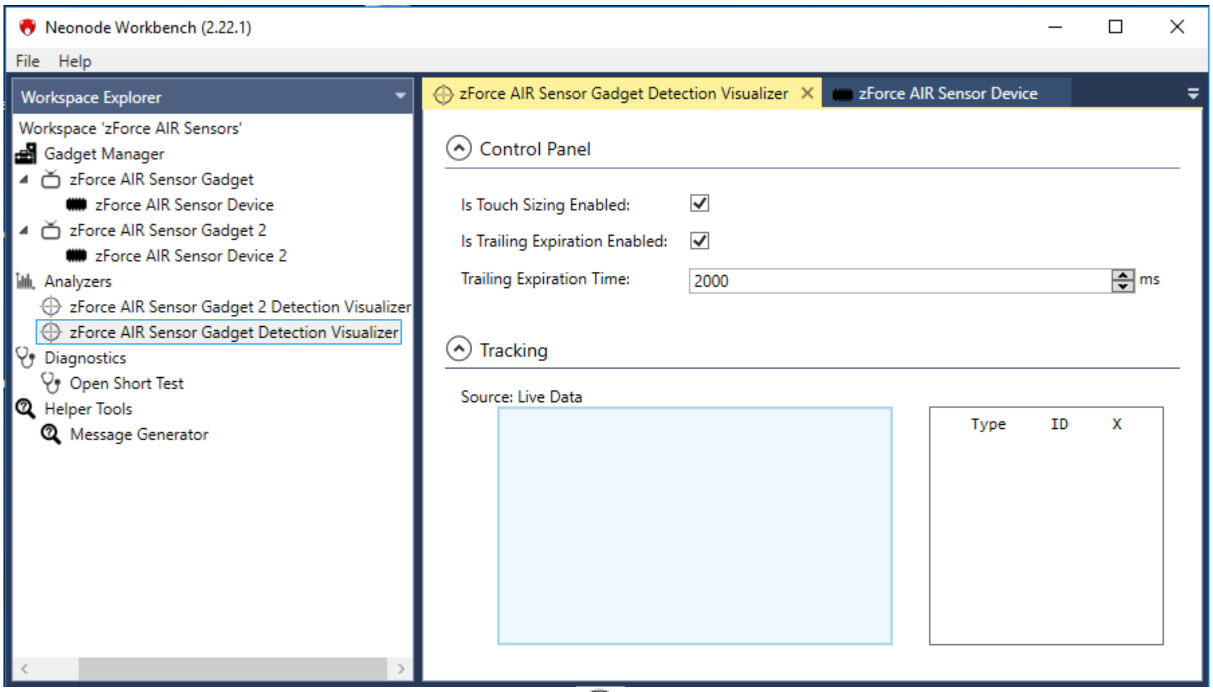
9. Navigate to the Workspace folder and double-click the .nww file inside the folder.



Name	Date modified	Type
Analyzers	2019-04-01 12:49	File folder
Diagnostics	2019-04-01 12:49	File folder
Gadget Manager	2019-04-01 12:49	File folder
Helper Tools	2019-04-01 12:49	File folder
zForce AIR Sensors.nww	2019-04-01 13:27	NWW File

3.2.4 Visualizing Touches with Workbench

1. In the left panel of the workspace, double-click **zForce AIR Sensor Gadget Detection Visualizer.** A tab with two sections, **Control Panel** and **Tracking,** opens in the right panel.



Neonode Workbench (2.22.1)

File Help

Workspace Explorer

Workspace 'zForce AIR Sensors'
- Gadget Manager
  - zForce AIR Sensor Gadget
    - zForce AIR Sensor Device
  - zForce AIR Sensor Gadget 2
    - zForce AIR Sensor Device 2
- Analyzers
  - zForce AIR Sensor Gadget 2 Detection Visualizer
  - zForce AIR Sensor Gadget Detection Visualizer
- Diagnostics
  - Open Short Test
- Helper Tools
  - Message Generator

zForce AIR Sensor Gadget Detection Visualizer | zForce AIR Sensor Device

Control Panel

Is Touch Sizing Enabled: ✓

Is Trailing Expiration Enabled: ✓

Trailing Expiration Time: 2000 ms

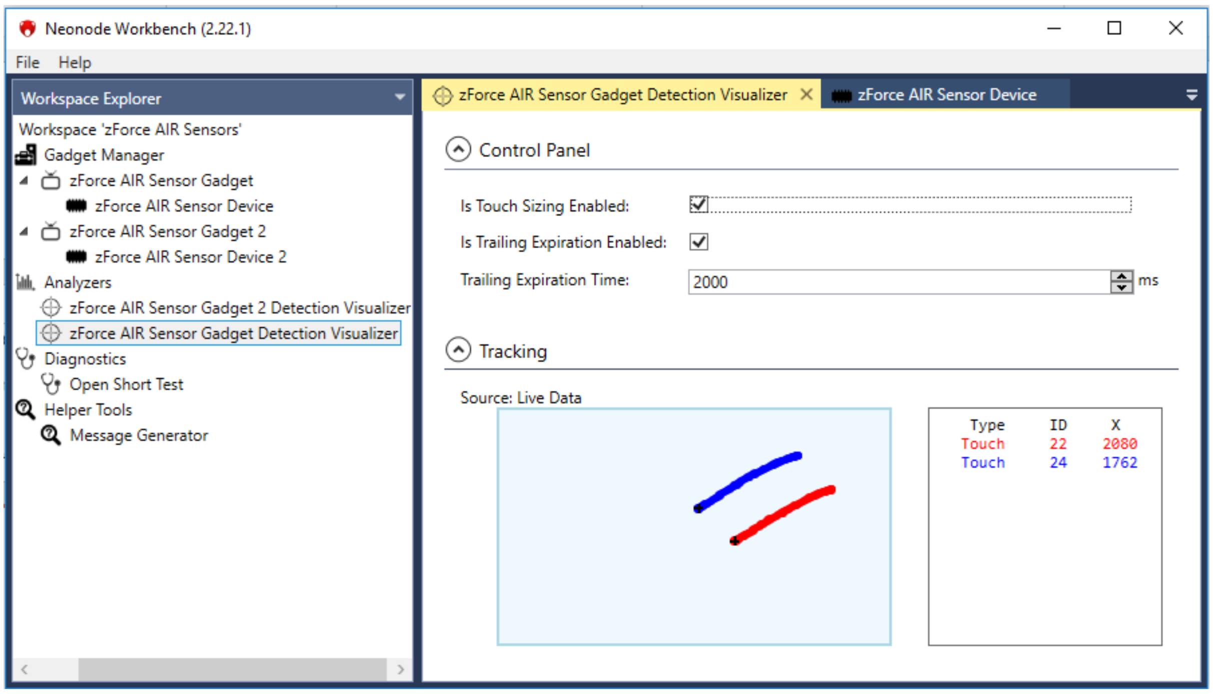
Tracking

Source: Live Data

Type	ID	X

2. If either section in the right panel is collapsed, click to expand it.
3. In the right panel
   a. Enable or disable **Touch Sizing**. With Touch Sizing enabled, the size of a detected object is indicated by the size of the tracking cursor.
   b. Enable or disable **Trailing Expiration.** With Trailing Expiration enabled, the trail of a detected object is shown, indicating its movement.

4. Move one or more fingers or other objects in the active area of the sensor. The registered touches show on the canvas. Type, ID an x- and y-coordinates of each touch is shown to the right of the canvas.


Neonode Workbench (2.22.1)
File Help
Workspace Explorer
Workspace 'zForce AIR Sensors'
Gadget Manager
zForce AIR Sensor Gadget
zForce AIR Sensor Device
zForce AIR Sensor Gadget 2
zForce AIR Sensor Device 2
Analyzers
zForce AIR Sensor Gadget 2 Detection Visualizer
zForce AIR Sensor Gadget Detection Visualizer
Diagnostics
Open Short Test
Helper Tools
Message Generator
zForce AIR Sensor Gadget Detection Visualizer
zForce AIR Sensor Device
Control Panel
Tracking
Source: Live Data

Is Touch Sizing Enabled: ✓
Is Trailing Expiration Enabled: ✓
Trailing Expiration Time: 2000 ms

Type	ID	X
Touch	22	2080
Touch	24	1762

In Workbench, you can also

- Access sensor information such as firmware version.
- Configure the sensor to explore different configurations.
- Perform a test to identify any damaged laser or photo diodes.
- Generate sensor messages in hexadecimal format without understanding the structure of the communication protocol message.

For more information, refer to the Workbench documentation at https://support.neonode.com/docs/display/Workbench/Getting+Started+with+Neonode+Workbench.[3]

3.3 Getting Started with Sensor Evaluation - I2C and Arduino

3.3.1 Required Equipment

The following equipment from the evaluation kit is required:

- 1 x zForce AIR Touch Sensor
- 1 x FPC cable with connector
- 1 x Interface board

Additional required equipment:

- For a sensor of the 90° type: double-sided adhesive tape.
- An Arduino-compatible board. The I2C library described here supports the following MCUs: ATmega168, ATmega8, ATmega328P. If you wish to use another MCU, make sure to use an I2C library that works with

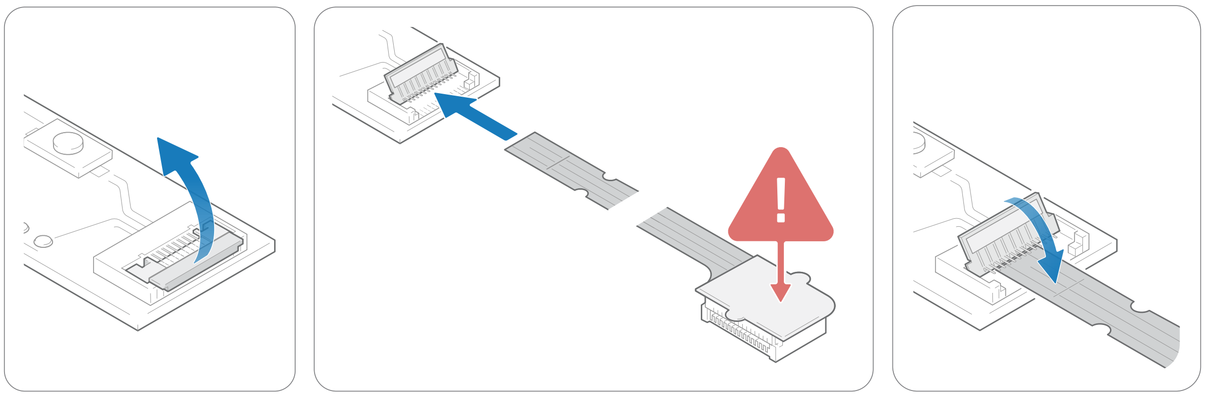
3 https://support.neonode.com/docs/pages/viewpage.action?pageId=9374867

your hardware.
Examples of boards with a supported MCU:
- Arduino Uno
- Adafruit Pro Trinket
- Arduino Nano

- An Arduino development environment, for example the Arduino IDE.

3.3.2 Connecting Sensor

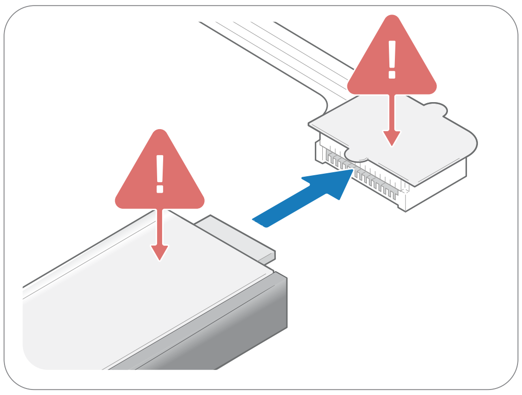
1. Connect the FPC cable to the interface board:



   a. Lift the flip lock on the interface board.
   b. Insert the FPC cable into the end of the connector, with the connector pads facing down, towards interface board. The yellow piece of PCB of the connector on the other side of the cable is facing upwards. Make sure the direction is straight into the connector and the pads have reached the end of the connector.

   Make sure the connector pads of the FPC cable are facing downwards, towards interface board. The sensor risks damage if the FPC cable is connected in wrong direction.

   c. Press down the flip lock.
2. Connect the FPC cable to the sensor:

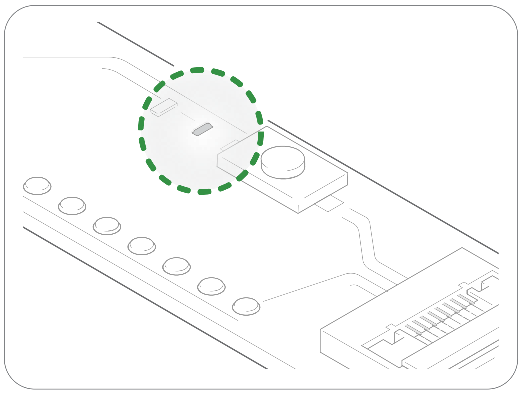


   a. Place the sensor so that the sensor connector pads of the sensor are facing downwards (steel surface upwards).

   b. Insert sensor into the connector on FPC cable (yellow piece of PCB of the FPC connector still facing upwards).
   c. Make sure the direction of the pads is straight into the connector, and the pads have reached the end of the connector.
3. Wire the pads of +5V, DR-B0, I2C-D, I2C-C, and GND on the interface board to the corresponding pins on the host system. For details, refer to Electrical Integration (see page 36). Do not connect power until the following steps have been performed.
4. If the sensor is of the 0° type: place the sensor on a table with the steel surface facing downwards and with the optical surface facing towards you.

> Make sure no object is within the touch active area of the sensor before connecting power to the sensor through I2C. The sensor calibrates itself when powered on and an object within the touch active area may interfere with the calibration.

5. If the sensor is of the 90° type: use double-sided adhesive tape to fasten the steel surface of the sensor to the edge of a table, with the optical surface facing towards you. For further information refer to Mechanical Integration (see page 30).
6. Connect power to the sensor through the I2C.
7. The green LED on the interface board lights up when connected.



3.3.3 Downloading and Installing the zForce AIR Interface Library for Arduino

1. Go to https://github.com/neonode-inc/zforce-arduino.
2. Download the repository as a .zip file or clone it.
3. Open the example program provided in the repository in an Arduino development environment, for example the Arduino IDE.
4. Compile the program.
5. Flash the Arduino with the example program.

3.3.4 Example Program Pseudocode

The following procedure is executed when you flash the Arduino with the example program:

1. Call Serial.begin() in order to print to the console window.
2. Initialize the I2C communication: call zforce.Start and provide which physical pin that is used for the Data Ready signal
3. Read the bootcomplete message.
   a. Print the message.
   b. Destroy the message by calling zforce.DestroyMessage.
4. Set the desired settings in the sensor. (In this case enable).

   a. Call zforce.Enable.
   b. Wait for the response to arrive.
   c. Print the response.
   d. Delete the message.

5. Repeat step 4 for all settings.
6. Go into the main loop.
   a. Pull zforce.GetMessage for touch notifications.
   b. Check if a touch message is NOT null.
      i. Print the contents of the message.
      ii. Destroy the message.
   c. End of loop.

4 Getting Started with Software Integration

The zForce AIR Touch Sensor can be integrated into any host system that supports either the I2C or the USB HID transport protocol. The zForce communication protocol is based on I2C- or USB HID-transport of messages that are serialized according to the zForce ASN.1 Serialization Protocol. ASN.1 is a standardized way to describe data regardless of language implementation, hardware system and operating system (ISO/IEC 8824).

4.1 Communicating without Deserializing ASN.1-encoded Messages - Use the zForce SDK

The zForce SDK is compatible with USB and Windows or Linux.

The SDK allows you to communicate with the sensor without considering encoded ASN.1-messages.

Use the SDK to create an application for communication with the sensor. The SDK contains an example program to get you going. The algorithm of the example program is described here[4].

Download zForce SDK from https://support.neonode.com/docs/display/Downloads/zForce+SDK+Downloads and refer to separate zForce SDK documentation[5].

4.2 Communicating with I2C and Arduino - Use the zForce AIR Interface Library for Arduino

The library is compatible with I2C and Arduino.

The zForce AIR interface library for Arduino is a primitive function library. Use it as a starting point for creating an application for communication with the sensor. The library contains an example program to get you going.

For more information, refer to zForce AIR interface library for Arduino (see page 88).

4.3 Communicating Using a System and a Programming Language of Your Choice

Learn more about the zForce Communication Protocol (see page 44) and write your own application to read and write data via one of the following transport modes:

- USB Raw HID Mode
- I2C Transport

Make sure to prepare the sensor for communication, refer to Preparing the Sensor for Communication (see page 43).

Neonode provides the following help to get you started:

- A Message Generator, as part of the Neonode Workbench. This tool can be used to generate serialized messages according to the zForce ASN.1 Protocol. Refer to separate Neonode Workbench documentation on https://support.neonode.com/docs/pages/viewpage.action?pageId=9374867.
- Examples of different implementations. Refer to Implementation Examples (see page 88).
- The Neonode Help Center. For any questions, refer to https://helpcenter.neonode.com/hc/en-us/requests/new.

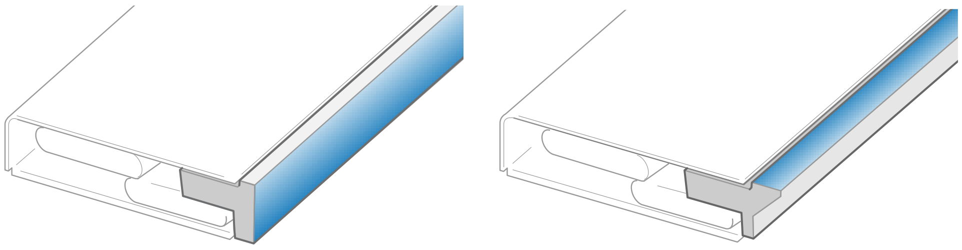
4 https://support.neonode.com/docs/display/SDKDOC/Example+Program+Algorithm
5 https://support.neonode.com/docs/pages/viewpage.action?pageId=9375245

5 Mechanical Integration

zForce AIR Touch Sensor can be used for different purposes, such as detecting touches on a surface or objects in mid-air. Assembly requirements differ depending on what purpose the Touch Sensor fulfills. In addition, different industries have different standards and demands to fulfill. Mid-air detection applications generally require lower mounting tolerances.

5.1 Means of Integration

zForce AIR Touch Sensor comes in two types: one is designed to be integrated horizontally and the other vertically. This allows different types of assembly possibilities and better adaptation of the available space in the host system. The two sensor designs are built on the same concept, but use two different front light pipes. One light path is unaffected; the other bent 90°.

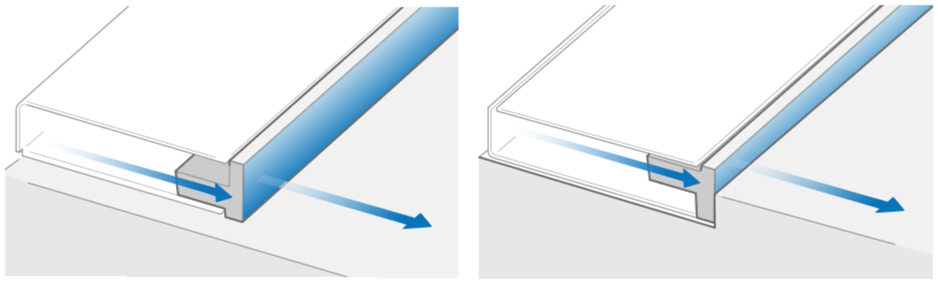


The front optical surface is not allowed to be blocked by the host system.

The short sides of the sensor should be protected from light of high intensity. If there is a risk for exposure to strong light, covering the short sides with, for example, black tape might improve performance.

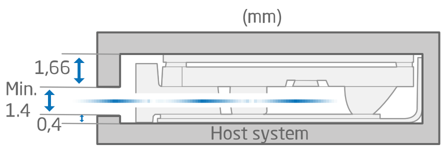
5.1.1 Horizontal Integration

Light is sent straight out and enables an active area in front of the module, in the same plane as the light path.



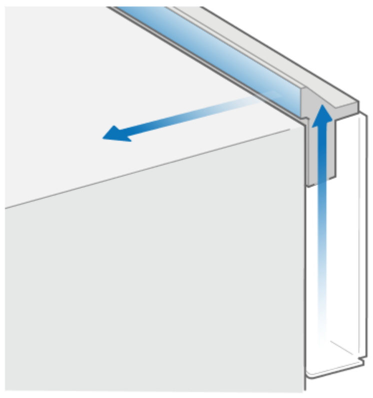
When integrating zForce AIR Touch Sensor into a host system make sure not to interfere with the light path. For horizontal integration, the opening for the sensors light path must be minimum 1.4 mm.

If the host system have large tolerances, opening must be adjusted to always be minimum 1.4 mm.

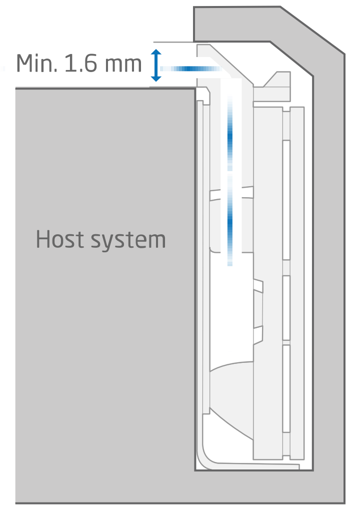


5.1.2 Vertical Integration

Light is bent 90 degrees within the Touch Sensor. This allows the sensor to be assembled vertically but still have an active area in the horizontal plane.



To make sure not to interfere with the sensor light path, the opening must be minimum 1.6 mm. If the host system has large tolerances, the opening must always be adjusted to be minimum 1.6 mm. Also note that it is not allowed to mount, glue or in any other way affect the sensor's optical surfaces since it will affect the performance. This applies to both the sensor's visible optical surface and the back of the mirror surface that bends the light path 90°.



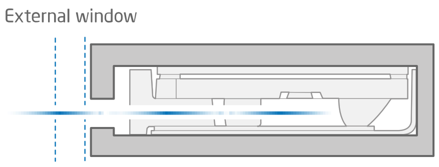
5.1.3 Options for Guiding and Fastening

- Double adhesive tape – for smaller sizes this can be used alone to hold the zForce AIR Touch Sensor. The host system geometry needs to provide a flat supporting surface.
- Snaps – Host system geometry provides some sort of snap features holding the zForce AIR Touch Sensor in place. These must be developed for each case to fit the host System cover and the surrounding.
- **Sandwiched** – the zForce AIR Touch Sensor is mounted by pressing the Touch Sensor between host system exterior cover and display. A structure (ribs, foam gasket or adhesive) is needed to make sure the Touch Sensor cannot move.

The zForce AIR Touch Sensor needs to be protected from outer pressure and forces that can bend the sensor and by that change the direction of the sensor light. The most common cause of bending is when a Touch Sensor is mounted on a non-flat surface, so the host system supporting structure needs to be flat. High point load on the PCBA side of the sensor can also affect touch performance. If any kind of clamp or similar setup is used for fastening, make sure that the contact surface with the sensor is as large as possible.

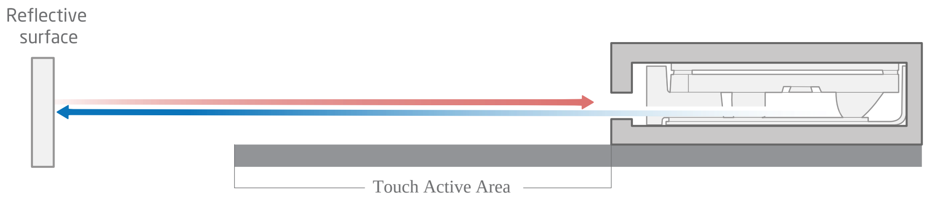
5.1.4 External Window

An external window is something placed between the sensor and the desired touch active area, usually in form of a plastic or glass "window". It is of high importance for the function that these surfaces fulfill the optical demands stated in Optical Requirements on External Window (see page 107). It is important to know that each window the light passes through will reduce the sensors received signal levels, even though the requirements are fulfilled, which in some applications might reduce the maximum detection range.



5.1.5 External Reflective Surface

An external reflective surface is a surface located outside the active area, but close enough to be reached by the IR light emitted by the sensor. Depending on the angle and the reflectance of the surface, reflected light can enter the sensor and interfere with touch object detection. If the external reflective surface is close to the touch active area, it is recommended to make sure it has a low reflectance in the direction back towards the sensor.



Lower reflectance can be achieved by

- Using a color on the reflective material which has low reflectance in the IR spectrum, e.g. black plastic or black paint.
- Using an angle of the reflective surface to divert the reflective light away from the sensor, meaning that the surface can not be perpendicular to the sensor's optical axis. It need to differ with at least 3 degrees compared to the perpendicular angle.

5.2 Touch Applications

The sections below describe integration aspects specific for touch applications and do not concern mid-air applications.

5.2.1 Touch Accuracy

Mechanical integration of zForce AIR Touch Sensor and assembly tolerances has a direct impact on touch accuracy. For this reason relaxed assembly tolerances might in some applications have an impact on the perceived touch performance. The best user experience is achieved when the projected touch Active Area from the zForce AIR Touch Sensor perfectly overlaps the intended touch sensitive area on the host device, for example, the active area on a display.

Touch active area of host system and zForce AIR Touch Sensor needs to be well aligned. Translational tolerances in x and y directions and rotational tolerances will affect accuracy. See Translational Tolerances (see page 33) (x and y direction) and Rotational Tolerances (see page 34) (angle "b").

5.2.2 Hovering Touches

Hovering touch means that the Touch Sensor reports a touch event before the object reaches the surface. The basic principle of the Touch Sensor is that light is sent above the surface. To provide a good user experience the Touch Sensor software adjusts the signal and reports a touch first when the object reaches the surface.

Hovering touches is also direct linked to how the zForce AIR Touch Sensor is integrated in the host system. It's important that the mounting surface has the correct angle compared to the intended touch surface. Twisting and tilting of zForce AIR Touch Sensor should always be avoided. Relaxed tolerances can lead to missed touches and increased hovering. See Translational Tolerances (see page 33) (z direction) and Rotational Tolerances (see page 34) (angle "a").

Furthermore, host system active area surface need to be flat or slightly concave. A convex surface can give false touches.

5.2.3 Assembly Tolerances

Translational Tolerances

Direction	Recommended Tolerances for Touch Applications
x-direction	±0.5 mm
y-direction	±0.5 mm
z-direction	0 mm to +0.5 mm

Translational tolerances affects the overlap between the display active area and the touch active area. For example, if the Touch Sensor is translated 0.5 mm in x-direction there will be a systematic touch offset of 0.5 mm for the complete sensor in x-direction.

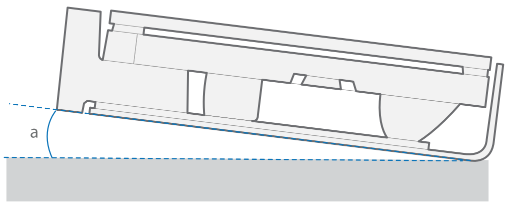
A 0 mm translation in z-direction means that the host system active area surface is positioned exactly at the edge of the light path. A positive translation means that zForce AIR Touch Sensor, and therefore the light path, is translated up from the host system active area surface. This will not affect the touch accuracy in the sensor, but it can affect the perceived touch performance, since it leads to increased hovering. A negative translation in z-direction should be avoided since parts of the light will be blocked which leads to no or reduced touch performance.

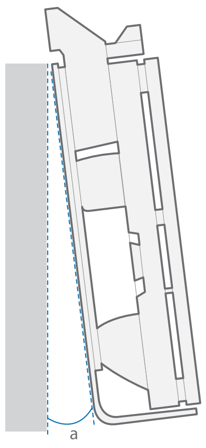
Rotational Tolerances

There are two types of rotations that can affect the performance; defined as the angles "a" and "b". Angle "a" affects the hovering and angle "b" affects the overlap between the intended active area and the Touch Sensor active area. Both these issues will grow with larger display sizes. The angles are exaggerated in the pictures to better illustrate the problem. For any uncertainty regarding rotational tolerances for a specific application, contact Neonode for recommendations.

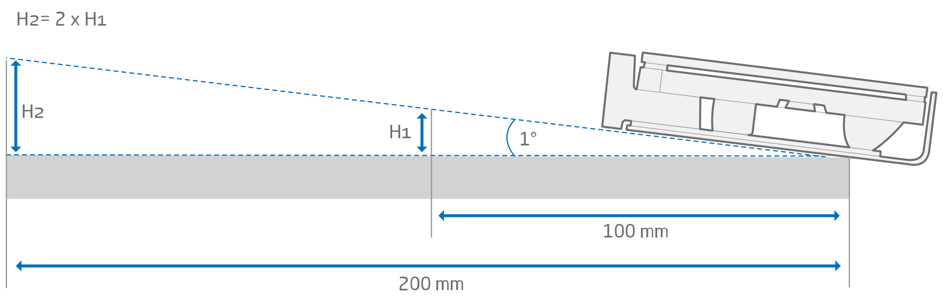
Angle "a"

The angle "a" is defined as shown in the images below.



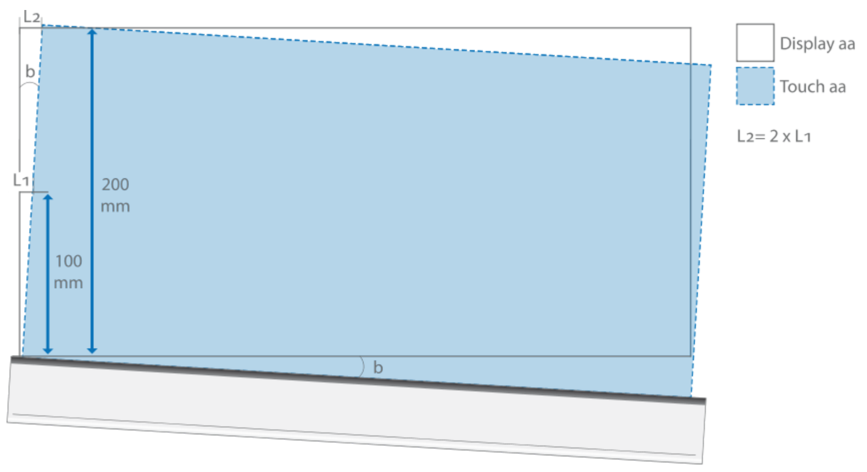


The example below illustrates how the problem increases with larger active areas.



Angle "b"

The angle "b" is defined as shown in the image below. How sensitive zForce AIR Touch Sensor is for assembly rotations is directly linked to the size. At any given angle b, the touch AA will be tilted twice as much at 200 mm compared to at 100 mm.



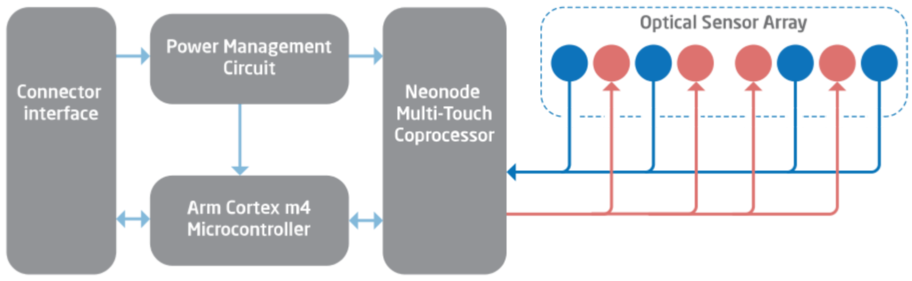
5.3 Models and Drawings

3D-models and 2D-drawings for the zForce AIR Touch Sensor can be downloaded at https://support.neonode.com/docs/display/Downloads.

6 Electrical Integration

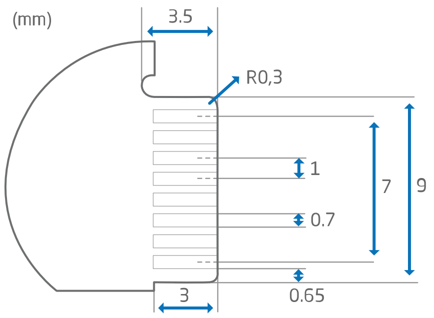
Electrostatic Sensitive Device!
To prevent equipment damage, use proper grounding techniques.

6.1 Electrical Block Diagram



6.2 Physical Connector

The Touch Sensor has 8 contact pads and a PCB outline that matches that of a standard 0.3-0.33 mm thick FFC/FPC with 1 mm pitch and top mounted connectors:



The contact pads are placed on the backside of the Touch Sensor PCBA.

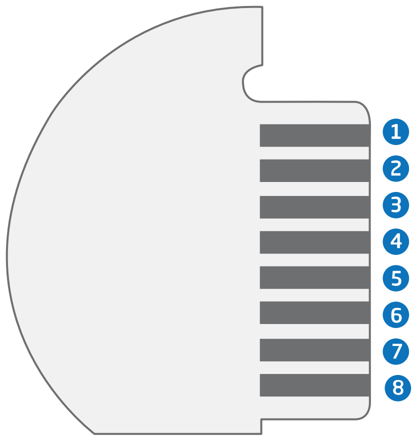
List of supported FFC connectors:

Supplier	**Part number**
Molex[6]	2005290080
Omron Electronic Components[7]	XF3M(1)-0815-1B
Wurth Electronics Inc[8].	686108148922

6 http://www.molex.com/molex/home
7 https://www.components.omron.com/
8 http://www.digikey.com/en/supplier-centers/w/wurth-electronics

Almita Connectors[9]	BL124H-8R-TAND

6.3 Pin-Out



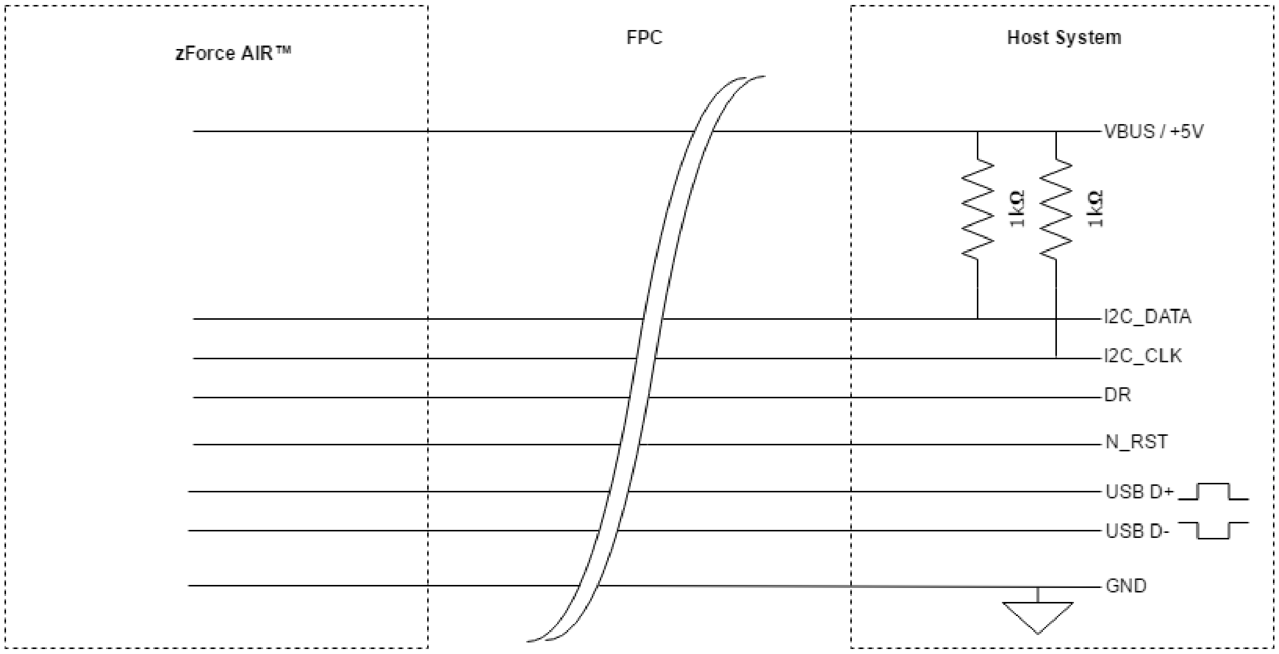
Function	Pin name	Pin No	Direction	Description	Comment
Power ground	GND	1	-	Ground	
Reset	N_RST	2	Input	Resets sensor to initial state. Active low.	A minimum of a 300 ns low pulse is required
Data Ready	DR	3	Output	Indicates that sensor has data to send	Push/pull output. Only used in I2C mode.
I2C Data	I2C_DATA	4	I/O	I2C data line	Requires external pull-up resistor
I2C Clock	I2C_CLK	5	Input	I2C clock line	Requires external pull-up resistor
USB DM	USB D-	6	I/O	USB DM line	USB 2.0 Compliant
USB DP	USB D+	7	I/O	USB DP line	USB 2.0 Compliant
Power supply	+5V	8	-	+5V power supply	USB 2.0 Compliant

Note: All pins use 3.3V voltage level and have 5V tolerance.

9 http://www.almita-connectors.com/

6.4 Interface Configuration

The zForce AIR Touch Sensor provides two interfaces for communication with the host system, I2C and USB HID-device. The user can choose to connect one of them, or both. The typical Touch Sensor connection to a host system is shown in the following diagram:



6.4.1 USB Connection

The zForce AIR Touch Sensor provides a USB full-speed device interface through its 8-pin connector. In this connection, PIN 1, 6, 7, 8 (GND, USB D-, USB D+, VBUS) are used. After connecting the sensor to the host system, it could be enumerated as a normal USB HID-device and act as a digitizer for a touch screen.

In this connection, only the default touch active area size could be used. Please refer to Product Variants (see page 0) for the actual values.

In this case, it is recommended to use two 1kΩ pull-up resistors to tie up I2C_DATA and I2C_CLK pins to VBUS or 3.3V power supply to avoid noise issue on I2C interface, and leave other pins as not connected. PIN 2 (N_RST) could be used to reset or enable/disable the sensor.

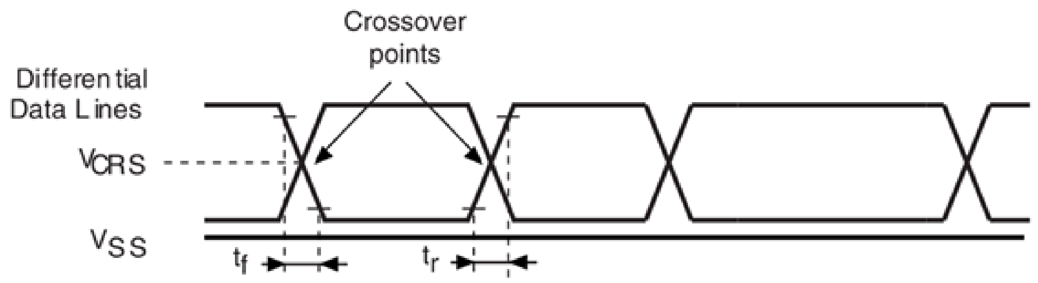
USB Characteristics

The USB interface meets the requirements of USB specifictions 2.0:

Symbol		Parameter	Conditions	Min	Typ	Max	Unit
Input levels	V_{DI}	Diff. Input sensitivity		0.2	-	-	V
	V_{CM}	Diff. common mode range		0.8		2.5	
	V_{SE}	Single ended receiver threshold		1.3		2	
Output levels	V_{OL}	Output level low	1.5kΩ to V_{DD}	-	-	0.3	
	V_{OH}	Output level high	15kΩ to V_{SS}	2.8	-	3.6	
R_{PD}		D+/D-	V_{IN}=V_{DD}	17	21	24	kΩ
R_{PU}		D+/D-	V_{IN}=V_{SS}	1.5	1.8	2.1	

USB full speed timings: the definitions of data signal rise and fall time are presented in the following table and figure:

Driver characteristcs				
Symbol	**Parameter**	**Conditions**	**Min**	**Max**
t_r	Rise time	C_L = 50pF	4	20
t_f	Fall time	C_L = 50pF	4	20
t_{rfm}	Rise/fall time matching	t_r/t_f	90	110
V_{CRS}	Output signal crossover		1.3	2



6.4.2 I2C Connection

The zForce AIR Touch Sensor provides an I2C interface through its 8-pin connector. The interface runs in fast mode, which means the speed is 400kbps. With this interface, more advanced configuration could be performed. PIN 1, 3, 4, 5, 8 (GND, DR, I2C_DATA, I2C_CLK, VBUS) are used for this connection. It is recommended to use two 1kΩ pull-up resistors to tie up I2C_DATA and I2C_CLK pins to VBUS or 3.3V power supply to perform proper I2C communication. If USB connection is not used in parallel, PIN 6, 7 (USB D-, USB D+) could be left unconnected.

After the Touch Sensor is powered on, it will act as a slave device on a I2C bus. For further information about what commands could be send or receive through this interface, please refer to I2C Transport (see page 63).

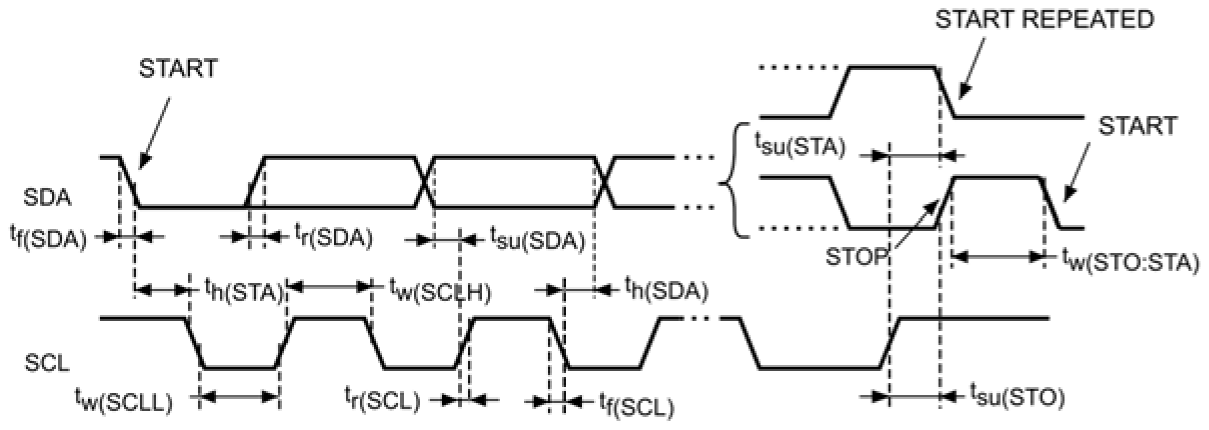
I2C Characteristics

The I2C interface meets the requirements of the standard I2C communication protocol with the following restrictions: SDA and SCL are mapped to I/O pins that are not "true" open-drain. When configured as open-drain, the PMOS connected between the I/O pin and VDD is disabled, but is still present.

The I2C characteristics are described in the following table:

Symbol	Parameter	Min	Max	Unit
$t_{w(SCLL)}$	SCL clock low time	4.7	-	us
$t_{w(SCLH)}$	SCL clock high time	4.0	-	
$t_{su(SDA)}$	SDA setup time	250	-	ns
$t_{h(SDA)}$	SDA data hold time	0	-	
$t_{r(SDA)}$	SDA and SCL rise time	-	1000	
$t_{r(SCL)}$				
$t_{f(SDA)}$	SDA and SCL fall time		300	
$t_{f(SCL)}$				
$t_{h(STA)}$	Start condition hold time	4.0	-	us
$t_{su(STA)}$	Repeated Start condition setup time	4.7	-	
$t_{su(STO)}$	Stop condition setup time	4.0	-	
$t_{w(STO:STA)}$	Stop to Start condition time (bus free	4.7	-	

Symbol	Parameter	Min	Max	Unit
t_{SP}	Pulse width of the spikes that are suppressed by the analog filter	0	50	ns
C_{load}	Capacitive load for each bus line	-	400	pF
V_{IL}	Input low level voltage		0.8	V
V_{IH}	Input high level voltage	2.3		V
V_{OL}	Output low level voltage		0.4	V
V_{OH}	Output high level voltage	2.9		V



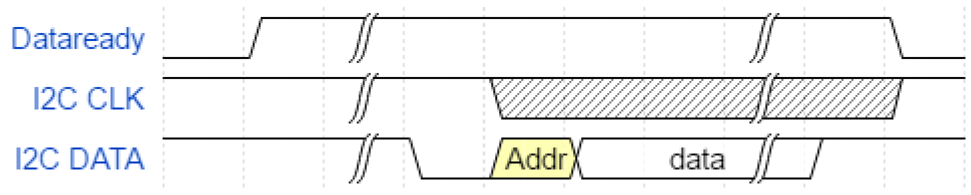
PIN 3 (DR) Characteristics

PIN 3 is used as signal output for DataReady (DR). The DataReady signal is only used in I2C communication.

The sensor can only act as an I2C slave, therefore this pin is needed to notify the host to read the data in the output buffer of the sensor:

- PIN 3 is set to high (1) when there is data in the buffer to be sent from the sensor.
- PIN 3 is reset to low (0) when there is no data in the buffer to be sent from the sensor.

PIN 3 can be used as an interrupt input or it can be read repeatedly by the host. When the pin is set to high, the FW will wait for the host to read data from the I2C bus. When the read transaction is finished, this DataReady signal will be reset automatically by the zForce AIR Touch Sensor. The following figure shows the timing behavior of a typical I2C transaction:



I2C Reading Sequence

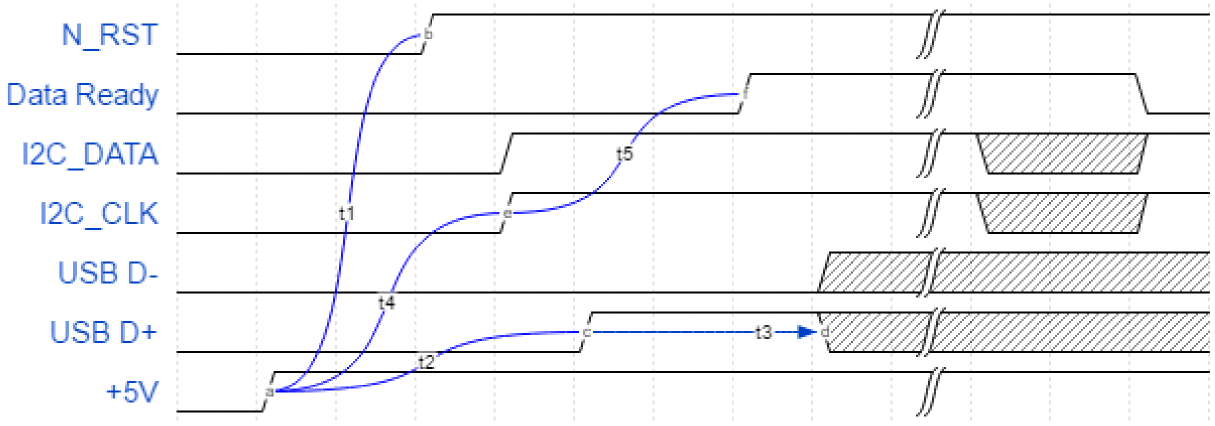
See I2C Transport (see page 63).

6.5 Power On and Boot Sequence

Power on timing latency are listed in the following table:

Name	Min	Typ.	Max	Unit	Comment
t1	-	15	20	ms	Delay time from power on to NRST to high voltage.
t2	-	60	70	ms	Delay time from power on to USB pins voltage ready.
t3	-	170	-	ms	Delay time from USB init ready to sending/receiving data.
t4	5	7	10	ms	Delay time from power on to I2C pins voltage ready.
t5	65	70	80	ms	Delay time from I2C pins voltage ready to triggering boot complete packet request.

The power on sequence is shown in the following figure.



7 Software Integration

7.1 Communication Protocol

zForce AIR Touch Sensors can communicate with a host system through USB HID transport or I2C transport. The structure of the communicated data is defined in ASN.1 notation and encoded using a defined set of encoding rules. For more information, refer to zForce Communication Protocol (see page 44).

7.1.1 Preparing the Sensor for Communication

When using the USB Raw HID interface or the I2C interface, the sensor must be prepared for communication before it can receive messages. Refer to Preparing the Sensor for Communication (see page 43).

7.2 Available Function Libraries

Neonode has developed the following function libraries to facilitate integration of the sensor:

- **The zForce Software Development Kit (SDK)** is a complete function library for communication via the USB HID interface. The SDK allows the user to communicate with the sensor via USB without deciphering the serialized ASN.1-messages. Read more under the separate SDK documentation.[10]
- **The zForce AIR interface library for Arduino** is a function library for communication via the I2C interface. This library is primitive, but the I2C read and write functions are public, so the user can receive sensor messages and send any information, that is correctly encoded, to the sensor. Refer to zForce AIR interface library for Arduino (see page 88).

7.3 Preparing the Sensor for Communication

The following procedures are required to prepare a sensor for communication with I2C or USB Raw HID mode.

7.3.1 USB Raw HID Mode

The sensor has a setting called operation mode, that determines which data will be sent to the host. When communicating over USB there are two different operation modes that deliver touch data, called detection mode and detection mode HID. By default the sensor is set in the operation mode called detection mode HID. This mode delivers touch data to the operating system according to the HID standard for touch screen devices. In order for the host to receive touch data that is serialized according to Neonode's ASN.1 serialization protocol, the operation mode has to be set to detection mode. In other words, setting the operation mode to detection mode allows the host to receive touch data over USB Raw HID mode.

Do the following procedure to prepare the sensor over USB Raw HID mode.

1. Power on the sensor.
2. Wait for the OS to enumerate the device and then enumerate the sensor in your application. Depending on which operating system that is used, the application might need permission from the operating system to access the device.
3. Set the sensor to the correct operation mode (detection mode) by sending a Feature Report with report id 1.
4. Wait for the sensor to signal that there is data to read. This comes as an Input Report 2 or you can poll Feature Report with id 2 for new data.

[10] https://support.neonode.com/docs/pages/viewpage.action?pageId=9375245

5. Read the response data from Feature Report with id 2. The data that is read reflects the current setting in the sensor.

The sensor is now ready to communicate. After the procedure, the sensor is enabled by default and will start sending ASN.1 serialized touch notifications. To disable the touch notifications, a Disable request must be sent. Refer to zForce Message Specification (see page 65) for examples of requests, responses and notifications.

For further details on how to communicate with the sensor over Feature Report 1 and 2 refer to USB HID Transport (see page 48).

7.3.2 I2C

Use the following procedure to prepare the sensor over I2C.

1. Power on the sensor.
2. Wait for sensor to assert Data Ready pin (DR).
3. Initiate 2 byte I2C read operation. Payload of this read should be EE XX where XX is the amount of bytes to read in a second I2C read operation.
4. Read XX amount of bytes (number of bytes to read is indicated by second byte of first I2C Read Operation). Now read a message called BootComplete. The message should be

   ```
   F0 11 40 02 00 00 63 0B 80 01 YY 81 02 03 YY 82 02 00 YY
   ```

   where YY is usually "00" but can have another value. This signals that the sensor is now booted.
5. To enable the sensor to start sending touch notifications, do the following:
   a. Send an Enable command:

      ```
      EE 09 40 02 02 00 65 03 81 01 00
      ```

   b. Read the response. The response should be:

      ```
      EF 09 40 02 02 00 65 03 81 01 00
      ```

The sensor is now ready to communicate. When DR is asserted the sensor will send a touch notification or a new BootComplete. A BootComplete indicates that the sensor has restarted for some reason; Enable must then be set again. For more details, refer to I2C Transport (see page 63).

7.4 zForce Communication Protocol

To communicate with the zForce AIR Touch Sensor, you need two things: to send/receive messages and to encode/decode the messages.

The sending and receiving can be done in one of the following ways:

- **USB HID Touch Digitizer**: the sensor can be used as a standard HID Touch Digitizer to report touch data to the OS.
- **USB RAW HID**: The sensor uses HID Get and Set Feature Reports as a pipe to read and write. For more information, refer to USB HID Transport (see page 48)
- **I2C transport**: The sensor has support for I2C communication with an extra pin for signaling when data is ready to be read, which allows the host system to be interrupt driven. The sensor takes the role of an I2C slave and has the I2C address 0x50. For more information, refer to I2C Transport (see page 63).

For the encoding/decoding, you need to understand the structure of the messages and the protocol that is used to serialize them:

The structure of the zForce AIR messages is defined in ASN.1 notation. ASN.1 is a standardized way (ISO/IEC 8824) to describe data regardless of language implementation, hardware system and operation system. For more information, refer to zForce Message Specification (see page 65).

The zForce communication protocol uses the Distinguished Encoding Rules (DER) to serialize messages. For more information, refer to Understanding the zForce ASN1 Protocol (see page 77).

7.4.1 Serialization Protocol Quick Start

The zForce AIR Touch Sensor communicates with messages that are serialized according to the zForce serialization protocol. Here is a quick introduction to the messages you need to send to get started and also how you interpret received messages.

Encoding Integers

ASN.1 encoded integers, for example values representing scanning frequency or touch active area size, are represented by one or more bytes:

- If the integer is between 0 and 127, it is represented by one byte (`00` to `7F`).
- If the integer is between 128 and 32767, it is represented by two bytes (`00 80` to `7F FF`).

The length of the message therefore varies depending on parameter values.

Enabling Sensors

Do the following to enable a sensor, that is, tell a sensor to start sending touch notifications.

1. Enable the sensor by sending a request with an Enable command:

   ```
   EE 09 40 02 02 00 65 03 81 01 00
   ```

   This enables the sensor to send touch notifications.
2. Read the response. The response should be:

   ```
   EF 09 40 02 02 00 65 03 81 01 00
   ```

3. After this, wait for the sensor to indicate it has something to send, which means that the device will send a Touch Notification or a BootComplete. A BootComplete indicates that the device has restarted for some reason, so rerun the initialization and enable the sensor to start receiving touch notifications again.

Disabling Sensors

Do the following to disable a sensor, that is, tell a sensor to stop sending touch notifications.

1. Disable the sensor by sending a request with the following command:

```
EE 08 40 02 02 00 65 02 80 00
```

This disables the sensor to send touch notifications.

2. Read the response. The response should be:

```
EF 08 40 02 02 00 65 02 80 00
```

Device Configuration

Device configuration is a command that includes different settings for the sensor, for example the Touch Active Area. When sending a device configuration message, all of the settings specified are not required to be sent, however the response from the sensor will include the full device configuration message.

This is an example message that changes the touch active area using the Device Configuration command:

```
EE 1A 40 02 02 00 73 14 A2 12 80 02 00 B5 81 01 43 82 02 06 98 83 02 04 34 85 01 FF
```

The message is explained in the table below:

Part	Description
`EE 1A`	ID for request followed by length of total payload (0x1A = 26 bytes)
`40 02 02 00`	Device address (always the same for the zForce AIR Touch Sensor)
`73 14`	ID for Device Configuration followed by the length of the total Device Configuration payload (20 bytes)
`A2 12`	ID for Sub Touch Active Area followed by the length of Sub Touch Active Area payload
`80 02 00 B5`	ID for xMin followed by payload length and an integer value (0x00B5 = 181)
`81 01 43`	ID for yMin followed by payload length and an integer value (0x43 = 67)
`82 02 06 98`	ID for xMax followed by payload length and an integer value (0x0698 = 1688)
`83 02 04 34`	ID for yMax followed by payload length and an integer value (0x0434 = 1076)
`85 01 FF`	ID for "Invert y axis" followed by length of payload and a Boolean (0xFF= True)

The response from the sensor to the above message will contain the full device configuration message, also the parts not set in the request.

Setting the Touch Active Area should be done before enabling the sensor with the ENABLE request.

Reflective Edge Filter

In the Device Configuration command there is something called Reflective Edge filter (from firmware version 1.45 and later). This setting is useful if there is a highly reflective material, right outside of the Touch Active Area. If such conditions are present, enabling this feature could increase the touch performance.

Command to Enable Reflective Edge Filter

```
EE 09 40 02 02 00 73 03 85 01 80
```

Command to Disable Reflective Edge Filter

```
EE 09 40 02 02 00 73 03 85 01 00
```

Setting Frequency

To set the finger frequency to 200 Hz and idle frequency to 63 Hz use a request with the following command:

```
EE 0D 40 02 00 00 68 07 80 02 00 C8 82 01 3F
```

ⓘ The zForce AIR Touch Sensor does not support Stylus mode, and setting the stylus frequency does not do anything.

Decoding Touch Notifications

A packet can contain from one up to 10 touches, and optionally a timestamp. On packets where the timestamp is not included, the 58 02 TT TT bytes are missing from the end and the length bytes are adjusted accordingly, For One touch (below), F0 15 in the beginning will be F0 11 and A0 0F in the middle will be A0 0B. The same bytes are decreased by 4 for Two and Three touches.

One Touch

A packet that contains one touch will look like:

```
F0 15 40 02 02 00 A0 0F 42 09 II VV XX XX YY YY GG HH JJ 58 02 TT TT
```

where the data is defined as follows:

Syntax	Meaning
II	ID of this specific touch object. More than one can be tracked simultaneously.

Syntax	Meaning
VV	Event: 00 = DOWN (new object). 01 = MOVE (existing object has moved). 02 = UP (existing object is no longer being tracked).
XX XX	X Coordinate of the object. This is in Network Byte Order / Big Endian / Motorola Endian.
YY YY	Y Coordinate of the object. See above.
GG	Size of object on the X Axis.
HH	Size of object on the Y Axis.
JJ	This value must be ignored.
TT TT	Timestamp of the touch.

Two Touches

A packet that contains two Touches will look like:

```
F0 20 40 02 02 00 A0 1A 42 09 II VV XX XX YY YY GG HH JJ 42 09 II VV XX XX YY YY GG
HH JJ 58 02 TT TT
```

where the first "II" and the following bytes up to and including "JJ" are from the first touch, and the second "II" and the following bytes up to and including "JJ" are from the second touch.

Three Touches

A packet that contains three Touches will look like:

```
F0 2B 40 02 02 00 A0 25 42 09 II VV XX XX YY YY GG HH JJ 42 09 II VV XX XX YY YY GG
HH JJ 42 09 II VV XX XX YY YY GG HH JJ 58 02 TT TT
```

For a more thorough explanation of the serialization protocol, refer to Understanding the zForce ASN.1 Serialization Protocol (see page 77).

7.4.2 USB HID Transport

When connected via USB, the sensor communicates in Full Speed (12 Mbit/s) in two modes: Raw HID mode (also called HID Pipe) and HID Touch Digitizer mode. HID Touch Digitizer mode is initiated automatically as soon as the sensor is plugged in. In order to use Raw HID mode, the sensor's operation mode must be changed. For more information, refer to Preparing the Sensor for Communication (see page 43).

HID Touch Digitizer Mode

The sensor acts as a HID Input device and communicates directly with the OS, and is completely plug and play.

Ubuntu 17.10 - 18.04
The sensor is not recognized as a touch screen in the Ubuntu versions 17.10 - 18.04. This has been fixed and works fine in Ubuntu 18.10.

Raw HID Mode / HID Pipe

This mode uses two HID Feature Reports to communicate with the host.

- Send data to the sensor by writing to Feature Report 1.
- Read data from the sensor by reading from Feature Report 2.

Refer to zForce Message Specification (see page 65) for examples of requests, responses and notifications.

USB Communication in Different Operating Systems

Depending on the system and programming language you are using to write and read from a feature report, the implementation differs. For example, in Windows, this is abstracted and the hid.dll offers a function to get and set feature reports, while in for example a UNIX based OS, you might have to implement your own function to get and set a feature report.

The **communication** heading below describes how to implement your own get and set feature report functions, using a control transfer.

USB Permission
Depending on operating system you might need explicit permission for your program to have access to the HID device.

How to Implement Custom Functions for Raw HID Communication

In order to communicate with the sensor the data flow type called *control transfer* should be used. The control transfer usually takes the following parameters:

- Request Type (*int)*
- Request (*int)*
- Value (*int)*
- Index (*int)*
- Data (*byte array)*
- Length (*int)*
- Timeout (*int)*

Writing to Feature Report 1

When writing to the sensor a full 257 bytes need to be sent, no matter how long the actual message is. Take a look at the code snippet below, to see how this could be done.

```
uint8_t operationMode[] = { 0x01, 0x17, 0xEE, 0x15, 0x40, 0x02, 0x02, 0x00,
                                                        0x67, 0x0F, 0x80, 0x01, 0xFF,
0x81, 0x01, 0x00,
                                                        0x82, 0x01, 0x00, 0x83, 0x01,
0x00, 0x84, 0x01, 0x00 }; // The first two bytes are the header. First byte is
feature report, second byte is length of the following data.
uint8_t data[257];
memcpy(data, operationMode, sizeof(operationMode));

int requestType = 0x00 | (0x01 << 5) | 0x01; // USB_HOST_TO_DEVICE | USB_TYPE_CLASS |
USB_RECIPIENT_INTERFACE
int request = 0x09; // SET_CONFIGURATION = 0x09
int value = 0x0301; // 0x03 for feature report, 0x01 for feature report 1
int index = 0x0000;
int length = sizeof(data);
int timeout = 0;

 connection.controlTransfer(
            requestType,
            request,
            value,
            index, data, length, timeout);
```

Reading from Feature Report 2

When reading from feature report 2, the message is always 258 bytes long.

```
uint8_t data[258];

int requestType = 0x80 | (0x01 << 5) | 0x01; // USB_DEVICE_TO_HOST | USB_TYPE_CLASS |
USB_RECIPIENT_INTERFACE
int request = 0x01; // CLEAR_FEATURE = 0x01
int value = 0x0302; // 0x03 for feature report, 0x02 for feature report 2
int index = 0x0000;
int length = sizeof(data);
int timeout = 0;

connection.controlTransfer(
            requestType,
            request,
            value,
            index, data, length, timeout);
```

HID Report Descriptor (click to expand)

HID Report Descriptor

ⓘ The HID Report Descriptor is subject to change. The descriptor below is from firmware version 1.47.

Item	Data
Usage Page (Digitizer)	05 0D
Usage (Touch Screen)	09 04
Collection (Application)	A1 01
Report ID (4)	85 04
Usage (Contact Count Maximum)	09 55
Logical Minimum (0)	15 00
Logical Maximum (-1)	25 FF
Report Size (8)	75 08
Report Count (1)	95 01
Feature (Data,Var,Abs,NWrp,Lin,Pref,NNul,NVol,Bit)	B1 02
Report ID (3)	85 03
Usage (Contact Count)	09 54
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Scan Time)	09 56
Logical Maximum (65535)	27 FF FF 00 00
Report Size (16)	75 10
Unit Exponent (-4)	55 0C
Unit (SI Lin: Time (s))	66 01 10
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Finger)	09 22
Collection (Logical)	A1 02
Usage (Tip Switch)	09 42
Logical Maximum (1)	25 01
Report Size (1)	75 01

Item	Data
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Contact Identifier)	09 51
Logical Maximum (127)	25 7F
Report Size (7)	75 07
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Generic Desktop)	05 01
Usage (X)	09 30
Logical Maximum (65535)	27 FF FF 00 00
Report Size (16)	75 10
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Y)	09 31
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Digitizer)	05 0D
Unit Exponent (-2)	55 0E
Unit (SI Lin: Length (cm))	65 11
Usage (Width)	09 48
Usage (Height)	09 49
Report Count (2)	95 02
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
End Collection	C0
Usage (Finger)	09 22

Item	Data
Collection (Logical)	A1 02
Usage (Tip Switch)	09 42
Logical Maximum (1)	25 01
Report Size (1)	75 01
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Contact Identifier)	09 51
Logical Maximum (127)	25 7F
Report Size (7)	75 07
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Generic Desktop)	05 01
Usage (X)	09 30
Logical Maximum (65535)	27 FF FF 00 00
Report Size (16)	75 10
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Y)	09 31
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Digitizer)	05 0D
Unit Exponent (-2)	55 0E
Unit (SI Lin: Length (cm))	65 11
Usage (Width)	09 48
Usage (Height)	09 49

Item	Data
Report Count (2)	95 02
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
End Collection	C0
Usage (Finger)	09 22
Collection (Logical)	A1 02
Usage (Tip Switch)	09 42
Logical Maximum (1)	25 01
Report Size (1)	75 01
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Contact Identifier)	09 51
Logical Maximum (127)	25 7F
Report Size (7)	75 07
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Generic Desktop)	05 01
Usage (X)	09 30
Logical Maximum (65535)	27 FF FF 00 00
Report Size (16)	75 10
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Y)	09 31
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Digitizer)	05 0D

Item	Data
Unit Exponent (-2)	55 0E
Unit (SI Lin: Length (cm))	65 11
Usage (Width)	09 48
Usage (Height)	09 49
Report Count (2)	95 02
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
End Collection	C0
Usage (Finger)	09 22
Collection (Logical)	A1 02
Usage (Tip Switch)	09 42
Logical Maximum (1)	25 01
Report Size (1)	75 01
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Contact Identifier)	09 51
Logical Maximum (127)	25 7F
Report Size (7)	75 07
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Generic Desktop)	05 01
Usage (X)	09 30
Logical Maximum (65535)	27 FF FF 00 00
Report Size (16)	75 10
Report Count (1)	95 01

Item	Data
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Y)	09 31
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Digitizer)	05 0D
Unit Exponent (-2)	55 0E
Unit (SI Lin: Length (cm))	65 11
Usage (Width)	09 48
Usage (Height)	09 49
Report Count (2)	95 02
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
End Collection	C0
Usage (Finger)	09 22
Collection (Logical)	A1 02
Usage (Tip Switch)	09 42
Logical Maximum (1)	25 01
Report Size (1)	75 01
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Contact Identifier)	09 51
Logical Maximum (127)	25 7F
Report Size (7)	75 07
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Generic Desktop)	05 01

Item	Data
Usage (X)	09 30
Logical Maximum (65535)	27 FF FF 00 00
Report Size (16)	75 10
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Y)	09 31
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Digitizer)	05 0D
Unit Exponent (-2)	55 0E
Unit (SI Lin: Length (cm))	65 11
Usage (Width)	09 48
Usage (Height)	09 49
Report Count (2)	95 02
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
End Collection	C0
Usage (Finger)	09 22
Collection (Logical)	A1 02
Usage (Tip Switch)	09 42
Logical Maximum (1)	25 01
Report Size (1)	75 01
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Contact Identifier)	09 51
Logical Maximum (127)	25 7F

Item	Data
Report Size (7)	75 07
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Generic Desktop)	05 01
Usage (X)	09 30
Logical Maximum (65535)	27 FF FF 00 00
Report Size (16)	75 10
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage (Y)	09 31
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Usage Page (Digitizer)	05 0D
Unit Exponent (-2)	55 0E
Unit (SI Lin: Length (cm))	65 11
Usage (Width)	09 48
Usage (Height)	09 49
Report Count (2)	95 02
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
End Collection	C0
End Collection	C0
Usage Page (Vendor-Defined 1)	06 00 FF
Usage (Vendor-Defined 1)	09 01
Collection (Application)	A1 01
Report ID (1)	85 01

Item	Data
Usage (Vendor-Defined 1)	09 01
Report Size (8)	75 08
Report Count (1)	95 01
Logical Minimum (0)	15 00
Logical Maximum (-1)	25 FF
Feature (Data,Var,Abs,NWrp,Lin,Pref,NNul,NVol,Bit)	B1 02
Usage (Vendor-Defined 2)	09 02
Report Count (255)	95 FF
Feature (Data,Var,Abs,NWrp,Lin,Pref,NNul,Vol,Buf)	B2 82 01
Report ID (2)	85 02
Usage (Vendor-Defined 1)	09 01
Report Count (1)	95 01
Feature (Data,Var,Abs,NWrp,Lin,Pref,NNul,NVol,Bit)	B1 02
Usage (Vendor-Defined 2)	09 02
Report Count (255)	95 FF
Feature (Data,Var,Abs,NWrp,Lin,Pref,NNul,Vol,Buf)	B2 82 01
Usage (Vendor-Defined 3)	09 03
Report Size (1)	75 01
Logical Maximum (1)	25 01
Report Count (1)	95 01
Input (Data,Var,Abs,NWrp,Lin,Pref,NNul,Bit)	81 02
Report Size (7)	75 07
Input (Cnst,Ary,Abs)	81 01
Report Size (8)	75 08

Item	Data
Report ID (128)	85 80
Usage (Vendor-Defined 1)	09 01
Feature (Cnst,Var,Abs,NWrp,Lin,Pref,NNul,NVol,Bit)	B1 03
Report ID (130)	85 82
Usage (Vendor-Defined 1)	09 01
Feature (Cnst,Var,Abs,NWrp,Lin,Pref,NNul,NVol,Bit)	B1 03
End Collection	C0

Parsed reports by Report ID

Input Report 2		
Bit offset	**Bit count**	**Description**
0	1	Internal use
1	7	(Not used)
Input Report 3		
Bit offset	**Bit count**	**Description**
0	8	Contact count
8	16	Scan Time
24	1	Tip Switch
25	7	Contact identifier
32	16	X
48	16	Y
64	16	Width
80	16	Height
96	1	Tip Switch
97	7	Contact identifier

104	16	X
120	16	Y
136	16	Width
152	16	Height
168	1	Tip Switch
169	7	Contact identifier
176	16	X
192	16	Y
208	16	Width
224	16	Height
240	1	Tip Switch
241	7	Contact identifier
248	16	X
264	16	Y
280	16	Width
296	16	Height
312	1	Tip Switch
313	7	Contact identifier
320	16	X
336	16	Y
352	16	Width
368	16	Height
384	1	Tip Switch
385	7	Contact identifier
392	16	X

408	16	Y
424	16	Width
440	16	Height
Feature Report 1 - Write		
Bit offset	**Bit count**	**Description**
0	8	Payload size (bytes)
8	2040	Payload
Feature Report 2 - Read		
Bit offset	**Bit count**	**Description**
0	8	Payload size (bytes)
8	2040	Payload
Feature Report 4		
Bit offset	**Bit count**	**Description**
0	8	Contact count maximum
Feature Report 128		
Bit offset	**Bit count**	**Description**
0	8	Internal use
Feature Report 130		
Bit offset	**Bit count**	**Description**
0	8	Internal use

7.4.3 I2C Transport

Introduction

Each I2C bus consists of two lines (signals): a clock line (SCL) and a data line (SDA). The devices on the I2C bus are either masters or slaves. The master is always the device that drives the clock line. The slaves are the devices that respond to the master. Only the master can initiate a transfer over the I2C bus. Each slave has a unique address.

All bytes in this section are written in hexadecimal form, if not indicated otherwise.

The sensor does not communicate using registers or memory accesses, so the documentation for the STM32 microcontrollers is not applicable.

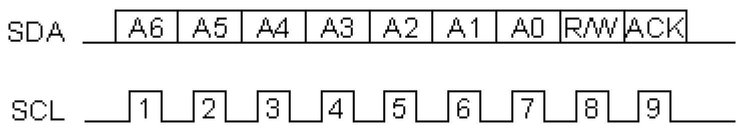
The DataReady signal

The zForce AIR sensor uses a signal called DataReady (DR) to inform the host that there is data to read and that a read operation can be initialized. Refer to Electrical Integration (see page 41) for more information.

Sensor Address

The slave I2C address of the sensor is 0x50 (7 bit). The address itself consists of 7 bits but 8 bits are always sent. The extra bit informs the slave if the master is reading from or writing to it. If the bit is 0 the master is writing to the slave. If the bit is 1 the master is reading from the slave.

The resulting address bytes are 0xA1 (read) and 0xA0 (write).



Syntax

The I2C Transport Protocol is simple and the syntax is identical in both directions (read or write):

Byte number	**1**	**2**	**3 to n**
Description	FrameStart, a constant. The value is always EE.	DataSize, the number of bytes in the payload. Datasize >= 1.	Payload (serialized ASN.1 message).

Examples:

1. The payload is 8 bytes long. The transmission reads:

```
EE 08 [payload]
```

2. The payload is 25 bytes long. The transmission reads:

```
EE 19 [payload]
```

Sending Data

To send data to the sensor, the host initiates a write operation for the sensor's address and writes the full payload.

(Do not confuse the I2C FrameStart constant with the type byte that indicates that a serialized message is a request. The value is EE for both bytes, but the meaning is completely different.)

Example: Sending a request with an ENABLE command to the sensor:

```
EE 0B EE 09 40 02 02 00 65 03 81 01 00
```

⚠ **DataReady**
If the sensor signals DataReady, it is NOT permitted to initiate an I2C write operation as the sensor is waiting for the host to initiate a read operation.
Always wait for the corresponding response from one command before sending another command. Note that not all commands have a response command. If there is no corresponding response command, the host is free to issue another command.

Receiving Data

The sensor triggers the DataReady signal when there is data for the host to receive. To maximize the performance and minimize the load on the I2C bus, the host is expected to read data in a certain sequence:

1. The sensor asserts DataReady
2. The host initiates a two bytes I2C read operation for the I2C 7-bit address 0x50.
3. The sensor fills in the first two bytes, FrameStart and DataSize.
4. The host initiates an I2C read operation for address 0x50 and reads XX bytes (as indicated by DataSize).
5. The sensor deasserts DataReady.

BootComplete

When the sensor has finished booting, and hardware such as the I2C module have been configured, the command BootComplete is put into the send queue. The DataReady signal is triggered and the host needs to read the data to acknowledge that the sensor is ready to operate. If the sensor powers on before the host system does, the host system needs to check if the DataReady signal is active, in which case it needs to read the data.

⚠ Do not send any commands to the sensor before BootComplete has been read.

7.4.4 zForce Message Specification

Definition and Encoding

The message structure that is used in the zForce communication protocol is defined in the zForce PDU definition file. PDU stands for Protocol Data Unit, the specific block of information that is going to be transferred. The definition is written according to Abstract Syntax Notation One (ASN.1), a standardized way to describe data regardless of language implementation, hardware system and operation system (ISO/IEC 8824).

To get the message data format used for information transfer, a set of encoding rules are applied to the ASN.1 definitions. The zForce communication protocol uses the Distinguished Encoding Rules (DER) to serialize the information that is going to be transferred. For more information, refer to Understanding the zForce ASN.1 Serialization Protocol (see page 77).

ASN.1 defines a number of universal types, from which all other types inherit traits. The result is that a set of encoding rules that covers the universal types can serialize any PDU, as long as the identifier numbers and the definition categories are available. The identifier numbers and definition categories for the zForce PDU are included in the PDU definition file.

Downloading the definition file

Download the zForce® PDU definition file from https://support.neonode.com/docs/display/Downloads/Communication+Protocol+Downloads.

The zForce message

The communication protocol uses three types of messages:

- Requests
- Responses
- Notifications

The host sends a request to the sensor, and the device responds with a response. The device may send notifications to the host at any time.

All messages contain a virtual device address. Virtual devices are functionally isolated from each other, and communicate separately with the host. There are two types of virtual devices:

- Platform – represents the system.
- Air – represents one zForce touch sensor.

A sensor will always contain one platform virtual device and can contain any number of instances of other virtual device types.

In the definition file, all sensor messages are described as instances of the top level PDU `ProtocolMessage` which have three child PDUs:

PDU	Content	Explanation
Request	deviceAddress	Specifies the virtual device within the sensor that receives the request.
	command	The command specifies what is being requested.

PDU	Content	Explanation
Response	deviceAddress	Specifies the virtual device within the sensor that sends the response.
	command	The command contains the result or requested information of the request.
Notification	deviceAddress	Specifies the virtual device within the sensor that sends the notification.
	notificationMessage	The message from the sensor to the host.
	notificationTimestamp (optional)	Timestamp.

PDU Description in GSER Notation

The PDU specifies the following message specification templates, notifications and pairs of requests and responses:

-
    - Application Interface (see page 67)
    - Device Information (see page 68)
    - Device Count (see page 69)
    - Frequency (see page 69)
    - Touch Sensor (see page 70)
    - Operation Mode (see page 70)
    - Touch Format (see page 71)
    - Enable Execution (see page 73)
    - Touch Notifications (see page 74)
    - Information (see page 74)
    - Configuration (see page 75)

The messages described here are encoded using the man-readable Generic String Encoding Rules (GSER), as the messages encoded according to DER can be difficult to read for a human.

A short introduction to the GSER notation:

- Sequences and/or sets (items containing sub items) are shown as curly brackets: **{ <sub elements> }**
- Values encoded as octet strings are written as hexadecimal octets enclosed within single quotes and suffixed with H: **'FF9900'H**
- Bit strings are also shown as octet strings when the number of bits is a multiple of 8, otherwise each bit is shown as a single 1 or 0, and suffixed with B: **'11010101001'B**
- In a choice element, the selected type is denoted by its name followed by a colon: **request:**

Refer to Generic String Encoding Rules (GSER) for ASN.1 Types[11] for a full reference.

The tool FFASN1Dump[12] can transcode from GSER to DER:

11 https://tools.ietf.org/html/rfc3641#page-6
12 http://www.bellard.org/ffasn1/

```
ffasn1dump -I gser -O der zforce_pdu_def.asn ProtocolMessage <input file> <output
file>
```

Currently ffasn1dump does not handle identifiers for Integer values. For this reason, they need to be replaced with numerical values.

Application Interface

The application interface specifies what requests can be made and what responses and notifications they activate. Messages are specified according to the following templates:

request

```
request: {
  deviceAddress <address>,
  <request command>
}
```

response

```
response: {
  deviceAddress <address>,
  <command response>
}
```

notification

```
notification: {
  deviceAddress <address>,
  <notification>
  notificationTimestamp <timestamp>
}
```

Where

- Address is an octet string with 2 octets, device type and index: '<device type><index>'H. The available device types are:

Device type	Device
0	Platform
1	Core

Device type	Device
2	Air
3	Plus
4	Lightning

Example: ‘0000’H for platform (there can be only one platform device per sensor system).

- Timestamp is an integer representing int16 counting at 32768 Hz.

Device Information

The deviceInformation command fetches for example the product id and the FW version. What information that is available differs depending on the type of device. The following example shows a response from a platform device.

request command

```
deviceInformation {
}
```

command response

```
deviceInformation {
  platformInformation {
    platformVersionMajor 7,
    platformVersionMinor 0,
    protocolVersionMajor 1,
    protocolVersionMinor 5,
    firmwareVersionMajor 1,
    firmwareVersionMinor 0,
    hardwareIdentifier "Demo board",
    hardwareVersion "R2",
    asicType nn1002,
    numberOfAsics 1,
    mcuUniqueIdentifier '340038000E51333439333633'H,
    projectReference "DEMO_1.0_REL",
    platformReference "734cebd",
    buildTime "16:01:14",
    buildDate "2016-07-01"
      }
}
```

The fields have the following meaning:

- platformVersion: FW platform version, version 7.0 in the example.
- protocolVersion: communication protocol version, version 1.5 in the example.

- firmwareVersion: product FW version, version 1.0 in the example.
- hardware: product hardware, configuration and revision.
- asicType: which type of the Neonode optical scanner ASIC is used, and count.
- mcuUniqueIdentifier: identifier created at mcu manufacturing.
- projectReference: FW GIT tags or hashes. Product specific. Uniquely identifies the FW revision.
- platformReference: FW GIT tags or hashes. Uniquely identifies generic firmware base commit for the platform.
- buildTime: time of build in Central European Time, a string.
- buildDate: date of build, a string.

Device Count

The deviceCount command enumerates the available virtual devices.

request command

```
deviceCount {
}
```

command response

```
deviceCount {
  totalNumberOfDevices 1,
  airDevices 1
}
```

Device type instances are indexed from zero. The response shown here means that the only virtual device available is Air[0].

Frequency

The frequency command changes the update frequency of all touch sensors globally, that is for all devices on all platforms.

The following update frequencies can be set, if enabled in the product:

- finger: activated when objects with characteristics matching regular fingers are detected.
- stylus: activated for narrow stylus-like objects. (Not enabled for the zForce AIR touch sensor.)
- idle: activated when no objects are detected, in order to minimize power usage.

The unit is Hz.

request command

```
frequency {
  finger 30,
  idle 10
}
```

The response contains the current frequency settings of the product:

command response

```
frequency {
  finger 30,
  idle 10
}
```

In this example, the touch sensor update frequency will be 30 Hz as long as finger-like objects were recently detected. When no objects are detected, the frequency will drop to 10 Hz.

Touch Sensor

There are a number of different touch sensor products that can co-exist on the same physical device. There are some product-specific commands, but the ones listed here are general.

The zForce AIR Touch Sensor will be used as example, which means the device address will be that of the first zForce Air virtual device

address

```
'0200'H
```

Operation Mode

The operationMode command sets what processing to perform on sensor signals, and what diagnostics that are exposed.

The following example sets the operation mode to normal object detection:

request command

```
  operationMode {
    detection TRUE,
    signals FALSE,
    ledLevels FALSE,
    detectionHid FALSE,
    gestures FALSE
  }
```

command response

```
  operationMode {
    detection TRUE,
    signals FALSE,
    ledLevels FALSE,
    detectionHid FALSE
  }
```

As can be seen gestures are missing in the response. This is a valid response, since the device is built with a subset of the protocol, or an older forward-compatible version.

Touch Format

The touchFormat command retrieves the binary format of the detected objects.

request command

```
  touchFormat {
  }
```

command response

```
  touchFormat {
    touchDescriptor { id, event, loc-x-byte1, loc-x-byte2, loc-y-byte1, loc-y-byte2,
size-x-byte1, size-y-byte1 }
  }
```

The touchDescriptor is a bit string, where each bit signifies one byte of payload being included in the touchNotification octet strings. A touchNotification is the concatenation of those bytes. The following table lists all bits. Bits used in the example are marked green.

Name	Description	Comment
id	Touch Identifier	
event	Up/Down/Move	0=Down; 1=Move; 2=Up; 3=Invalid; 4=Ghost
loc-x-byte1	X coordinate	
loc-x-byte2	X expanded	for higher precision
loc-x-byte3	X expanded	for higher precision
loc-y-byte1	Y coordinate	
loc-y-byte2	Y expanded	for higher precision
loc-y-byte3	Y expanded	for higher precision
loc-z-byte1	Z coordinate	
loc-z-byte2	Z expanded	for higher precision
loc-z-byte3	Z expanded	for higher precision
size-x-byte1	X size	
size-x-byte2	X size	for higher precision
size-x-byte3	X size	for higher precision
size-y-byte1	Y size	
size-y-byte2	Y size	for higher precision
size-y-byte3	Y size	for higher precision
size-z-byte1	Z size	
size-z-byte2	Z size	for higher precision
size-z-byte3	Z size	for higher precision
orientation	Orientation	Hand orientation
confidence	Confidence	Ignore. This value is not reliable for the zForce AIR Touch Sensor.
pressure	Pressure	

Location and size coordinates can be specified with up to 3 bytes. The byte order in decreasing significance - big-endian. For example:

- 1 byte: location x = loc-x-byte1

- 2 bytes: location x = (loc-x-byte1 << 8) + loc-x-byte2
- 3 bytes: location x = (loc-x-byte1 << 16) + (loc-x-byte2 << 8) + loc-x-byte3

Location is signed, and size is not.

The location coordinate scale is one of two systems, depending on which detector is used:

- Physical: Robair Air and Core detectors: The unit is 0.1 mm. A coordinate value of 463 thus means 46.3 mm from origin.
- Relative: Triangles and Shape Air detectors: Fraction of the largest screen dimension as fixed point with 14 bits after the radix point (q14). On a widescreen display, the horizontal axis ranges [0, 2^{14}[, and vertical [0, 2^{14} * 9/16[([0, 16383], [0, 9215]).

The zForce AIR Touch Sensor uses Robair, thus the unit is 0.1 mm.

Size is in mm.

Confidence and pressure are fractions of the full values, in percent.

Enable Execution

The enable command activates the touch sensor, and notifications of detections start to stream.

request command

```
enable {
  enable 0
}
```

command response

```
enable {
  enable
}
```

To deactivate the touch sensor, send the disable command:

request command

```
enable {
  disable NULL
}
```

command response

```
  enable {
    disable NULL
  }
```

Touch Notifications

A detected object is reported with a touchNotification. The touchNotification payload is a touchDescriptor bit string. Every concurrently tracked object is represented by its own touchNotification payload.

notification

```
notificationMessage touchNotifications: {
    '0001013600730A0A64'H
  },
```

The following table shows the value of the example payload interpreted with the touch descriptor.

Name	Description	Comment	Value
id	Touch Identifier		0
event	Up/Down/Move	0=Down; 1=Move; 2=Up; 3=Invalid; 4=Ghost	1
loc-x-byte1	X coordinate		1
loc-x-byte2	X expanded	for higher precision	54
loc-y-byte1	Y coordinate		0
loc-y-byte2	Y expanded	for higher precision	115
size-x-byte1	X size		10
size-y-byte1	Y size		10

The touchNotification is from a Core device and translates to "Object 0 moved. Location is (31.0, 11.5) mm. Size is 10x10 mm."

Information

The command deviceInformation retrieves some information about the virtual device instance.

request command

```
deviceInformation {
}
```

command response

```
deviceInformation {
  deviceInstanceInformation {
    productVersionMajor 1,
    productVersionMinor 38,
    physicalWidth 1584,
    physicalHeight 1341,
    numberOfSignalAxes 0
  }
}
```

The response contains the deviceInstanceInformation structure, with the following parts:

Part	Description
productVersion	The specific type version of the virtual device.
physical	Size in unit 0.1 mm. See section Touch Format for the relationship to location coordinates.
numberOfSignalAxes	Only applicable for Core devices. The number of sensor arrays, each monitoring one dimension/axis of a touch sensor. Generally 2.

Configuration

Some configurations of the touch sensor device can be changed at run-time. The deviceConfiguration request command and command response are identical, except some configuration items in the request may be omitted in order to leave them in their current state.

For instance, to set object size restrictions only, omit all other items:

request command

```
deviceConfiguration {
  sizeRestriction {
    maxSizeEnabled TRUE,
    maxSize 100,
    minSizeEnabled FALSE
  }
}
```

The command response contains the state of all configuration items:

command response

```
deviceConfiguration {
  subTouchActiveArea {
    lowBoundX 0,
    lowBoundY 0,
    highBoundX 1584,
    highBoundY 1341,
    reverseX FALSE,
    reverseY FALSE,
    flipXY FALSE,
    offsetX 0,
    offsetY 0
  },
  sizeRestriction {
    maxSizeEnabled FALSE,
    maxSize 0,
    minSizeEnabled FALSE,
    minSize 0
  },
  detectionMode default,
  numberOfReportedTouches 2,
  hidDisplaySize {
    x 1584,
    y 1341
  }
}
```

The items are:

- subTouchActiveArea: Crop the touch sensor to a rectangle between the specified low and high coordinates in each dimension. Offset can be applied and flip the X and Y axis. Origin of reported locations is set to low coordinates, or if reversed, the high coordinate with increasing coordinates toward low.
- sizeRestriction: Limit detection to objects within this size range. Unit is 0.1 mm.
- detectionMode, one of the following:
    - default: finger and stylus
    - finger: Finger only
    - mergeTouches: Merges all touch objects into one

    - insensitiveFTIR: Unsupported
- numberOfReportedTouches: Maximum number of reported tracked objects.
- hidDisplaySize: Scaling the coordinate system when using the sensor in HID Touch Digitizer mode.

7.4.5 Understanding the zForce ASN.1 Serialization Protocol

All communication with the zForce AIR touch sensor is serialized with Neonodes ASN.1 serialization protocol, and when implementing your own solution for the touch sensor it is vital to know how to encode and decode it. This article explains the basics of ASN.1 DER/BER encoding and then walks you through the encoding of a DeviceConfiguration Message from the zForce ASN.1 Protocol.

Downloading the definition file

Download the zForce® PDU definition file from https://support.neonode.com/docs/display/Downloads/Communication+Protocol+Downloads.

Type, Length, Value

All ASN.1 messages are structured by type, length and value:

- Type describes the type of the whole message or a subpart of a message. Type includes information on class and tag number.
- Length defines how many bytes there are in the message or in other words, the size of the value.
- Value is the actual value you are sending to the device, it is either a primitive value or a list. The primitive value types that are used in this protocol are:
    - Integer
    - Boolean
    - Octet String
    - Bit String

The Type Byte(s)

Type bytes can be constructed or primitive. A constructed type is a list, and in this protocol, all lists are defined by a sequence, and will hereafter be referred to as sequences.
Class tags and tag numbers are used to encode a type byte. The following ASN.1 class tags are used:

Class	Bit 8	Bit 7	Description
Universal	0	0	Not used in our protocol
Application	0	1	Shared
Context-specific	1	0	Local. For example specific to an Application
Private	1	1	Only used to describe the type of the whole message, Request/ Response/Notification

The encoding for tag numbers up to and including 30 (higher code numbers are encoded differently, but those are not used in our protocol):

Bit position		8th	7th	6th	5th	4th	3rd	2nd	1st
Specific bit value	**Binary representation**	1000 0000	0100 0000	0010 0000	0001 0000	0000 1000	0000 0100	0000 0010	0000 0001
	Decimal representation	128	64	32	16	8	4	2	1
	Hexadecimal representation	0x80	0x40	0x20	0x10	0x08	0x04	0x02	0x01
Description		Reserved for class tag	Reserved for class tag	Reserved for primitive/ sequence	Reserved for tag number	Reserved for tag number	Reserved for tag number	Reserved for tag number	Reserved for tag number

In short this means that the 8th and 7th bits are reserved to specify the class, and the 6th bit is reserved to show if it is a sequence. Bits 5 to 1 are used to specify the tag number.

Example: The type byte for the command deviceConfiguration

The command as seen in the protocol:

```
deviceConfiguration [APPLICATION 19] Sequence
```

This tells us that the deviceConfiguration is a sequence with the class tag Application and 19 as tag number. The deviceConfiguration type byte looks like this when it is represented as an octet:

Bit position	8th	7th	6th	5th	4th	3rd	2nd	1st
Bit	0	1	1	1	0	0	1	1
Hexadecimal Value		0x40	0x20	0x10			0x02	0x01

Description	Class tag	Class tag	Sequence tag	Tag number value	Tag number value	Tag number value	Tag number value	Tag number value

All of the hexadecimal numbers are then added together to get the type byte → 0x40 + 0x20 + 0x10 + 0x02 + 0x01 = 0x73.

The Length Byte(s)

The length byte defines the number of bytes in the value byte(s) that follows it, and if the number is 127 or below, the length byte is only one byte. If the number is 128 or higher, the length byte splits into two pieces: The first piece, is the first byte that describes the amount of length bytes that follows it, and the second piece is the unsigned integer that holds the whole length value.

Example: The length byte for a value that is 50 bytes long

The decimal value 50 translates to 0x32 in hexadecimal representation and 0011 0010 in binary representation

Bit position	**8th**	**7th**	**6th**	**5th**	**4th**	**3rd**	**2nd**	**1st**
Bit	0	0	1	1	0	0	1	0
Hexadecimal Value			0x20	0x10			0x02	
Description	If this bit is set the length of the value is 128 bytes or longer	Value	Value	Value	Value	Value	Value	Value

Example: The length bytes for a value that is 300 bytes long

The length bytes for a value that is 300 bytes long consists of three bytes. The first byte indicates that the following two bytes ((0x01) 0000 0001 (0x2C) 0010 1100) should be added together. The first byte is described in the following table:

Bit position	**8th**	**7th**	**6th**	**5th**	**4th**	**3rd**	**2nd**	**1st**
Bit	1	0	0	0	0	0	1	0
Hexadecimal Value	0x80						0x02	
Description	If this bit is set, the length of the value is 128 bytes or longer	Number of length bytes	Number of length bytes	Number of length bytes	Number of length bytes	Number of length bytes	Number of length bytes	Number of length bytes

The Value Byte(s)

The value byte(s) can be as few as one byte or they can be a whole sequence following the Type Length Value format:

- Integers are represented by one or more bytes. An integer between 0 and 127 is represented by one byte (00 to 7F). An integer between 128 and 32767 is represented by two bytes (00 80 to 7F FF).
- A Boolean only requires one byte, since it is either true or false. The Boolean is either 0x00 or 0xFF.
- An Octet String takes up just as many bytes as the number of octets.
- Bit string: the number of bytes needed to represent a bit string depends on the number of bits and is easily explained in code:

```
int valueLength = 0;

 void CalculateValueLength()
 {
         valueLength = bitString.Length / 8;

         if((bitString.Length % 8) != 0)
         {
                valueLength++;
         }
 }
```

Request, Response, and Notification

When the host is communicating with the sensor, all of the messages are defined as either request, response, or notification.

- Request is a message that is sent to the sensor from the host.
- Response is a message that responds to the request.
- Notification is a message that is read by the host and is generated without any input from the host, for example a touch message or a boot complete message.

The messages look like this in the protocol:

```
*Message Definition*
    ProtocolMessage ::= CHOICE {
        request [PRIVATE 14] Message,
        response [PRIVATE 15] Message,
        notification [PRIVATE 16] Notification
    }
```

All three have the class tag private, and they are all sequences which means that the 8th, 7th, and 6th bits are all set. In binary this evaluates to 1110 0000 which in hexadecimal translates to 0xE0. Now all that needs to be done is to define which type of message it is, which in this case is either tag number 14, 15, or 16. In order to define a request, tag number 14 (0x0E) needs to be added to 0xE0, which sums up to 0xEE.

Device Address

All messages include a Device Address. Most messages go to the Air Device, but some go to the Platform Device. In the protocol, the DeviceAddress looks like this:

```
*Device Address Definition*
    DeviceAddress ::= [APPLICATION 0] OCTET STRING (SIZE (2))
    -- Addressing information used when multiple touch devices are present
    -- in the system.
    -- Byte0 - deviceType, Byte1 - deviceIndex
    -- DeviceTypes:     0x00    -    Platform
    --                 0x01    -    zForce Core
    --                 0x02    -    zForce Air
    --                 0x03    -    zForce Plus
    --                 0x04    -    Lighting devices
```

Example: Evaluate the device address

How to evaluate the address:

1. Type byte: The deviceAddress has the class tag Application, the tag number 0 and contains two octet strings. An octet string is primitive, and therefore the 6th bit is set to 0. In binary this evaluates to 0100 0000 and in hexadecimal that is 0x40.
2. Length byte: 2 (two octets).
3. Value bytes: The first byte is deviceType, the second is deviceIndex.
    a. Device type: In this case this is the zForce Air, represented by 0x02.
    b. Device index: On a zForce Air the index is always 0.

The complete device address then evaluates to 0x40 0x02 0x02 0x00:

Type	Length	Value
DeviceAddress	Value length	deviceType followed by deviceIndex
0x40	0x02	0x02 0x00

Encoding a Device Configuration Message

Device Configuration will be used as an example as it is a message that contains a large number of values with both context-specific primitive values and context-specific sequences.

```
*Device Configuration ASN.1 Protocol*
-- Instance specific settings for a device
   deviceConfiguration [APPLICATION 19] Sequence {
            -- Set / get the number of touches to be tracked:
            numberOfTrackedTouches    [0] INTEGER (0..255) OPTIONAL,
            -- Set / get the minimal distance for updating a tracked touch in move
state
            trackingMinDistanceMove    [1] INTEGER (0..16383) OPTIONAL,
            -- Set / get the sub touch active area low bound in X coordinate
            subTouchActiveArea        [2] Sequence {
                -- Write Request and Read Response only:
                -- Set / get the sub touch active area low bound in X coordinate
                lowBoundX         [0] INTEGER (0..16383) OPTIONAL,
                -- Set / get the sub touch active area low bound in Y coordinate
                lowBoundY        [1] INTEGER (0..16383) OPTIONAL,
                -- Set / get the sub touch active area high bound in X coordinate
                highBoundX     [2] INTEGER (0..16383) OPTIONAL,
                -- Set / get the sub touch active area high bound in Y coordinate
                highBoundY     [3] INTEGER (0..16383) OPTIONAL,
```

All settings are optional and therefore does not require all settings to be defined in the message that is sent to the sensor.

We want to set the following settings in the sensor:

SubTouchActiveArea:

- LowBoundX: 500
- LowBoundY: 500
- HighBoundX: 2000
- HighBoundY: 2000

This is how to do it (the length bytes are represented by XX, and are added in the last step):

Step	What to do	Details	Result	The message
1	Add the code for a **request**, since the message will be sent from the host to the sensor: 0xEE 0xXX	See Request, response and notification (see page 80).	EE XX	EE XX
2	Add the **device address** 0x40 0x02 0x02 0x00	See Device Address (see page 81).	40 02 02 00	EE XX **40 02 02 00**

3	Add the bytes for **deviceConfiguration**	The command deviceConfiguration has the class tag Application, tag number 19 and is a sequence.	Binary: 0111 0011 Hexadecimal: 0x73.	EE XX 40 02 02 00 **73**
4	Add the bytes for **SubTouchActiveArea**	SubTouchActiveArea is a context-specific sequence with tag number 2.	Binary: 1010 0010 Hexadecimal: 0xA2	EE XX 40 02 02 00 73 **XX A2 XX**
5	Add the variables inside of SubTouchActiveArea..	All the variables are context-specific and primitive (binary 1000 0000, hexadecimal 0x80). Depending on which variable that is currently being added, add the specific tag number.	Per variable: Binary: 1000 0000 plus tag number. Hexadecimal: 0x80 plus tag number.	EE XX 40 02 02 00 73 XX A2 XX 80 XX 01 F4 81 XX 01 F4 82 XX 07 D0 83 XX 07 D0
6	Add the length bytes of the message.	Add the number of bytes for each specific part of the message.	-	EE **18** 40 02 02 00 73 **12** A2 **10** 80 **02** 01 F4 81 **02** 01 F4 82 **02** 07 D0 83 **02** 07 D0

7.5 Updating Firmware

The firmware on a zForce AIR sensor can be updated easily using the **Neonode zForce AIR Sensor Firmware Update** application for Windows. Download it here: https://support.neonode.com/docs/display/Downloads/Firmware+Update+Software.

7.5.1 Prerequisites

Hardware requirements

- CPU: 1 GHz
- RAM: 512 MB
- Disk space: 20 MB
- Internet connection (for the automatic download of necessary Windows drivers)
- The interface board provided with the evaluation kit.

Operating System requirements

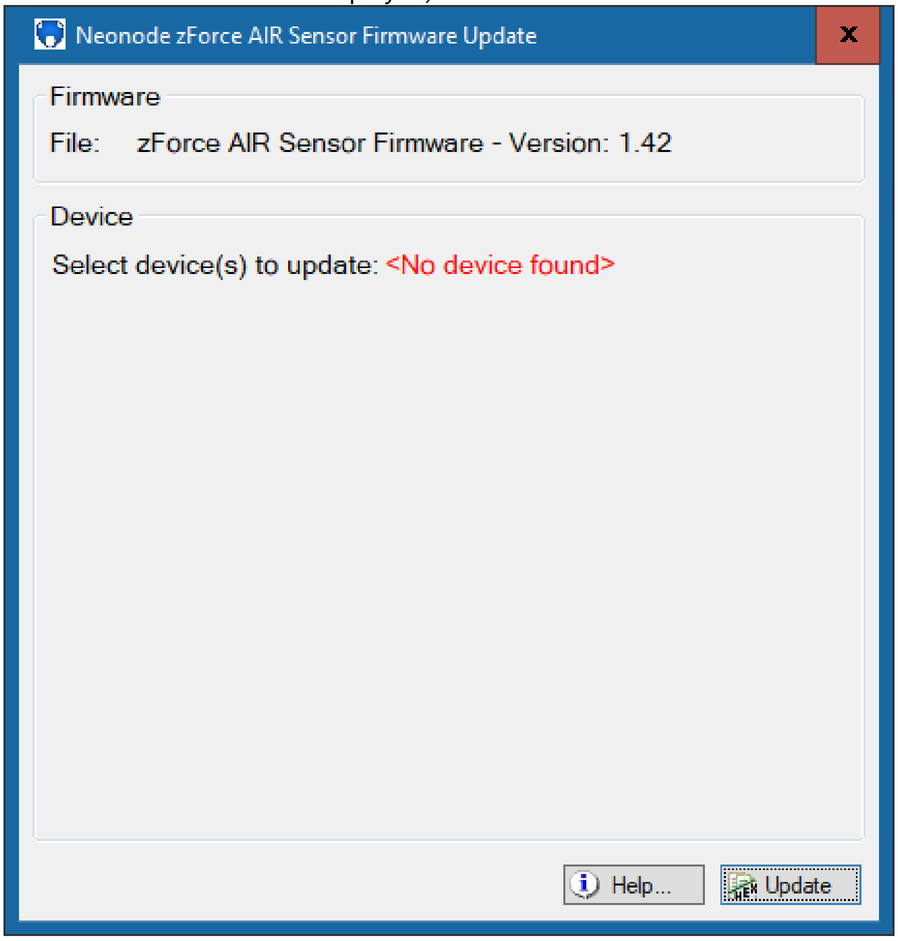
- Windows 10
- Windows 8.1

Software requirements

- .NET Framework 4.5 or higher is required and can be downloaded from Microsoft's official website. Windows 8 and higher has this installed by default.

7.5.2 Procedure

1. Download and run the application, https://support.neonode.com/docs/display/Downloads/Firmware+Update+Software.
   The new firmware version is displayed, under **Firmware**

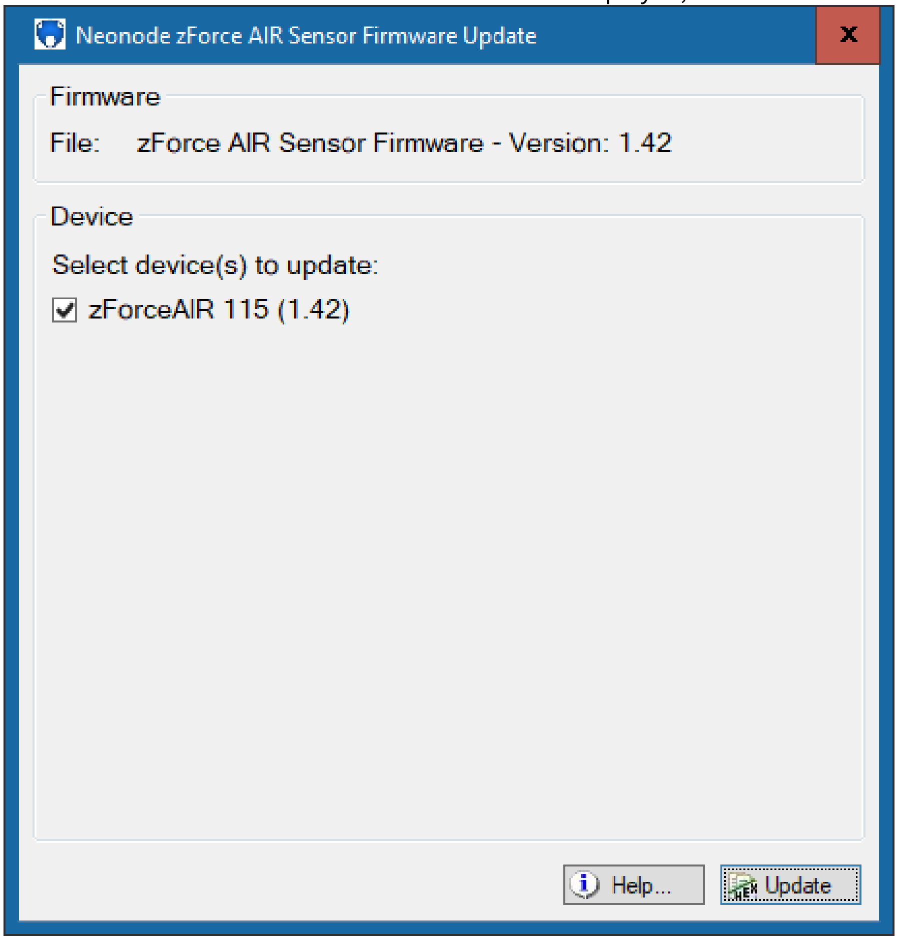


File: zForce AIR Sensor Firmware - Version: 1.42

Select device(s) to update: <No device found>

2. Connect the zForce AIR sensor to the computer via the provided interface board. Refer to Getting started with zForce AIR Touch Sensor Evaluation (see page 16) for details on how to connect the sensor.

The connected sensor's current firmware version is displayed, under **Device**.


Neonode zForce AIR Sensor Firmware Update

Firmware

File: zForce AIR Sensor Firmware - Version: 1.42

Device

Select device(s) to update:

☑ zForceAIR 115 (1.42)

3. Make sure the checkbox for the sensor is checked and click **Update**.
   The new firmware will be loaded into the sensor. If it is the first time the application is used to update the firmware, an internet connection will be required to install necessary drivers.
   A progress bar will be displayed with status during the firmware update. This process may take a few seconds to a minute depending on the computer.
   When the firmware update is completed, a pop up message is displayed. The sensor can be used right away after the update is finished.

7.5.3 Troubleshooting

If the updating fails or the device does not show up in the application, check the following possible scenarios. If the problem persists, please contact support.

The sensor does not appear under Device in the application after it is plugged in

1. Click **Help...** and follow the instructions.

The progress bar gets stuck at 0% to 5% during the firmware update

1. Click **Help...** and follow the instructions to set the sensor in DFU mode.
2. Check "*STM device in DFU mode*" or "*STM32 BOOTLOADER*" device under "*Universal Serial Bus controller*" or "*Other devices*" in Windows Device Manager to ensure drivers are working properly. Uninstall or update the driver if necessary.

The firmware update fails with the message "*Failed to download new firmware*" or the progress bar gets stuck at about 50 to 60%

1. Click **Help...** and follow the instructions.

The progress bar gets stuck at 100% during firmware update with the message "*Waiting for USB configuration...*",

This is because the sensor failed to leave "boot mode" but the firmware is already updated.

1. Click on **Cancel** button and re-plug the sensor. The new firmware is updated and the sensor is ready to be used.

7.5.4 Firmware Release Notes 1.49

Contents of Release

- Bug fix.
- Modified the relationship between Hid Display Size and Offset.
- Extended range.

Fixed bugs

- Fixed an off by one error in the reported Physical Height.

Features and Modifications

- The settings Hid Display Size and Offset (in Device Configuration) are now independent of each other and changing one of these settings will not affect the other.
- Added an additional firmware package for NNAMC3460PC01 and NNAMC3461PC01 with support for extended range.

7.5.5 Firmware Release Notes 1.47

Contents of Release

- Bug fixes

Fixed bugs

- Fixed a bug where Flip XY did not work as expected, when ReversY and ReverseX was also set to true.
- FIxed a bug for "Sub Area Offset" when using "Flip XY".

7.5.6 Firmware Release Notes 1.46

Contents of Release

- Bug fixes

Fixed bugs

A bug was fixed in the gesture feature, that caused poor performance.

7.5.7 Firmware Release Notes 1.45

Contents of Release

- Added a reflective edge filter
- Bug fixes
- Changed name of the hardware id

New features

A new reflective edge filter has been added and is disabled by default. Instructions on how to enable it is available here[13].

Changed the name of the hardware id to "zForceAIR sensor". Previously called "AirModule".

Enhancements

Fixed bugs

A bug was fixed in the X size of the touching object and the Y size is no longer reported

13 https://support.neonode.com/docs/display/AIRTSUsersGuide/Communication+Protocol+Quick+Start

8 Implementation Examples

The following examples are here to give you an idea of different ways to use the sensor, and different ways of integrating the sensor into your system.

8.1 zForce AIR Interface Library for Arduino

8.1.1 Use Case

This library is useful if you would like to easily get started with a prototype, understand how to communicate with the sensor using I2C or if you would like to see how the library has implemented the communication.

8.1.2 Introduction

The library offers an easy way to communicate with the sensor as well as some primitive parsing of the ASN.1 serialized messages. This makes it easy for the end user to get x and y coordinates from touch notifications or set different settings such as the correct touch active area. The library does not have support for all messages available in the ASN.1 protocol, however the I2C read and write functions are public and can be used if any setting or request not supported by the library needs to be sent/read from the sensor.

8.1.3 Open Source

This library is distributed under the GNU LGPL v2.1 open source license and is available on https://github.com/neonode-inc/zforce-arduino along with additional documentation as well as a full example program. For questions regarding how to use the library, please refer to our helpcenter.

8.1.4 How to use the library

Main Loop

The library is built around using zforce.GetMessage() as the main loop for reading messages from the sensor. GetMessage checks if the data ready pin is high and if it is, the function zforce.Read() will be called. The read function takes a buffer parameter which is used to store the data from the sensor.

GetMessage

```
Message* Zforce::GetMessage()
{
  Message* msg = nullptr;
  if(GetDataReady() == HIGH)
  {
    if(!Read(buffer))
    {
      msg = VirtualParse(buffer);
      ClearBuffer(buffer);
    }
  }

  return msg;
}
```

When GetMessage has been called it is up to the end user to destroy the message by calling zforce.DestroyMessage() and passing the message pointer as a parameter.

Send and Read Messages

The library has support for some basic settings in the sensor, for example zforce.SetTouchActiveArea(). When writing a message to the sensor the end user has to make sure that data ready is not high before writing. This is done by calling GetMessage and reading whatever might be in the I2C buffer.

When a message has been sent, the sensor always creates a response that has to be read by the host. It could take some time for the sensor to create the response and put it on the I2C buffer, which is why it is recommended to call the GetMessage function in a do while loop.

Send and Read

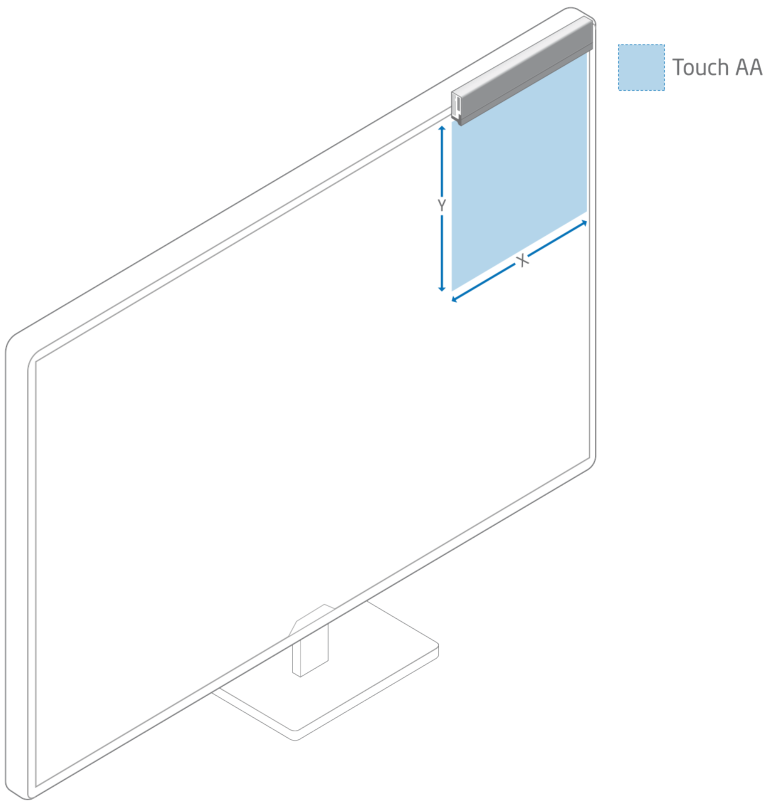
```
// Make sure that there is nothing in the I2C buffer before writing to the sensor
Message* msg = zforce.GetMessage();
if(msg != NULL)
{
  // Here you can read whatever is in the message or just destroy it.
  zforce.DestroyMessage(msg);
}

// Send Touch Active Area request
zforce.TouchActiveArea(50,50,2000,4000);

// Wait for the response to arrive
do
{
  msg = zforce.GetMessage();
} while (msg == NULL);

// See what the response contains
if(msg->type == MessageType::TOUCHACTIVEAREATYPE)
{
  Serial.print("minX is: ");
  Serial.println(((TouchActiveAreaMessage*)msg)->minX);
  Serial.print("minY is: ");
  Serial.println(((TouchActiveAreaMessage*)msg)->minY);
  Serial.print("maxX is: ");
  Serial.println(((TouchActiveAreaMessage*)msg)->maxX);
  Serial.print("maxY is: ");
  Serial.println(((TouchActiveAreaMessage*)msg)->maxY);
}
// Destroy the message
zforce.DestroyMessage(msg);
```

8.2 Selective Area Touch

8.2.1 Use Case

This method of configuring sensor(s) can be used to get one or multiple touch areas on a larger screen or on a large projected area, further referred to as Screen.

8.2.2 Illustrations



8.2.3 Introduction

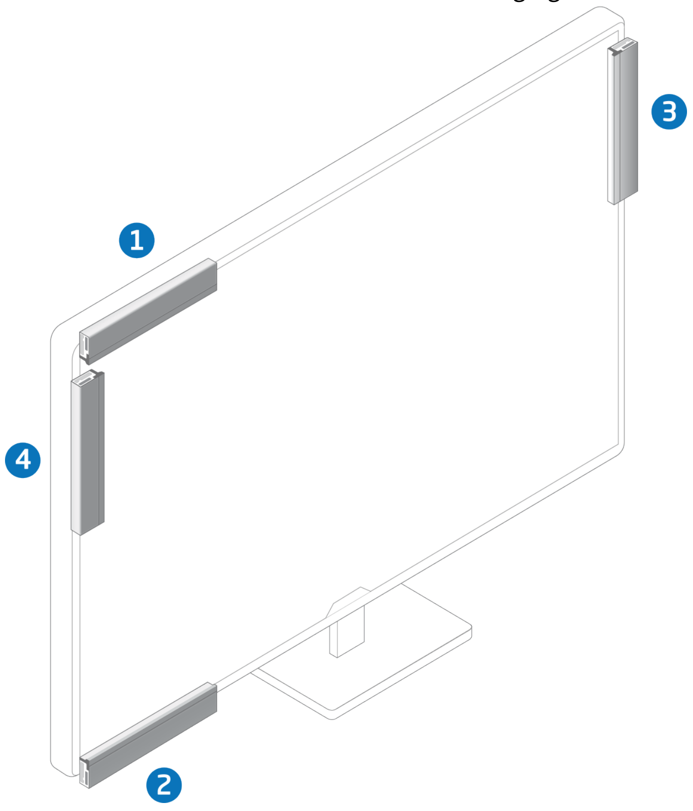
A sensor can be mounted on four sides of a screen and with the connector to either the right or the left (PCB or silver side down) but we recommend mounting it with the silver side towards the screen, as the touch area is then closer to the screen.

This will give a total of eight different configurations.

It is possible to mount a sensor "on" or "in" the screen. However this will cover/block part of the screen and is therefore not a part of this example.

1. Top: Sensor on top of the screen facing down.
2. Bottom: Sensor on bottom of the screen facing up.
3. Right: Sensor on right side of the screen facing left.

4. Left: Sensor on the left side of the screen facing right.



8.2.4 HID Display Size

HID Display Size is the physical size of the screen in tenths of millimeters (1/10 ; 1 mm = 10)

8.2.5 Configurations With One Sensor

NOTE: Values in **bold** has to be changed from default to make the configuration work.

Top - Connector to the right

Configuration	**1 (Top - Connector to the right)**
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>

Configuration	**1 (Top - Connector to the right)**
Sub Area Reverse X	**True**
Sub Area Reverse Y	False
Sub Area Flip XY	False
Sub Area Offset X	**The offset distance left side of the screen and the (left side of the) sensor.** If the sensor sticks out to the left of the screen change "Sub Area High Bound X" . Subtract the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).
Sub Area Offset Y	Zero (0) If you have the sensor above the screen change the "Sub Area Low Bound Y" to the distance between screen and sensor.
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

Top - Connector to the left

Configuration	**1 (Top - Connector to the left)**
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>
Sub Area Reverse X	False
Sub Area Reverse Y	False
Sub Area Flip XY	False

Configuration	1 (Top - Connector to the left)
Sub Area Offset X	**The offset distance left side of the screen and the (left side of the) sensor**. If the sensor sticks out to the left of the screen change "Sub Area Low Bound X" . Add the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).
Sub Area Offset Y	Zero (0) If you have the sensor above the screen change the "Sub Area Low Bound Y" to the distance between screen and sensor.
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

Bottom - Connector to the right

Configuration	2 (Bottom - Connector to the right)
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>
Sub Area Reverse X	**True**
Sub Area Reverse Y	**True**
Sub Area Flip XY	False
Sub Area Offset X	**The offset distance left side of the screen and the (left side of the) sensor.** If the sensor sticks out to the left of the screen change "Sub Area High Bound X" . Subtract the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).

Configuration	2 (Bottom - Connector to the right)
Sub Area Offset Y	**This is the value of "Hid Display Size Y" minus "Sub Area High Bound Y" plus "Sub Area Low Bound Y"** If the sensor is below the screen change the "Sub Area Low Bound Y " to the distance between screen and sensor. Also update the value of "Sub Area Offset Y" to correspond to the new offset.
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

Bottom - Connector to the left

Configuration	2 (Bottom - Connector to the left)
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>
Sub Area Reverse X	False
Sub Area Reverse Y	**True**
Sub Area Flip XY	False
Sub Area Offset X	**The offset distance left side of the screen and the (left side of the) sensor.** If the sensor sticks out to the left of the screen change "Sub Area Low Bound X" . Add the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).
Sub Area Offset Y	**This is the value of "Hid Display Size Y" minus "Sub Area High Bound Y" plus "Sub Area Low Bound Y"** If the sensor is below the screen change the "Sub Area Low Bound Y " to the distance between screen and sensor. Also update the value of "Sub Area Offset Y" to correspond to the new offset.

Configuration	**2 (Bottom - Connector to the left)**
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

Left - Connector to the top

Configuration	**3 (Left - Connector to the top)**
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>
Sub Area Reverse X	False
Sub Area Reverse Y	False
Sub Area Flip XY	**True**
Sub Area Offset X	Zero (0) If you have the sensor to the left of the screen change the "Sub Area Low Bound Y" to the distance between screen and sensor.
Sub Area Offset Y	**The offset is the distance from the sensor to the top of the screen.** **Max offset is "Hid Display Size Y" minus "Sub Area High Bound X" plus "Sub Area Low Bound X".** If the sensor sticks out to the top of the screen change "Sub Area Low Bound X" . Add the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

Left - Connector to the bottom

Configuration	**3 (Left - Connector to the bottom)**
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>
Sub Area Reverse X	False
Sub Area Reverse Y	**True**
Sub Area Flip XY	**True**
Sub Area Offset X	Zero (0) If you have the sensor to the left of the screen change the "Sub Area Low Bound Y" to the distance between screen and sensor.
Sub Area Offset Y	**The offset is the distance from the sensor to the top of the screen.** If the sensor sticks out to the top of the screen change "Sub Area High Bound X" . Subtract the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

Right - Connector to the top

Configuration	**4 (Right - Connector to the top)**
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>

Configuration	**4 (Right - Connector to the top)**
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>
Sub Area Reverse X	**True**
Sub Area Reverse Y	False
Sub Area Flip XY	**True**
Sub Area Offset X	**This is the value of "Hid Display Size X" minus "Sub Area High Bound Y" plus "Sub Area Low Bound Y".** If you have the sensor to the right of the screen change the "Sub Area Low Bound Y" to the distance between screen and sensor.
Sub Area Offset Y	**The offset is the distance from the sensor to the top of the screen.** If the sensor sticks out to the top of the screen change "Sub Area Low Bound X" . Add the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

Right - Connector to the bottom

Configuration	**4 (Right - Connector to the bottom)**
Sub Area Low Bound X	<Default values from sensors original configuration>
Sub Area Low Bound Y	<Default values from sensors original configuration>
Sub Area High Bound X	<Default values from sensors original configuration>
Sub Area High Bound Y	<Default values from sensors original configuration>

Configuration	**4 (Right - Connector to the bottom)**
Sub Area Reverse X	**True**
Sub Area Reverse Y	**True**
Sub Area Flip XY	**True**
Sub Area Offset X	**This is the value of "Hid Display Size X" minus "Sub Area High Bound Y" plus "Sub Area Low Bound Y".** If you have the sensor to the right of the screen change the "Sub Area Low Bound Y" to the distance between screen and sensor.
Sub Area Offset Y	**The offset is the distance from the sensor to the top of the screen.** If the sensor sticks out to the top of the screen change "Sub Area High Bound X" . Subtract the distance the sensor sticks out from the left edge of the screen and the SW (Software origin).
Hid Display Size X	**Width of screen in tenths of millimeters.**
Hid Display Size Y	**Height of screen in tenths of millimeters.**

8.2.6 Configurations With Multiple Sensors

If you would like to configure multiple sensors for touch on different parts of the screen, please use the settings above for each sensor. If you would like to make this setting with Neonode Workbench, please use the Workspace designated for multiple sensors. If you would like to create your own solution, the zForce SDK can be used to implement this.

9 Specifications

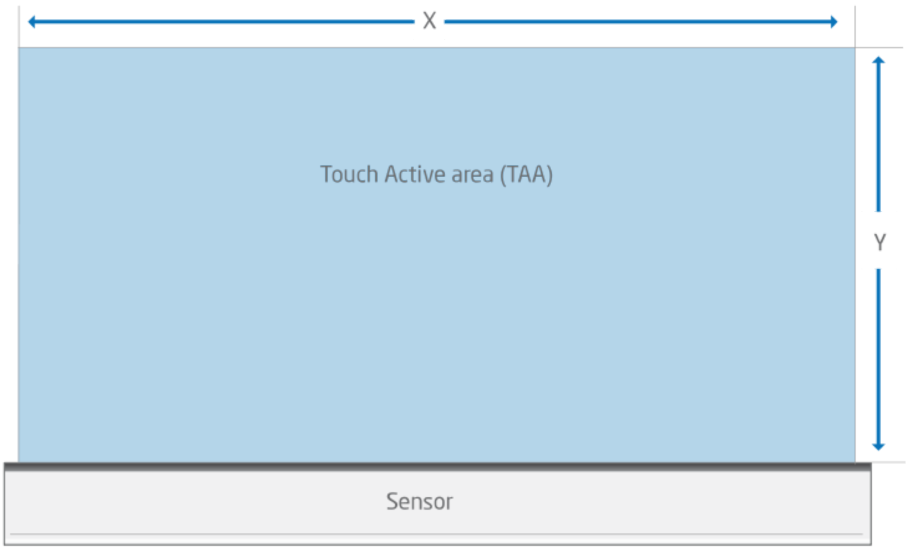
9.1 Specifications Summary

9.1.1 Touch Performance Specification

Item	Specification
Input methods	Finger, hand or glove.
Minimum object size (diameter)	5 mm
Number of touch objects	1, 2, or more, depending on application
Touch resolution	0.1 mm
Touch activation force	0 N (no activation force required)
Touch Active Area	Up to 345.6 x 327.7 mm. For details, refer to information on product variants in Introduction (see page 6).
Response time	~50 ms (initial touch, at 33 Hz in idle mode) 10 ms (continuous tracking, at 100 Hz in active mode)
Scanning frequency	Configurable up to 900 Hz, depending on product variant. For details, refer to Touch Performance (see page 103).

Touch accuracy

The specified values are valid for the used test setup. For more information, refer to Performance Test Methods (see page 114). The touch accuracy is measured inside the TAA, using a silicone based cylindrical test rod with a diameter of 16 mm.



Touch Accuracy for Normal Range Sensors of the 90° **and 0° Types**

Product Number	Typical Value (mm)	μ ± 2σ (mm)
NNAMC346XPC01	1.5	3.5
NNAMC310XPC01	1.5	3.5
NNAMC295XPC01	1.5	3.5
NNAMC259XPC01	1.5	3.5
NNAMC209XPC01	1.5	3.5
NNAMC180XPC01	1.5	3.5
NNAMC158XPC01	1.5	3.5
NNAMC122XPC01	1.5	3.5
NNAMC115XPC01	1.5	4

Typical Value: The accuracy on average, within the TAA.
μ ± 2σ: 95% of reported touch positions deviate less than this value. (2σ standard deviation).
Product number: "X" indicates if the sensor is of type 0º ("0") or 90º ("1").

The accuracy specification (normal range, 0° and 90°) is valid for units produced from 15th January 2020. Please contact our support team for specification regarding earlier produced sensors, or general questions about the accuracy specification.

Touch Accuracy for Extended Range Sensor of the 90**° and 0° Types**

Product Number	**Typical Value (mm)**	**μ ± 2σ (mm)**
NNAMC346XPC01	2.5 [1]	5 [1]

Typical Value: The accuracy on average, within the TAA.
μ ± 2σ: 95% of reported touch positions deviate less than this value. (2σ standard deviation).
Product number: "X" indicates if the sensor is of type 0º ("0") or 90º ("1").
[1] Preliminary value.

The accuracy specification (extended range, 0° and 90°) is valid for units produced from 15th January 2020. Please contact our support team for specification regarding earlier produced sensors, or general questions about the accuracy specification.

Technical Specification

Item	**Sensor Variant**	**Specification**
Module size (LxHxW)	0° Type	L x 3.46 x 14.5 mm L depending on product variant.
	90° Type	L x 3.46 x 16.05 mm L depending on product variant.
Power consumption I2C interface Active mode (100 Hz)	NNAMC0720PC01, NNAMC0721PC01	57 mW
	NNAMC2090PC01, NNAMC2091PC01	80 mW
	NNAMC3460PC01, NNAMC3461PC01	104 mW
	NNAMC3460PC01, NNAMC3461PC01, Extended Range	135 mW
Power consumption I2C interface Idle mode (33 Hz)	NNAMC0720PC01, NNAMC0721PC01	44 mW
	NNAMC2090PC01, NNAMC2091PC01	45 mW
	NNAMC3460PC01, NNAMC3461PC01	47 mW

Item	Sensor Variant	Specification
	NNAMC3460PC01, NNAMC3461PC01, Extended Range	61 mW

9.2 Touch Performance

9.2.1 Touch Object Requirement

zForce AIR Touch Sensors detect and trace objects by detecting diffusely reflected infrared light.

Requirements on the object to detect include:

- A minimum reflectance of 30% in the near IR-spectrum is needed for proper signal levels, that is, the object can not be too dark.
- Object surface must be diffuse. A glossy or mirror-like object may not scatter enough light towards correct receivers in order to generate a reliable detection.
- An object must be ≥ 5 mm to ensure sufficient signal levels. This is closely related to reflectance. A white, diffuse object may be smaller than a dark, glossy one.

9.2.2 Touch Accuracy

Specification

Measured touch coordinate error in X and Y axis is less or equal than the specified value for about 95% of the cases.

Touch coordinate error data is calculated by subtracting the actual position and measured position in X and Y axis.

Definition

The touch accuracy of the zForce AIR Touch sensor can be described statistically with the normal distribution and a standard deviation of 2 sigma. This means that the touch position reported by the sensor will deviate less than the specified value in 95% of the cases.

9.2.3 Response Time

The specification of response time reflects the reaction speed of a zForce AIR Touch Sensor.

Specification

- **Initial touch**: 16-46 ms, at 33 Hz scanning frequency (default frequency in idle mode).
- **Continuous tracking**: 10 ms, at 100 Hz scanning frequency (default frequency in active mode).

Increasing the scanning frequency decreases the response time.

Definition

Initial Touch

The specified response time for the **initial touch** starts from the instant an object is presented in the sensor's active area and stops when the sensor starts to send the first touch notification for this object. The specified response time consists of two numbers reflecting the best case and the worst case, with the average response time right in the middle.

The response time (t) can be calculated for different idle mode frequencies (f) can be calculated by the formulas below:

Best case: $t = 16\ ms$

Worst case: $t = 1/f + 16\ ms$

Average: $t = (1/f + 32\ ms) / 2$

In touch applications, an object will be detected slightly before it reaches the touch surface, making the perceived response time shorter.

Continuous Tracking

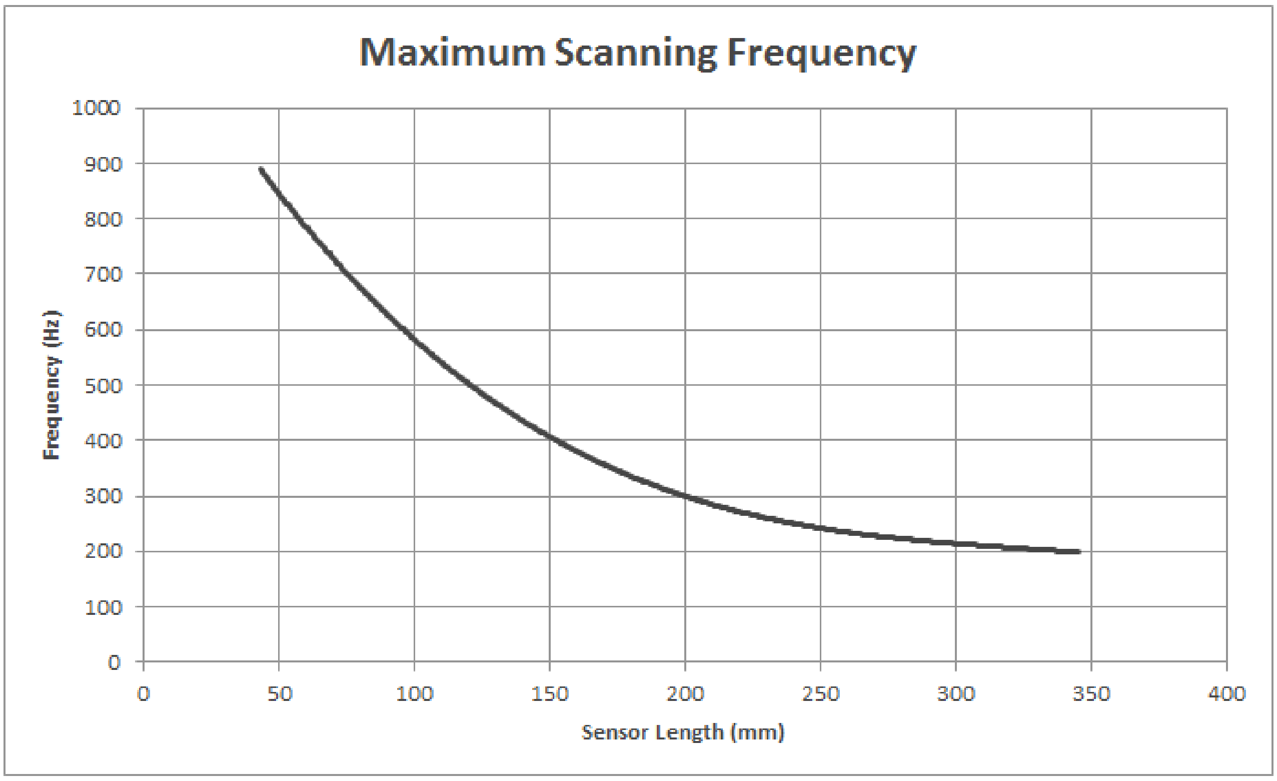
After the first touch notification, the sensor will **continuously track** and send touch notifications to update the object position. The response time is therefore defined as the time between subsequent touch notifications.

The response time (t) can be calculated for different active mode frequencies (f) can be calculated by the formula below:

$t = 1/f$

9.2.4 Scanning Frequency

The scanning frequency can be set using the Neonode API. The default value is 100 Hz in active mode, that is, when an object is detected or tracked. The default value in idle mode, that is, when no object is detected or tracked, is 33 Hz. The maximum scanning frequency depends on the product variant (sensor length). See the following chart.

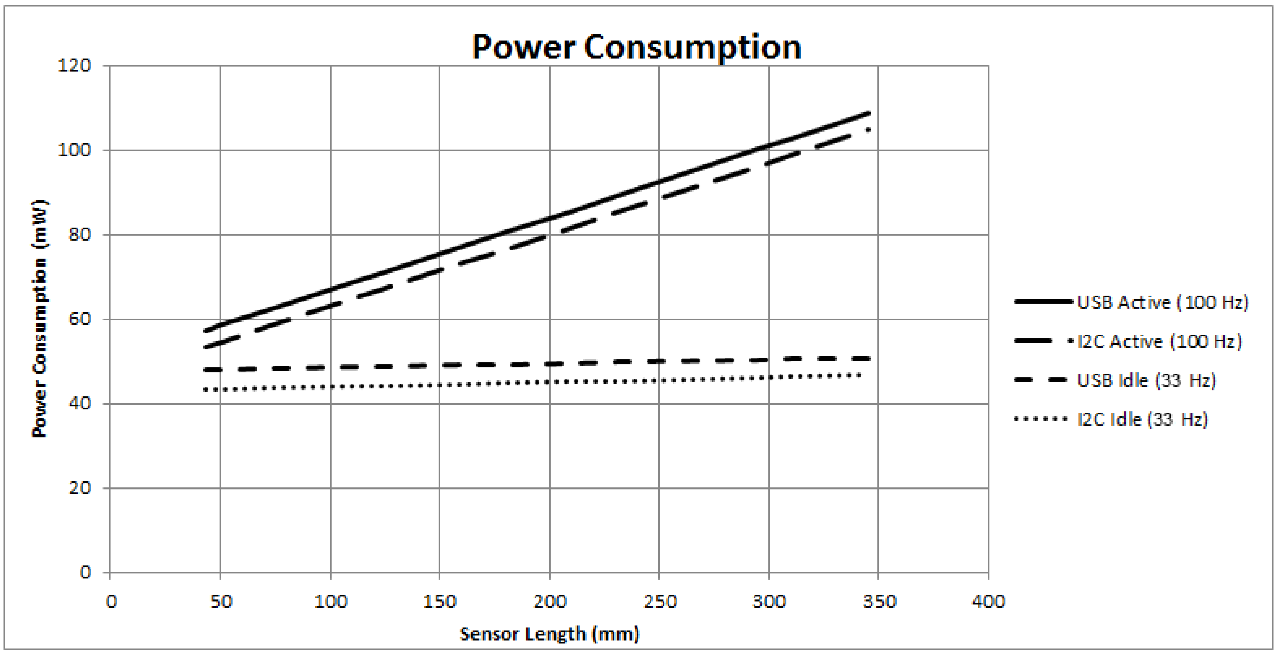


The maximum scanning frequency for product variants NNAMC3460PC01 and NNAMC3461PC01 with Extended Range is 175 Hz.

9.3 Power Consumption

9.3.1 Specification

The graph below shows the power consumption for various sensor lengths, in active and idle mode. In active mode, the scanning frequency is set to 100 Hz, and one object is presented in active area. In idle mode the scanning frequency is set to 33 Hz, with a clean active area. With higher scanning frequency or more detected objects, the power consumption might slightly higher than the values in the graph. The sensor will only be in active mode when a touch object is being detected or tracked.



.

From firmware version 1.49 and higher, sensor variants NNAMC3460PC01 and NNAMC3461PC01 are provided with Extended Range, and their power consumption increases 30% in both USB active mode and USB idle mode. The power consumption for sensor variants shorter than 237 mm is not affected by Extended Range.

9.3.2 Definition

The power consumption is calculated from the current consumption when supplying the sensor with 5 V.

The current consumption is, in turn, defined as the average current that goes through a sensor. This is measured from the +5V power pin and reflects how much electric energy that is consumed by the whole sensor. In real time, the current is not a stable value. Since the Touch Sensor has a low power consumption design, the processor and some peripheral circuits will switch to sleep mode during the time between two scan periods, to save power. Therefore, the current is frequently changing during run time.

According to the different working modes of the Touch Sensor, the current consumption value also changes between Active mode and Idle mode.

9.4 Environmental Requirements

9.4.1 Operating and Storage Conditions

Condition	Operation	Storage
Temperature	–20°C to +65°C	–40°C to +85°C
Humidity	5% to 95%	0% to 95%

Condition	Operation	Storage
Altitude	≤5000 m	≤15 km

9.4.2 ESD rating

EN55024
(61000-4-2)
Direct contact discharge: 4 kV
Indirect contact discharge: 4 kV
Air discharge: 8 kV

9.4.3 Agency Approvals

RoHS, IEC60825-1 Class 1

9.5 Electrical Requirements

9.5.1 Absolute Maximum Ratings

Parameter	Max Rating	Unit
Supply voltage	-0.3 to 6.0	V
Input voltage on I/O pins	-0.3 to 5.5	V

9.5.2 Recommended Operating Conditions

Parameter	Min	Typ	Max	Unit
Supply voltage	4.50	5.00	5.50	V

9.6 Optical Requirements on External Window

Most applications will require an outer cover window, for design cosmetics and protection against dust and humidity.

The optical properties on cover windows placed in front of the sensor are essential in order to maintain a high touch performance. If light is lost, scattered or diverted it will lead to shorter detection range and lower touch accuracy.

9.6.1 Optical Requirements

Window material must be optically clear, without absorption and have optical quality surfaces.

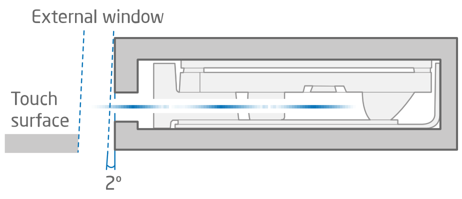
- Transmission: > **88 % at 945nm**
- Haze: **< 3%**
- Surface finish: **SP1-A2 (max Ra 0.05µm).**

Proven plastic materials include optical grade acrylic (PMMA) and polycarbonate. For glass windows, transmission at 945 nm must be verified. Many borosilicate glasses (such as Borofloat) work well, but some common window glasses show substantial absorption due to high iron content.

9.6.2 Geometrical Constraints

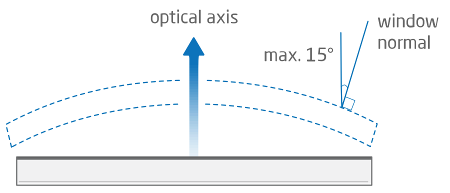
The zForce AIR Touch Sensor is an optical system that both emits and receives IR-light at different incident angles. When the light hits a transparent material, most of the light is transmitted through the material and exit on the other side. But in reality the amount of light being transmitted is angle dependent, why some shape constraints exist on windows placed in front of the sensor:

- **Window surfaces must be parallel.**
  A wedge, or lens shaped window will shift light beams out of the active area.
- It is a good practice to install the window at a slight angle (~2°) to reduce reflected stray light. See the image below. The angle can be up to approximately 30° without affecting performance.

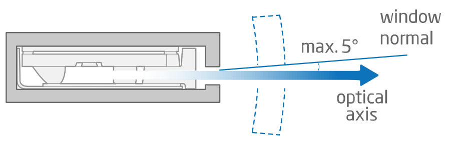


- A slight curvature on the window can be allowed.

- In x-direction, a maximum angle of 15° between window normal and sensors optical axis is recommended, for all parts of the window within the sensor TAA.



- In z-direction, the angle should be maximum 5°.



, which corresponds to a minimum radius of 12 mm for the surface closest to the sensor.

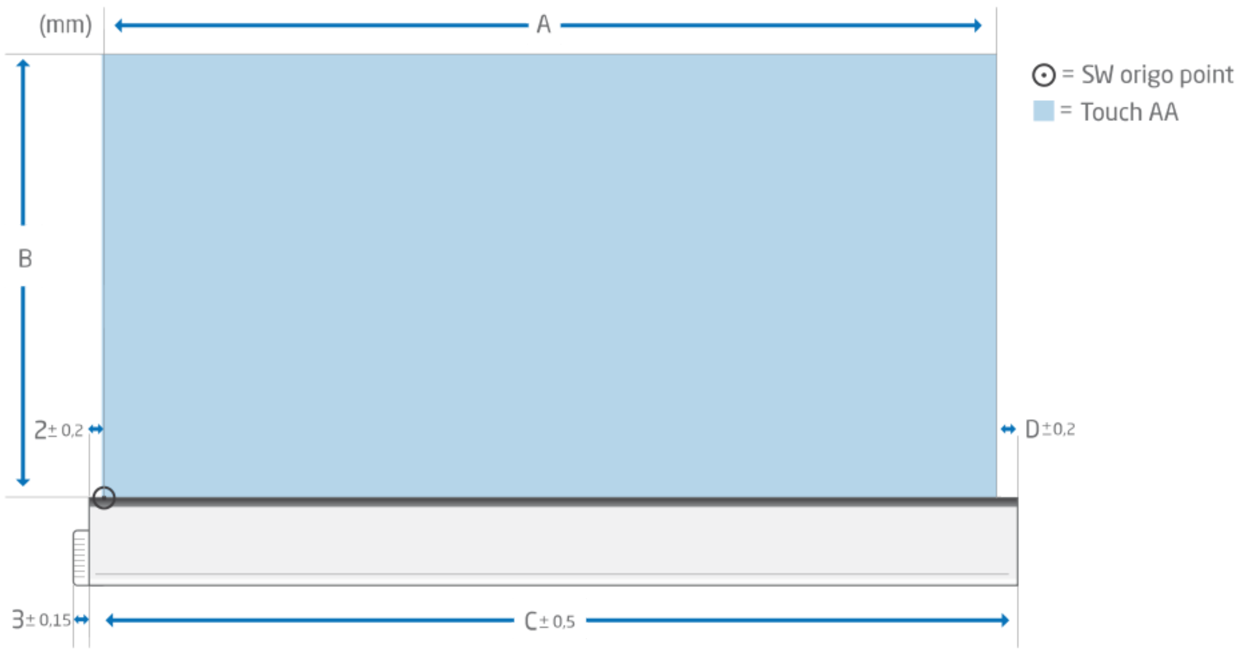
- Keep window thickness as small as mechanically feasible, to reduce absorption losses.

9.7 Mechanical Data

9.7.1 Physical Dimensions and Position of Origin

Top View

Dimensions **C** and **D** vary between the Touch Sensor variants and therefore also the Touch Active Area (TAA) sizes (**A** and **B**). For Touch Sensor variants with A ≥ 237.6 mm, dimension B also depends on the installed firmware version.



Product number		Measurements (mm)			
0°	90°	A	B	C	D
NNAMC0430PC01	NNAMC0431PC01	43.2	14.9	47.2	2
NNAMC0500PC01	NNAMC0501PC01	50.4	29.8	55.9	3.5
NNAMC0580PC01	NNAMC0581PC01	57.6	29.8	61.6	2
NNAMC0640PC01	NNAMC0641PC01	64.8	44.7	70.3	3.5
NNAMC0720PC01	NNAMC0721PC01	72	44.7	76	2

Product number		**Measurements (mm)**			
0°	**90°**	**A**	**B**	**C**	**D**
NNAMC0790PC01	NNAMC0791PC01	79.2	59.6	84.7	3.5
NNAMC0860PC01	NNAMC0861PC01	86.4	59.6	90.4	2
NNAMC0940PC01	NNAMC0941PC01	93.6	74.5	99.1	3.5
NNAMC1010PC01	NNAMC1011PC01	100.8	74.5	104.8	2
NNAMC1080PC01	NNAMC1081PC01	108	89.4	113.5	3.5
NNAMC1150PC01	NNAMC1151PC01	115.2	89.4	119.2	2
NNAMC1220PC01	NNAMC1221PC01	122.4	104.3	127.9	3.5
NNAMC1300PC01	NNAMC1301PC01	129.6	104.3	133.6	2
NNAMC1370PC01	NNAMC1371PC01	136.8	119.2	142.3	3.5
NNAMC1440PC01	NNAMC1441PC01	144	119.2	148	2
NNAMC1510PC01	NNAMC1511PC01	151.2	134.0	156.7	3.5
NNAMC1580PC01	NNAMC1581PC01	158.4	134.0	162.4	2
NNAMC1660PC01	NNAMC1661PC01	165.6	148.9	171.1	3.5
NNAMC1730PC01	NNAMC1731PC01	172.8	148.9	176.8	2
NNAMC1800PC01	NNAMC1801PC01	180	163.8	185.5	3.5
NNAMC1870PC01	NNAMC1871PC01	187.2	163.8	191.2	2
NNAMC1940PC01	NNAMC1941PC01	194.4	178.7	199.9	3.5
NNAMC2020PC01	NNAMC2021PC01	201.6	178.7	205.6	2
NNAMC2090PC01	NNAMC2091PC01	208.8	193.6	214.3	3.5
NNAMC2160PC01	NNAMC2161PC01	216	193.6	220	2
NNAMC2230PC01	NNAMC2231PC01	223.2	208.5	228.7	3.5
NNAMC2300PC01	NNAMC2301PC01	230.4	208.5	234.4	2

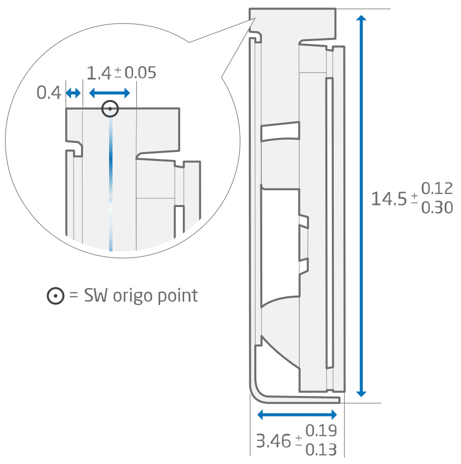
Product number		**Measurements, Non-Extended Range (mm)**					**Measurements, Extended Range (mm)**				
0°	**90°**	**A**	**B**	**C**	**D**	**From Firmware Version**	**A**	**B**	**C**	**D**	**From Firmware Version**
NNAMC2380PC01	NNAMC2381PC01	237.6	208.5	243.1	3.5	v1.38	237.6	Available on request	243.1	3.5	TBA
NNAMC2450PC01	NNAMC2451PC01	244.8	208.5	248.8	2	v1.38	244.8	Available on request	248.8	2	TBA
NNAMC2520PC01	NNAMC2521PC01	252	208.5	257.5	3.5	v1.38	252	Available on request	257.5	3.5	TBA
NNAMC2590PC01	NNAMC2591PC01	259.2	208.5	263.2	2	v1.38	259.2	Available on request	263.2	2	TBA
NNAMC2660PC01	NNAMC2661PC01	266.4	208.5	271.9	3.5	v1.38	266.4	Available on request	271.9	3.5	TBA
NNAMC2740PC01	NNAMC2741PC01	273.6	208.5	277.6	2	v1.38	273.6	Available on request	277.6	2	TBA
NNAMC2810PC01	NNAMC2811PC01	280.8	208.5	286.3	3.5	v1.38	280.8	Available on request	286.3	3.5	TBA
NNAMC2880PC01	NNAMC2881PC01	288	208.5	292	2	v1.38	288	Available on request	292	2	TBA
NNAMC2950PC01	NNAMC2951PC01	295.2	208.5	300.7	3.5	v1.38	295.2	Available on request	300.7	3.5	TBA
NNAMC3020PC01	NNAMC3021PC01	302.4	208.5	306.4	2	v1.38	302.4	Available on request	306.4	2	TBA
NNAMC3100PC01	NNAMC3101PC01	309.6	208.5	315.1	3.5	v1.38	309.6	Available on request	315.1	3.5	TBA
NNAMC3170PC01	NNAMC3171PC01	316.8	208.5	320.8	2	v1.38	316.8	Available on request	320.8	2	TBA
NNAMC3240PC01	NNAMC3241PC01	324	208.5	329.5	3.5	v1.38	324	Available on request	329.5	3.5	TBA
NNAMC3310PC01	NNAMC3311PC01	331.2	208.5	335.2	2	v1.38	331.2	Available on request	335.2	2	TBA

Product number		Measurements, Non-Extended Range (mm)					Measurements, Extended Range (mm)				
0°	**90°**	**A**	**B**	**C**	**D**	**From Firmware Version**	**A**	**B**	**C**	**D**	**From Firmware Version**
NNAMC3380PC01	NNAMC3381PC01	338.4	208.5	343.9	3.5	v1.38	338.4	Available on request	343.9	3.5	TBA
NNAMC3460PC01	NNAMC3461PC01	345.6	208.5	349.6	2	v1.38	345.6	327.7	349.6	2	v1.49

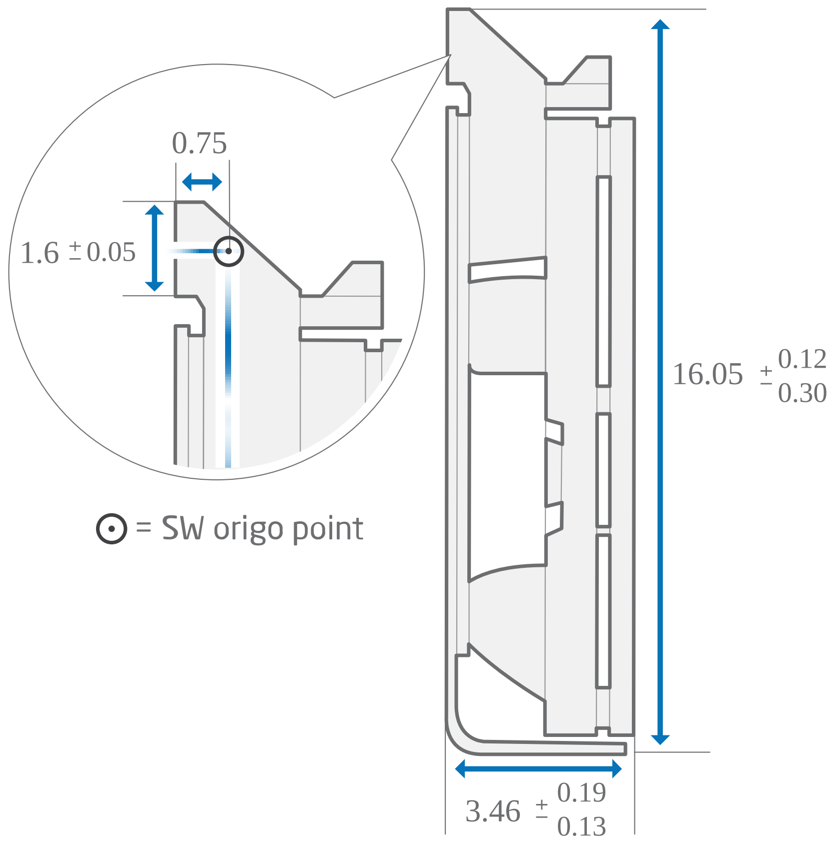
Side View

These measurements are identical for all sensor lenghts but vary some between the 0° and 90 ° types. The position of origin is marked with "zero software".

0° Type



90 ° Type



9.7.2 Packaging

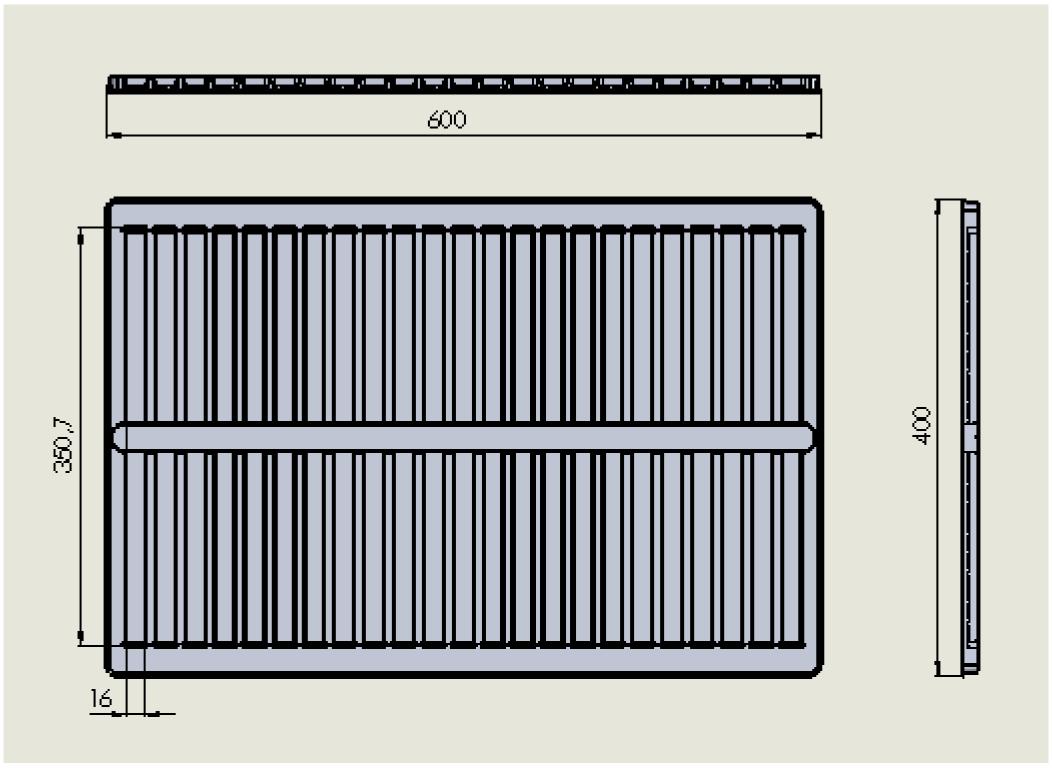
zForce AIR Touch Sensors are packed in trays stacked in cardboard boxes. The size of the sensor determines which tray size that is used.

Sensor size	Tray number	Blueprint (link)
043-122	36142	36142.EDRW[14]
130-158	36139	36139.EDRW[15]

14 http://confluence.neonode.local/download/attachments/76711547/36142.EDRW?api=v2&modificationDate=1557844336700&version=1
15 http://confluence.neonode.local/download/attachments/76711547/36139.EDRW?api=v2&modificationDate=1557844336653&version=1

Sensor size	Tray number	Blueprint (link)
166- 266	36141	36141.EDRW[16]
274-346	36138	36138.EDRW[17]

The image below shows the tray with number 36138:



9.8 Test Specifications and Definitions

9.8.1 Performance Test Methods

For specifications for the performance test methods, contact Neonode Support. Refer to https://helpcenter.neonode.com/hc/en-us/requests/new.

16 http://confluence.neonode.local/download/attachments/76711547/36141.EDRW?api=v2&modificationDate=1557844336677&version=1
17 http://confluence.neonode.local/download/attachments/76711547/36138.EDRW?api=v2&modificationDate=1557844336627&version=1