NANO Wireless Sensor
User Manual

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12	4/8/2022			SH	Updates to the UCT section
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9	7/16/2021			SH	Added customer service phone number and corrected section references
8	7/14/2020	AA	AW	SH	Addition of Wake Up feature to section 6. Moved UCT to section 5.
7	6/16/2020		AA	SH	Addition of the UCT Section
6	6/11/2020			SH	
5	2/5/2020			SH	Added MD instructions, minor grammar edits
4	11/5/2020			SH	Incorporated other manuals to make one
3	6/29/2020	AA	PL	SH	Inserted page breaks, added to specs
1	6/23/2020	AA	PL	SH	Initial combination of information into one doc.
Rev	Date				Description

TABLE OF CONTENTS

1 Introduction 6
2 Physical Specifications 7
3 Installation 8
3.1 Establishing Power 8
3.1.1 Step 1: Cover removal 8
3.1.2 Step 2: Battery Tab Insulator Removal 8
3.1.3 Step 3: Reassembly 10
3.2 Surface Preparation 11
3.3 NANO Orientation 12
3.4 Network Topology 16
4 Configuring a NANO in Machine Dossier 18
4.1 Configuration Steps 18
5 User Configuration Tool (UCT) 22
5.1 Requirements and Recommendations 22
5.2 Directions to Connect to the X8II 22
5.3 Nano Configuration 23
5.3.1 Configure NANO Device 24
6 General Operation 30
6.1 Measurement Configuration 30
6.2 Alarm Thresholds 31
6.3 Measurement Trigger 32
6.4 Measurement 32
6.5 Advertising 33
6.6 Connection 33
6.7 Sleep 34
6.8 Wake Up 34
6.8.1 Configuring the Wake-Up Settings via UCT 35
7 X8II Behavior 38
7.1 NANO Communication 38
7.2 Data Buffering 38
8 Maintenance and Troubleshooting 40
8.1 Battery Replacement 40

8.1.1 Step 1: Cover Removal 40
8.1.2 Step 2: Battery Support Removal 40
8.1.3 Step 3: Remove the Existing Battery 41
8.1.4 Step 4: Install New Battery 42
8.1.5 Step 5: Reassemble 42
8.2 LED Flash Codes 44
8.3 Firmware Update 45
8.3.1 Set the NANO to “Firmware Update Mode” 45
8.3.2 Using IOS to Perform a Device Firmware Update (DFU) 46
8.3.3 Using Android to Perform a DFU 52
9 Glossary 56
10 Index 57

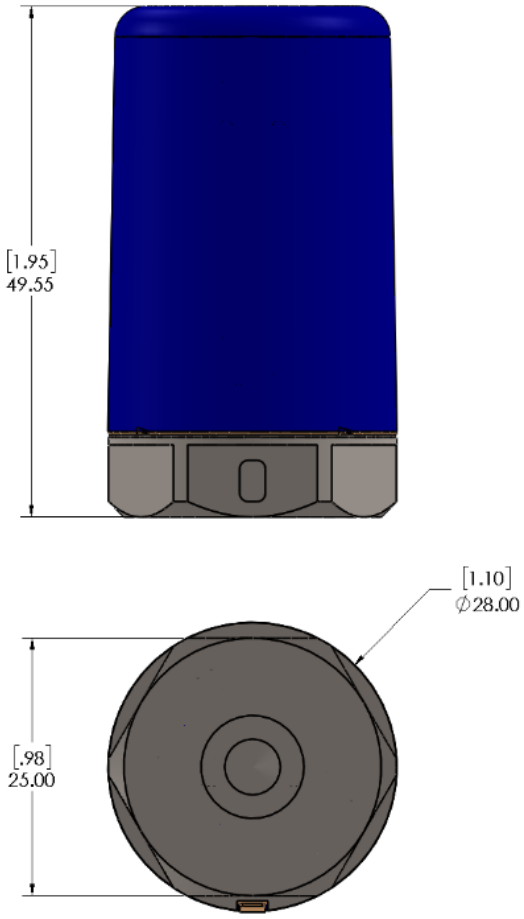
1 INTRODUCTION

The purpose of this document is to introduce the user to the new NANO wireless condition monitoring device and provide information on installation, maintenance, and operation.

The NANO wireless sensor comes equipped with a triaxial measurement point, designed to capture vibration profiles of production equipment, and a surface temperature sensor. This data is used to help predict future downtime due to mechanical imbalance or failure. The device is battery powered which enables easy installation onto existing equipment.

NANO measurement intervals are configured inside of Machine Dossier (Section 4). Measurements are sent wirelessly via Bluetooth Low Energy (BLE) 5.0 to an X8II which transmits via Wi-Fi 802.11b/g/n to the Machine Dossier server. This BLE link between NANO and X8II allows the NANO to minimize power consumption to prolong battery replacement intervals. One X8II can service multiple NANOs (up to 16) in a round robin fashion.

2 PHYSICAL SPECIFICATIONS



Dimensions
Height: 49.55mm (1.95”)
Diameter: 28mm (1.10”)

Weight
73g (0.16lbs)

Temperature Range
-40°C to 85°C internal
-40°F to 185°F

Humidity Range
IP66 with sealed gasket

G-Force Maximum
16g

Battery
½ AA ER14252 XL-050F
Voltage: 3.6V
Nominal Capacity: 1.2Ah

3 INSTALLATION

3.1 ESTABLISHING POWER

Before putting the NANO into service, power needs to be established. This can be done by removing the cover which will expose the plastic tab interrupting battery power to the positive terminal. Please follow the steps below to establish power.

3.1.1 Step 1: Cover removal

Unscrew the blue cover by placing one hand on the metal hex base and one hand on the cover (Figure 1). Rotate the cover counterclockwise, and the hex base clockwise, until the cover is fully disengaged with the hex base and pull it straight up and off the unit.

Figure 1: Cover Removal

3.1.2 Step 2: Battery Tab Insulator Removal

Pull the plastic tab disconnecting the battery from the positive terminal away from the unit (Figure 2). It should slide from in between the positive terminal and battery, and power should be connected once the tab is removed. Discard the plastic tab.

Figure 2: Battery Insulator Removal

On top of the unit, you should see an LED light (Figure 3) flash bright green 7 times, then remain solid green for 10 seconds before finally turning off. This means you have established power and the unit is ready to be reassembled and installed.

If the LED flashes red during this step, it means it has failed one or more self-tests. The unit will continue to loop the same self-tests every 10 seconds if one or more failures are present. Remove the battery and re-install to see if this resolves the problem. If it does not, and the unit continues to fail and repeat its self-test procedure, please refer to section 8.2.

Figure 3: LED Location

3.1.3 Step 3: Reassembly

Once power is established and the battery insulator tab has been discarded re-install the cover by screwing it back on the metal hex base, rotating them in reverse directions from step 1. The cover should be seated at a torque value no greater than 15 in-lbs (2.63N-mm). Hand tighten only and do not overtighten, as this might compromise the seal.

If the NANO is being installed in a severe environment, additional gasket seal will be supplied and should be applied before cap is installed. Please apply a thin bead of the supplied gasket seal on the lip around the metal hex base, where the cover and base contact when the cover is fully tightened. See figure 4 below.

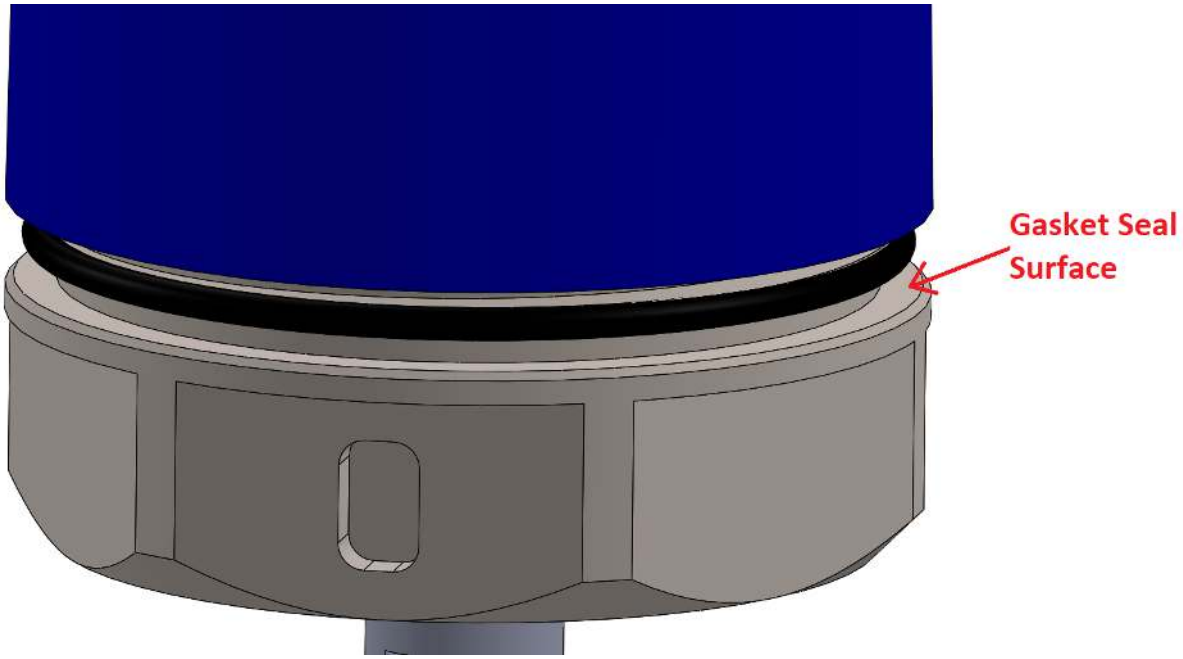


Figure 4: Gasket Seal Application Location

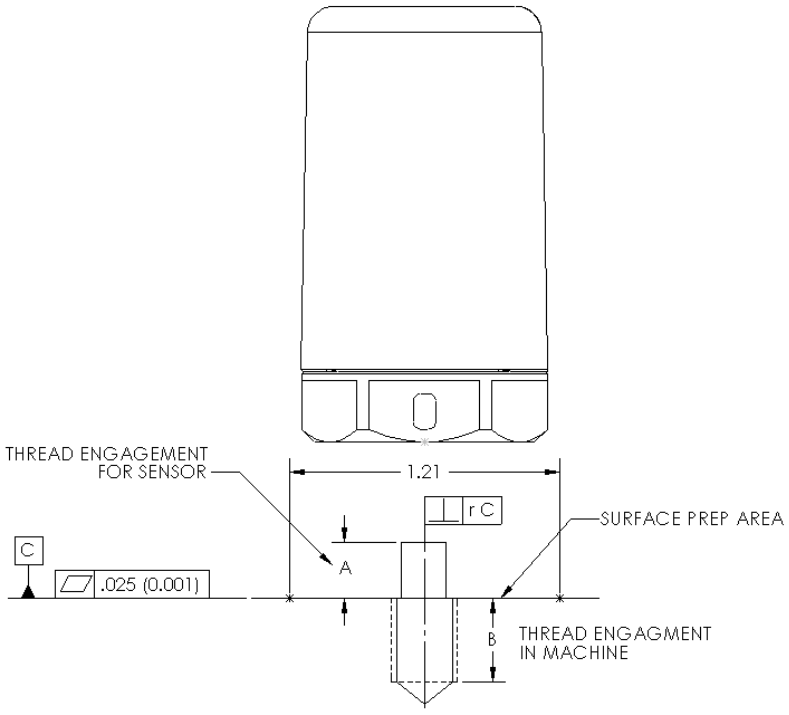
3.2 SURFACE PREPARATION

There are many types of mounting methods for vibration sensors with stud mounted, adhesive mounted, magnet mounted and probe tip being the most popular choices.

Stud mounting provides the most secure method of attachment and widest frequency response and is recommended when mounting the NANO. Most other mounting methods reduce the upper frequency range of the NANO device. When intimate contact with the measurement point is disturbed by introducing alternate mounting pieces such as adhesive pads, magnets, or probe tips, the mounted resonance is altered.

Distance from the measurement point is also something to consider. The further the NANO is from the measurement point, the lower the mounted resonance and the lower the useable frequency range.

To stud mount the NANO proper surface preparation is recommended. Figure 5 below illustrates the ideal mounting area preparation.



	1/4-28 Stud	1/4-28 Captive Screw
A (in.)	0.250	0.250
B (in.)	0.375	0.375
Torque (in-lb)	26	30

Figure 5: Surface Prep

It is also recommended to lightly coat the mounting surface with a lubricant. This coating aids in the transmissibility of the higher frequency response of the NANOs. Silicone vacuum grease, heavy machine oil, or bees wax are commonly used.

3.3 NANO ORIENTATION

The NANO can take measurements in three directions that are defined as the X, Y and Z axes. Figure 6 below shows the orientation of these axes as they relate to the NANO geometry.

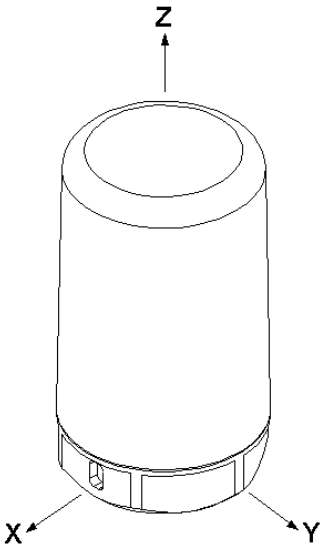


Figure 6: Axis Orientation

Take note of the X and Y axes orientations, which can be identified during installation by using the axis indicator located on the metal hex base (Figure 7). This indicator will be used to identify the X-direction. Once the X-direction has been identified, one can deduce the Y-direction is perpendicular to this indicator.

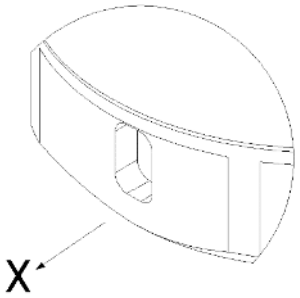


Figure 7: X-axis Indicator

Figure 8 shows the potential positioning of three different NANOs on a motor that have been attached using motor fin mounts. Facing the motor shaft face of figure 8 below we can identify the NANO positions as 12 o'clock (vertical, top), 9 o'clock (horizontal, left side) and 3 o'clock (horizontal, right side).

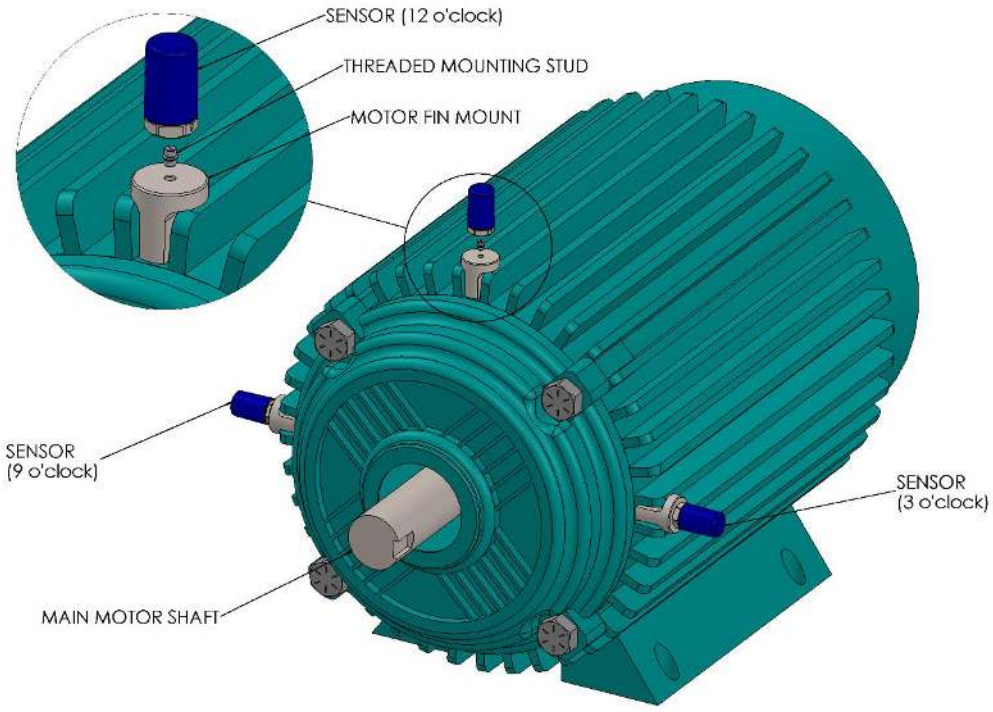


Figure 8: Location of NANOs on a Machine

X and Y-axis orientation of each measurement point is critical during installation. Figure 6 can be used to determine the X, Y and Z orientation of each NANO. Figure 9 shows the proper positioning of the NANO when mounted in the 12 o'clock (vertical) position. The Y-axis should be parallel with the main motor shaft, while the X-axis should be perpendicular.

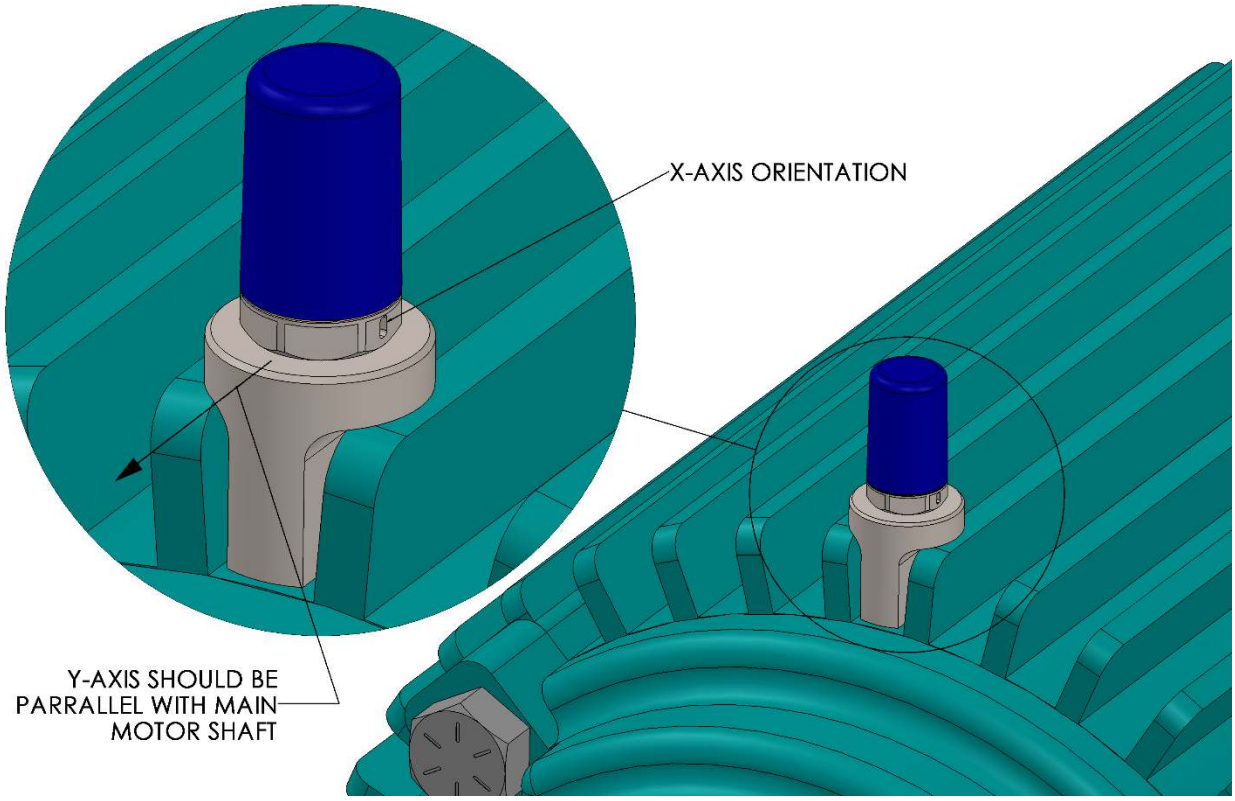


Figure 9: 12 o'clock NANO Orientation

Figures 10 and 11 show the correct mounting orientation of the NANO when mounted horizontally in the 9 o'clock or 3 o'clock position. The X-axis indicator should face toward the ground and should not point upward. If the axis indicator faces upward this might add additional error to any measurements taken in the X-axis direction.

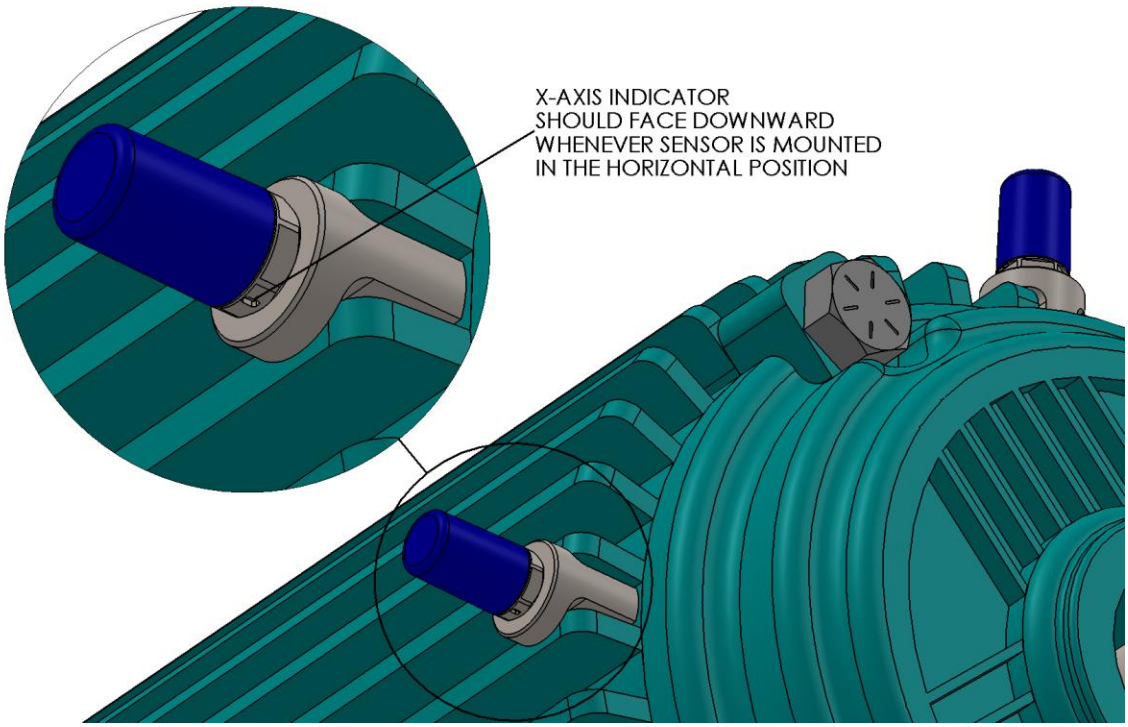


Figure 10: 9 o'clock NANO Orientation

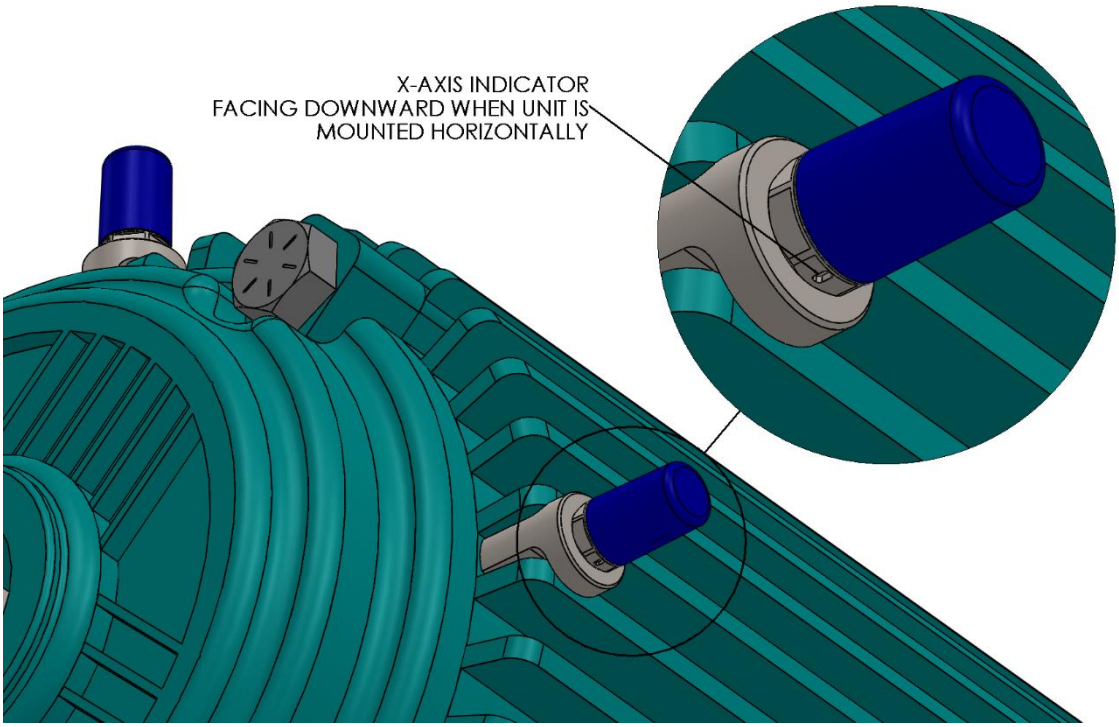


Figure 11: 3 o'clock NANO Orientation

3.4 NETWORK TOPOLOGY

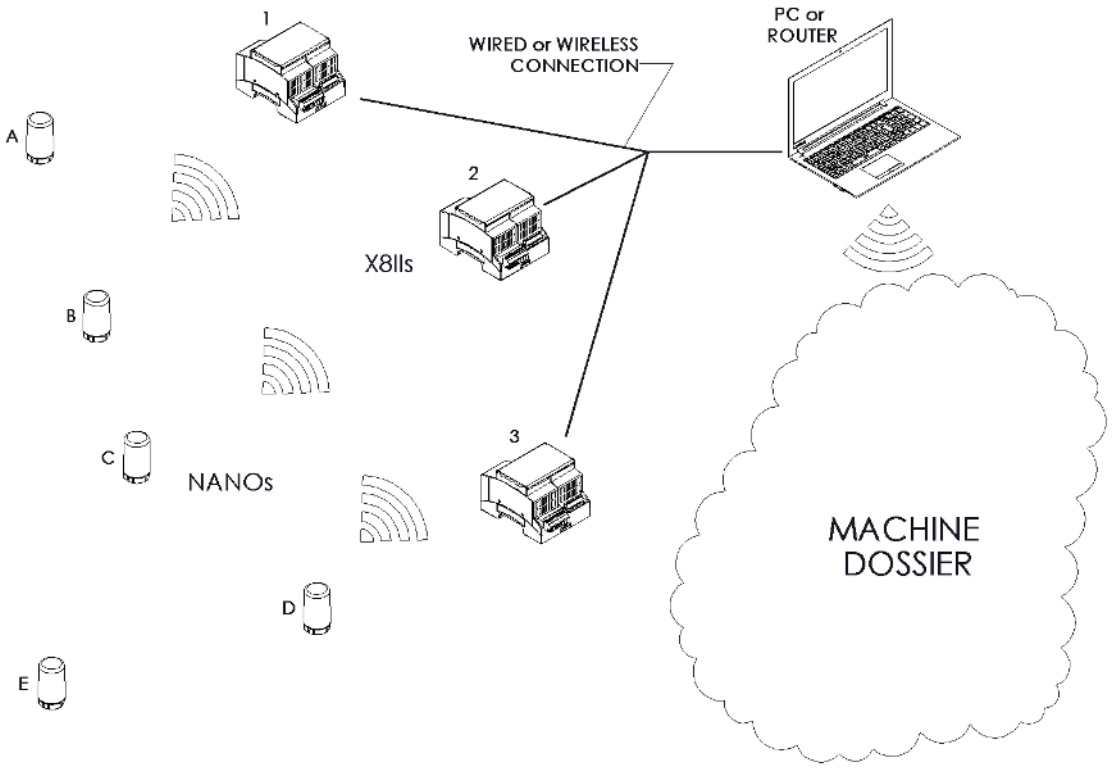


Figure 12: Network Environment

Upon successful installation a NANO will communicate – via Bluetooth transmission – with every X8II within reach of its signal. Once a NANO takes measurements it will send out a signal letting the X8IIs within range know it is ready to offload measurement data. The first X8II to receive this signal will begin uploading data from the NANO. For example, if NANO C is ready to offload data and sends an advertisement signal out letting X8IIs 1, 2 and 3 know it is ready, the first X8II to receive this signal will upload NANO C's data. Even though this method is like a traditional mesh network system, it is more efficient on sensor battery life since each NANO can power down after it has successfully offloaded measurement data.

Once the data has been received by an X8II, it can be forward via a wired or wireless signal to a PC or router which can then transmit the data to Machine Dossier for further analysis. NANOs cannot forward data directly to a router or PC and cannot forward data to one another, they only forward data to an X8II. By tracking which X8IIs forward which NANOs data, one can see how well the X8IIs are distributed in the installation environment. Efficiency of communication can then be monitored, and X8IIs can be moved into a formation that optimizes throughput without the need to re-connect NANOs since they will automatically connect with any X8II within signal range.

X8IIs can also communicate directly via a hard-wired USB connection. When choosing to communicate with the X8II in this fashion the user can change the configuration,

update firmware or perform direct connection to a NANO for machine vibration diagnostics. For example, let us say X8II #3 above is connected to NANOs C, D and E. If the end user connects to X8II #3 using a USB to USB (male to male) cable and connects the other end to their PC, they can then log into the User Configuration Tool (UCT) software on their PC and select which NANO (C, D or E) they would like to communicate with and configure.

Tips for maximum performance:

1) Locate NANOs as close as possible to at least one X8II unit.
2) Ensure clear line of site between NANOs and X8IIs. This will minimize communication interference.
3) Minimize RF interference in the installation environment.

Warnings:

1) Difficult-to-Reach Locations: Narrow corridors, tight spaces, areas crowded with machines and low to the ground applications can hinder wireless connectivity. If the installation environment includes multiple rows of machines, a canyon effect might occur between the rows if wireless devices are installed within a canyon. This effect might hinder communication to these devices. Antenna height can be raised to overcome such an effect, but antenna adjustment is not possible in every case. Another solution is to use the reflectivity of adjacent machines to bounce the signal down into the canyon, taking advantage of the reflective nature of the surrounding equipment.
2) RF Interference: Many common devices produce RF energy: microwave ovens, cell phone hotspots, automobile hotspots, personal Bluetooth devices and many others. RF energy can interfere with factory wireless operations and steps should be taken to ensure the installation environment is protected from RF interference as much as possible. Distance, containing rooms and changing RF band are a few of the ways to mitigate RF interference from outside devices, and should be implemented if RF interference is prevalent in your factory's installation environment.
3) Ensure pipes, conduit and any other metal or concrete structures are accounted for during installation. Wireless communication can be affected negatively by any such structures. Steps should be taken to optimize location and line of site between all NANOs and X8IIs. Failure to take these suggestions into account during the initial installation might lead to intermittent signal issues, or worse no signal transmission at all.

4 CONFIGURING A NANO IN MACHINE DOSSIER

The purpose of this section is to outline the steps necessary to properly configure a NANO in MD. Staging MD was used to show these steps.

4.1 CONFIGURATION STEPS

Assuming that a machine has already been properly added to Staging, hover over the “Add” button and click “Measurement Point”.

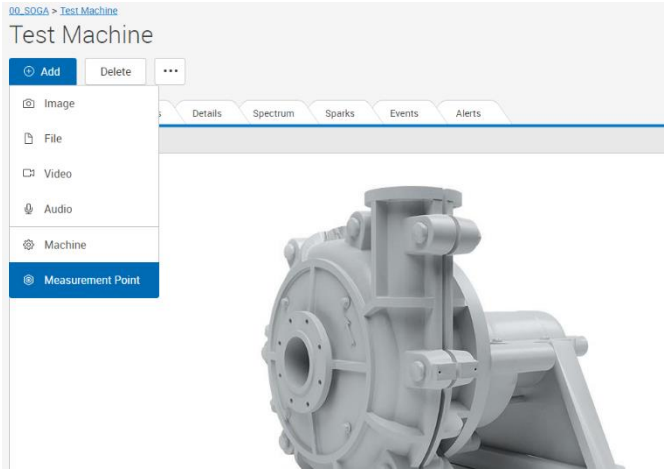


Figure 13: Adding a measurement point to a machine.

In the menu that appears afterwards, select “Zark Nano”.

Figure 14: Adding a NANO to the machine.

The details menu is where the user can make specific configurations to the NANO. The “Name” field can be anything, but the NANO SN should match the assigned SN of the NANO. The serial number(SN) of the NANO can be located on the physical device. The “sensor orientation” allows the user to specify which axis will be displayed once the unit begins to send measurements. The “Spectrum Resolution” field allows the user to select how much detail they would like to see in the spectra for the NANO. The spectra and the waveform plots can also be specified in this page. Filters can also be configured here. Once complete, click “Next Step”.

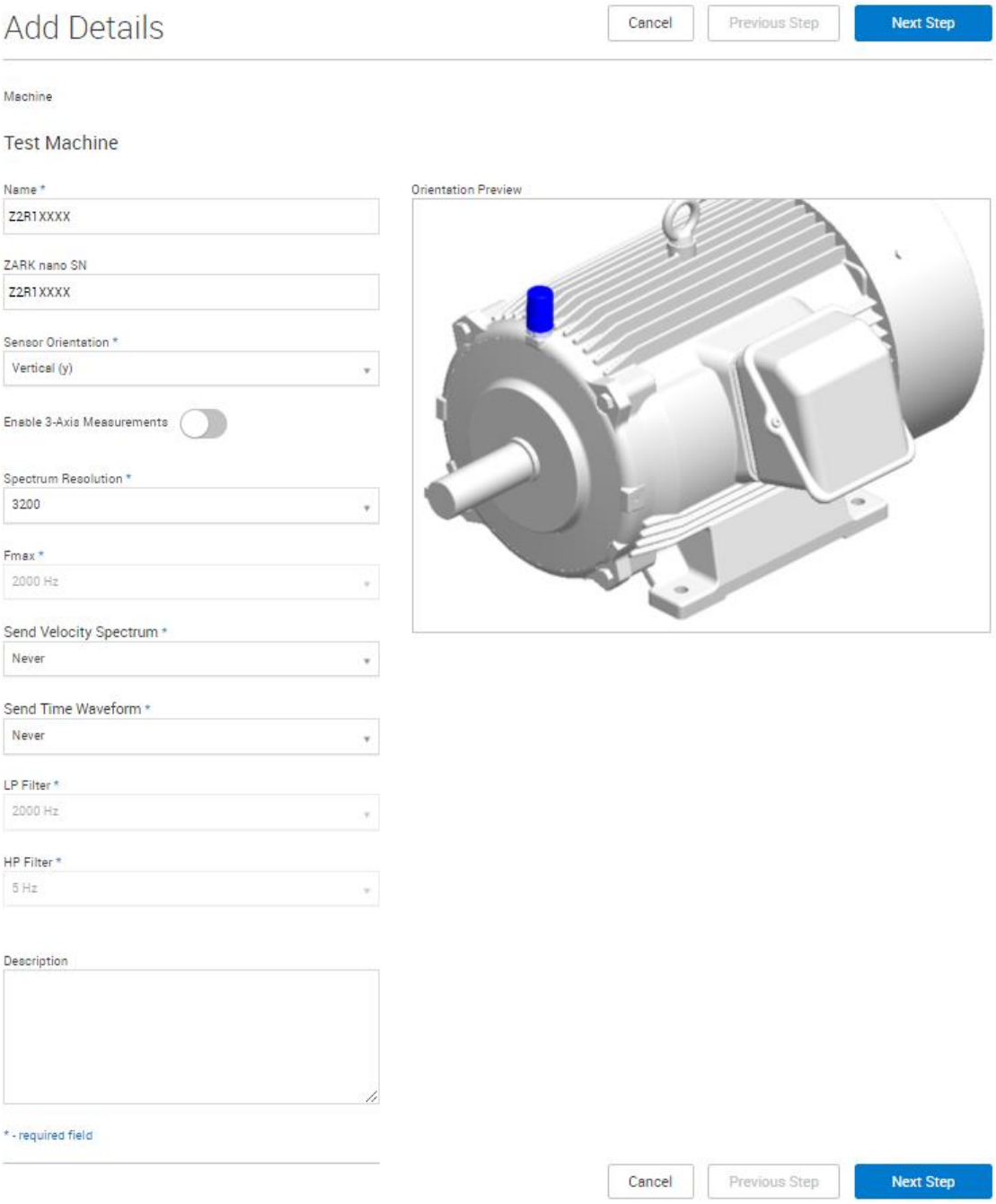


Figure 15: Details of NANO configuration.

In the location menu, the user can move the “New Measurement Point” to where they desire. The position and orientation of the measurement point along with the unit displayed can also be configured here. Keep in mind that all these changes are not permanent and measurement point can be edited later if the user chooses to make a different configuration. Click “Next Step” when finished.

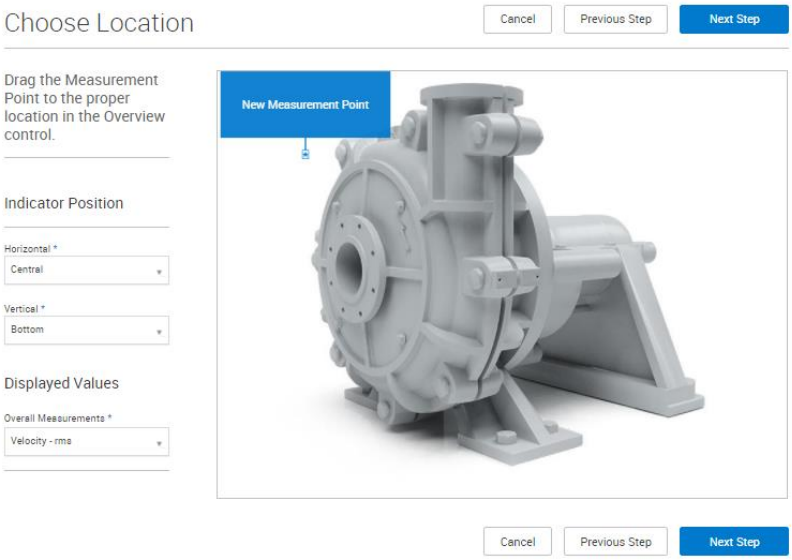


Figure 16: Choosing a location for the new measurement point.

The summary page shows all the configurations for the new measurement point. Click “Add Measurement Point” after reviewing the details.

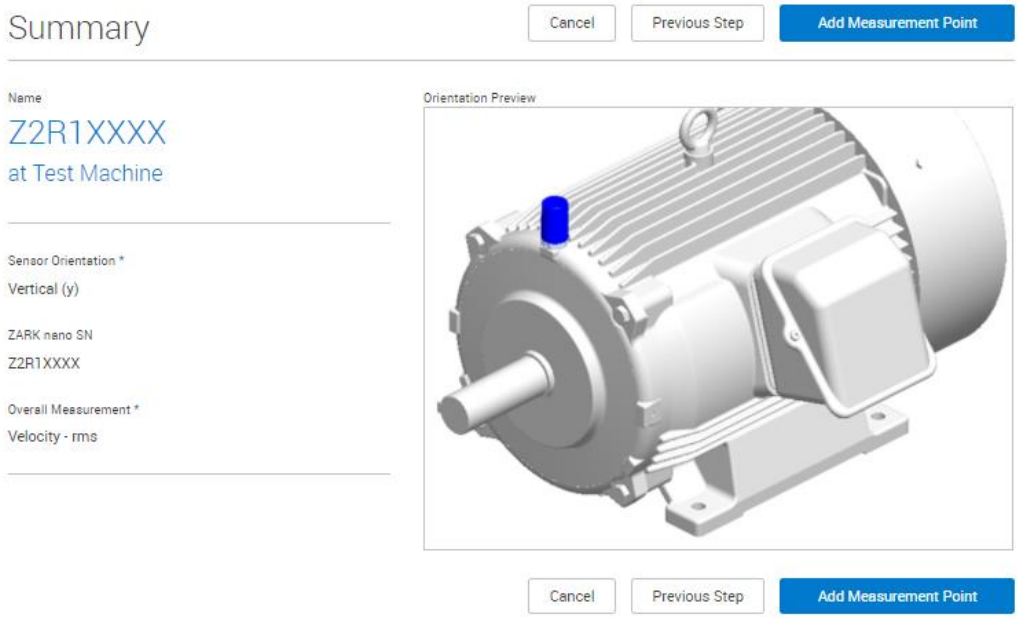


Figure 17: Summary of the new measurement point.

A message will pop up saying that a new measurement was configured. Verify the serial number of the unit and click “Ok.”

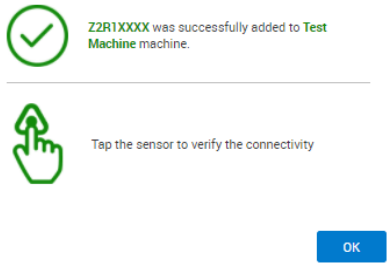


Figure 18: Final dialogue box to complete setup.

This is what the measurement point will look like after the user has successfully added it to the machine.

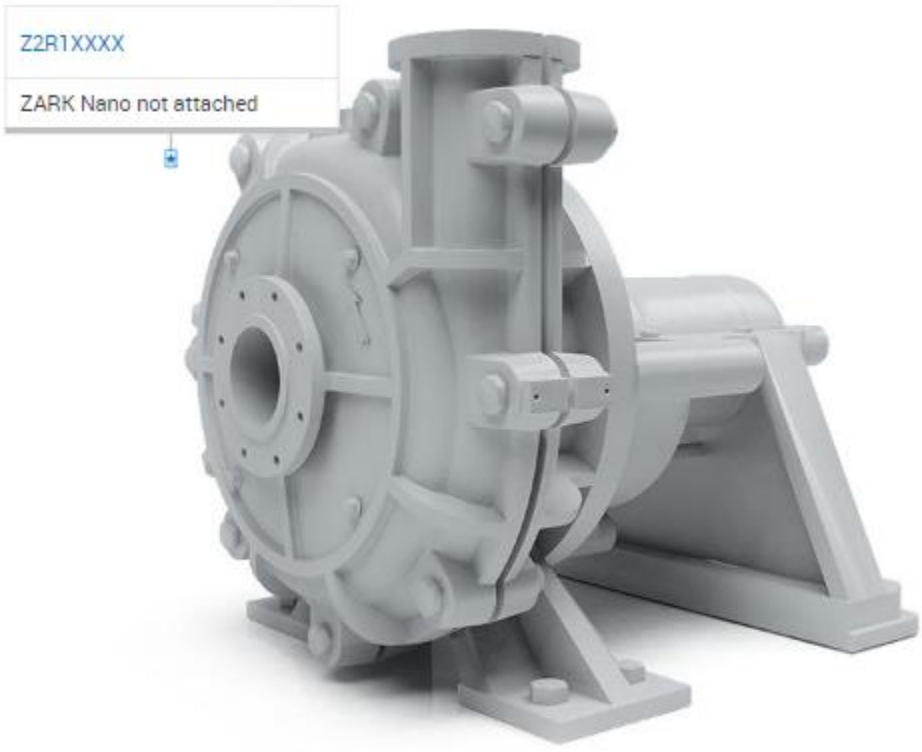


Figure 19: NANO registered to the machine.

5 USER CONFIGURATION TOOL (UCT)

This section will provide a clear step-by-step description of how the NANO can be configured using the User Configuration Tool (UCT). The User Configuration Tool is a Windows graphical application that can directly configure the X8II and the NANO. It is also equipped with the ability to import, export, and to retrieve configurations from the X8II and NANO units.

This section only covers NANO Configuration within the UCT. For more information on the UCT please refer to section 6 in the X8II User Manual.

5.1 REQUIREMENTS AND RECOMMENDATIONS

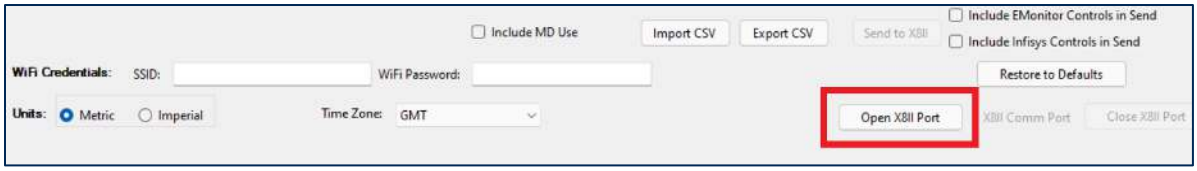
- A micro-USB cable to establish connection with the hardware.
- Access to Microsoft Excel is recommended to access full functionality of the X8II but is not required.
- To have full access to all described features, the X8II must be on firmware version 2.2.4 or later.

5.2 DIRECTIONS TO CONNECT TO THE X8II

Prior to running the UCT and connecting to the X8II, it is expected that the user has already made the physical connection between the X8II and PC by using a mini-USB (X8II) to USB (PC) cable (see cable example below).

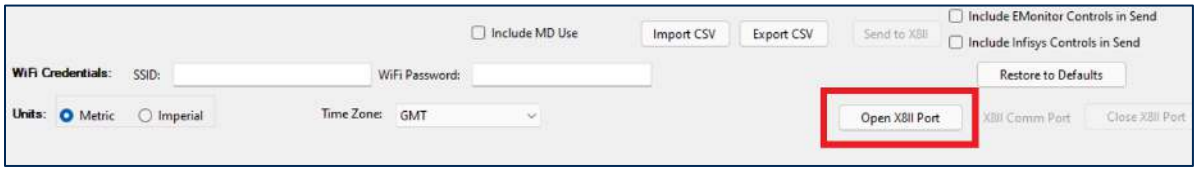
If the X8II is NOT currently powered on, follow this sequence:

1) Power on the X8II
2) Open the UCT and click the “Open X8II Port” button.
3) A dialogue box will appear letting the user know a connection has been established.

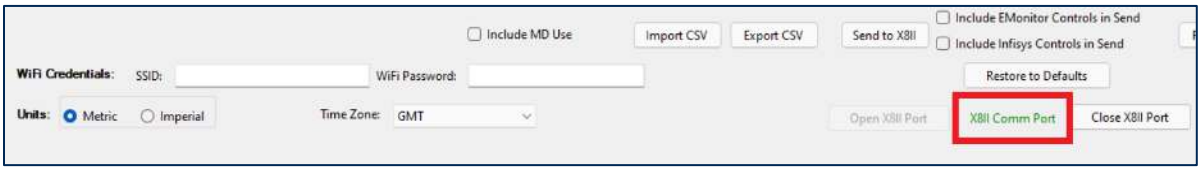


If the UCT is running already and the X8II is also powered up and running, follow this sequence:

1) Power cycle the X8II
2) In the already opened UCT, click the “Open X8II Port” button.
3) A dialogue box will appear letting the user know a connection has been established.



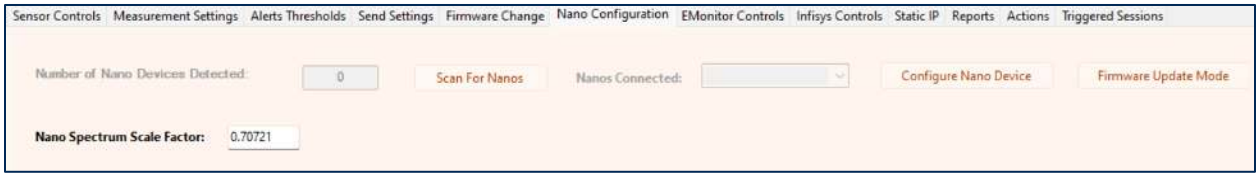
This will make the X8II available for the UCT to configure. Note the “X8II Comm Port” text will turn green when the port is available.



To disconnect, simply click the “Close X8II Port” button.

5.3 NANO CONFIGURATION

Once connected to the UCT, navigate to the Nano Configuration tab. This tab will be used for all the instructions that follow.

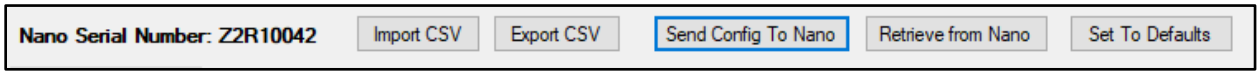


Number of NANO Devices Detected: This field will show how many NANOs that the X8II can see after clicking the “Scan for NANOs” button.
Scan for NANOs: This button will scan for all available NANOs. It will update the **Number of NANOs Detected** box and will show all NANOs under the **NANO’s Connected** drop-down.
NANO’s Connected: This drop-down displays the serial numbers of all NANO units that the X8II was able to scan for.
Configure NANO Device: Once a NANO is selected from the **NANO’s Connected** drop-down, it can be configured via this button which will bring up a new configuration window.
Firmware Update Mode: This button will place the specified NANO from the drop-down list to activate bootloader mode.
Nano Spectrum Scale Factor: This scale factor allows the user to scale the spectrum values if there is a desire to scale them. It should normally be left at .70721

5.3.1 Configure NANO Device

The NANO configuration window has five main sections: *General Use*, *Global Configuration*, *Per-Axis Configurations, Reports* and *Actions* sections.

5.3.1.1 General Use



This section reports the serial number of the unit and has three main buttons.
Import CSV: This button is used to import configurations from a CSV file to the Zark Nano device.
Export CSV: This button is used to export configurations to a CSV file from a Zark Nano device.
Send Config to Nano: This button will send the configurations made by the user to the NANO. A confirmation dialogue box will pop up when the send is successful.
Retrieve from Nano: This button will retrieve the configurations from the NANO unit and populate all necessary field.
Set to Defaults: This button will set all configurable fields to default values.

5.3.1.2 Global Configurations

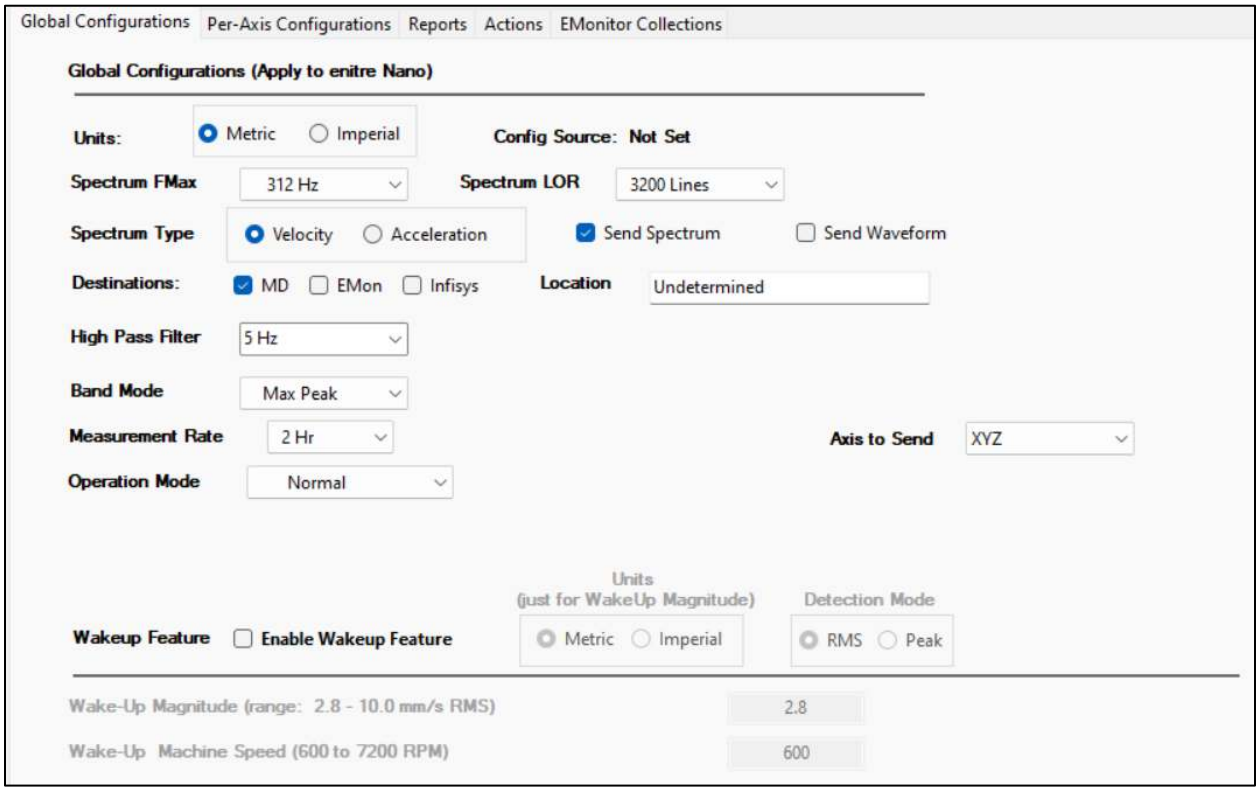


*Image above displays all possible entry fields but depending on which version of the UCT is being used, not all these fields (or tabs) may display.

Units: Metric vs. Imperial. This will influence the units on how measurements are reported.
Config Source: This will change with configurations either set by the UCT or MD.
Spectrum Fmax: Used to change the Fmax value via a drop-down menu. Available values from the drop-down menu include:

- 312 Hz
- 625 Hz
- 1250 Hz
- 2500 Hz

Spectrum LOR: Resolution of Spectra of measurements.

- 800 LOR
- 1600 LOR
- 3200 LOR

Spectrum Type: Velocity or Acceleration.
Send Spectrum: Checkbox that will send the spectrum of the measurement.
Send Waveform: Checkbox that will send the waveform of the measurement.
Destinations: the unit can send to Machine Dossier (MD), EMonitor (EMon), and/or infiSYS Lite.
Location: Entry box for user defined location of unit.

High Pass Filter: Drop-down menu allows selection of 2 or 5 Hz.
Band Mode: Energy band thresholds of NANOs.

- Max Peak
- Root Sum of Squares (RSS)
- MD Mix: Configurations received by MD. (Called such because it is the non-configurable mix that MD allows)

There are 6 different frequency bands, all of them are velocity thresholds:

- BandA: 1x RPM
- BandB: 2x RPM
- BandC: 3x RPM
- BandD: 4x RPM
- BandE: Sub 1x RPM
- BandF: Over 1x RPM

Band Mode choices are applied to all 6 for “Max Peak” and “Root Sum of Squares (RSS).”
If “MD Mix” is specified, the unit measurement type for the 1st four frequency bands (1x, 2x, 3x, 4x RPM) will be Max Peak, but the bottom 2 (Sub 1x RPM and Over 1x RPM) will be RSS.
Measurement Rate: Controls how often the NANO sends a measurement to the specified location.

- 1 Hour
- 2 Hour
- 4 Hour
- 6 Hour
- 12 Hour
- 24 Hour

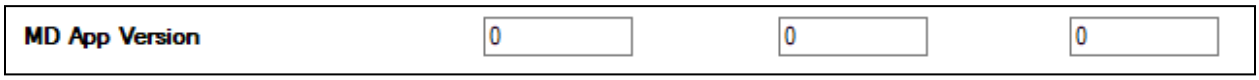
Operation Mode: Swap between Normal and Triggered Sessions. Triggered Sessions mode allows measurement intervals to be triggered at a defined custom rate.
Axis to Send: Controls which Axis will be sent to the specified location.

- X, Y, Z and XYZ

Wake-Up Feature: Checkbox that allows the use of the Wake-Up feature if enabled.
Units: Choose between Metric or Imperial units.
Detection Mode: RMS or Peak options are available currently.
Wake-Up Axis Reference: The reference value of the wake-up feature, set to 9806.65 $\frac{mm}{s^2}$.
Wake-Up Axis Magnitude: Magnitude of wake up required for the feature to trigger. Consult section 6.8 of the NANO User Manual for additional information.
Wake-Up Machine Speed: Machine speed required to for feature to trigger. Consult section 6.8 of the NANO User Manual for additional information.

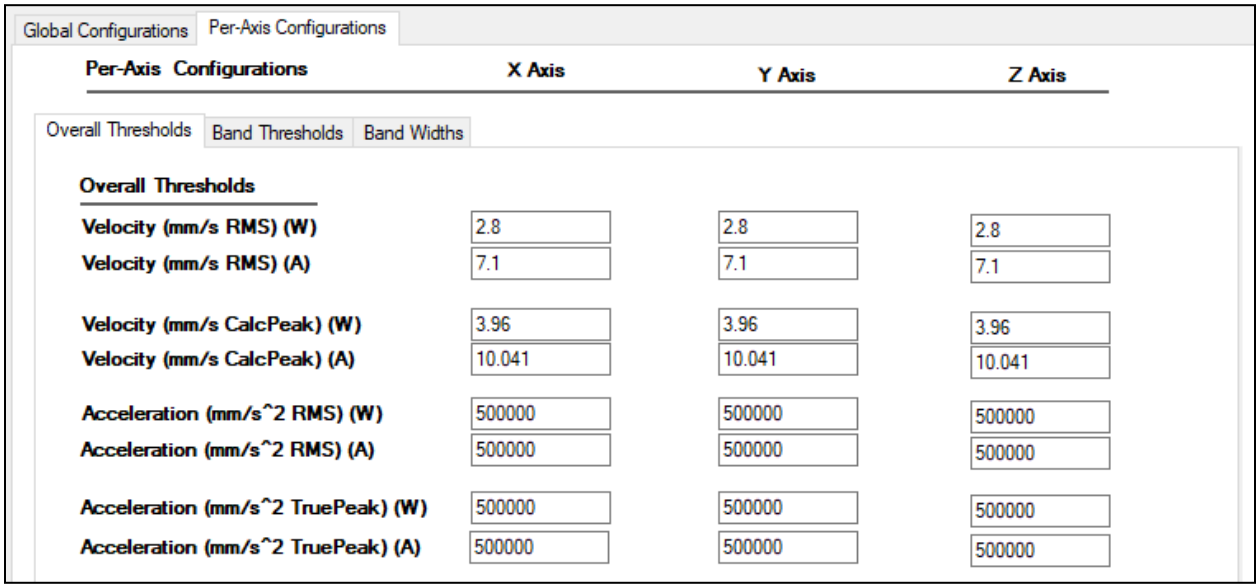
5.3.1.3 Per-Axis Configurations

This tab has three main views: *Overall Thresholds*, *Band Thresholds*, and *Band Widths*. These tabs are used to make axis specific configurations to the NANO.



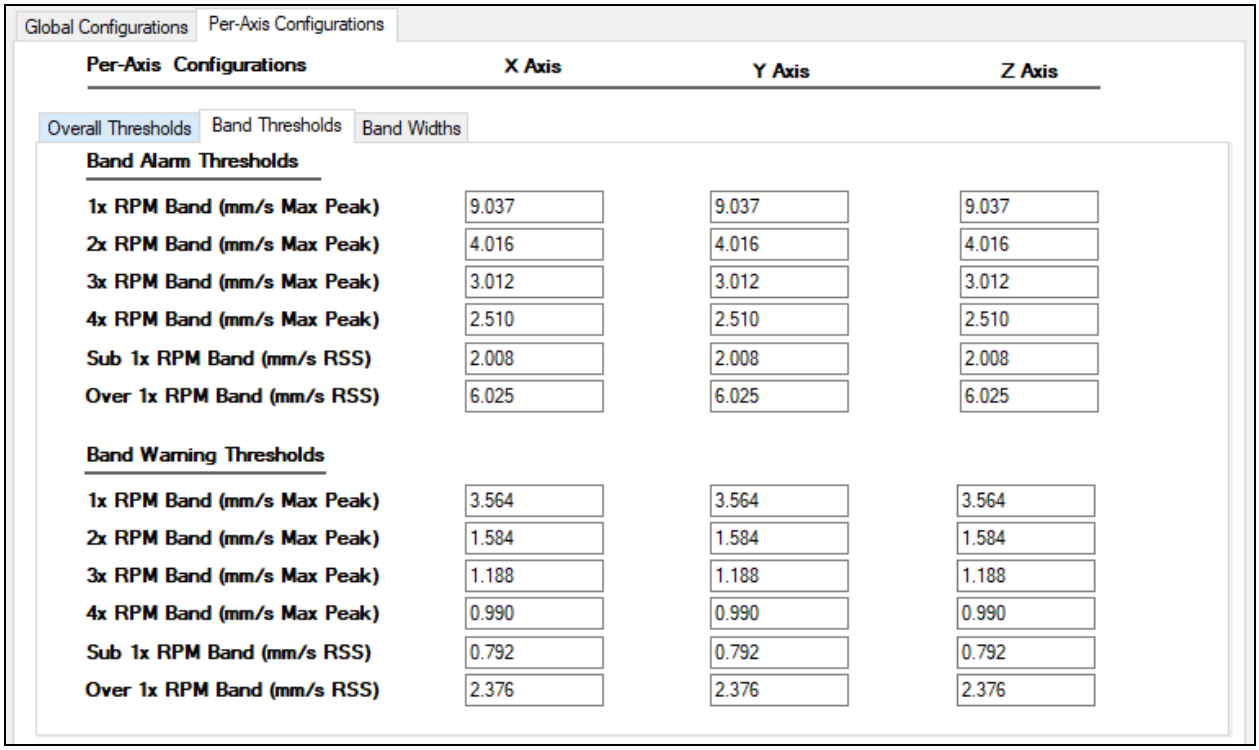
The MD App version is reported below the tab for each axis, but this will only be visible if MD has been selected as one of the destinations in the NANO Configuration form. If EMonitor has been selected, this will not display.

Overall Thresholds



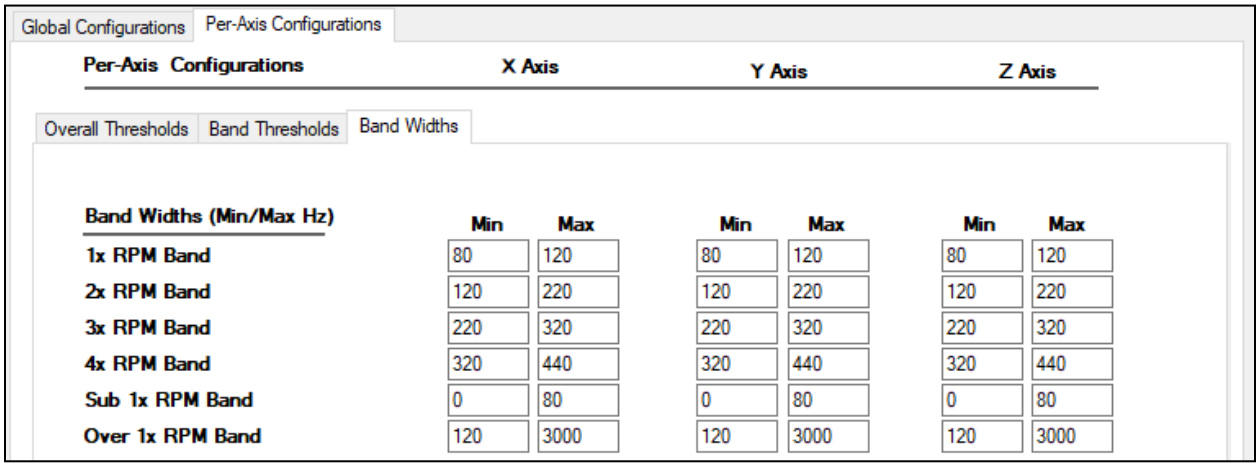
This tab defines warming and alarm values for velocity and acceleration measurements for all three axes.

Band Thresholds



This tab allows the user configure Band Alarm Thresholds and Band Warning Thresholds for all axes.

Band Widths



This tab can be used to specify Min and Max values for the allotted RPM Bands.

5.3.1.4 Reports

Get Nano Firmware Version: Retrieves current FW version of selected NANO.

5.3.1.5 Actions

Basic

Trigger Measurement: Triggers a measurement from the NANO unit.
Delete Measurement: Deletes all saved measurements on the NANO unit.

6 GENERAL OPERATION

An overview of the major components of the NANO are detailed below. Specifics of each component are detailed further in later sections.

Measurement Configuration – The parameters used to define the NANOs behavior are configured from within Machine Dossier or smart phone application. These updates will be saved local to the NANO.

Alarm Thresholds – Machine Dossier allows for setting variable alarm thresholds. These thresholds when exceeded will decrease the measurement interval.

Measurement Trigger – Four events trigger a measurement: acceleration magnitude, tap to wake, interval elapse, or valid BLE connection request for measurement.

Measurement – Following a measurement trigger event for each axis configured the NANO will sample, compute, and store results.

Advertising – NANO is a Bluetooth Low Energy (BLE) 5.0 peripheral. It advertises its status for BLE scanners. This advertisement is dynamically updated to reflect the NANOs status at a rate of 100-2000milliseconds.

Connection – X8II or smart phone application can attempt to form a connection with the NANO at any time based on its advertisement data. The X8II will form these connections to download measurement data or update the measurement configuration.

Sleep – The NANO is in sleep state between measurement triggers or BLE advertisements.

NANO Wake Up – Detects high magnitude events and gathers more data. The NANO Wake Up feature is only supported for the Z axis orientation.

6.1 MEASUREMENT CONFIGURATION

To accommodate multiple installation environments the measurement parameters can be configured to adjust the measurement results. The configuration, or baseline, is saved local to the NANO and is able to survive battery change intervals. The chart below highlights the options available for configuration.

Parameter	Range	
Measurement Range	± 2,4,8,16	G
Sampling Frequency	800, 1600, 3200, 6400	Hz
Low Pass Filter Cutoff (Frequency max)	355, 710, 1420, 2840	Hz
Samples Gathered	6144, 12,288, 24,576	Samples
Spectrum Resolution	800, 1600, 3200	LOR
Spectrum Sample Overlapping	50%	
Spectrum Averages	5	Spectrums
Spectrum Windowing	Hanning	

Measurement Interval	1,2,4,6,12,24	*Hours

* During initial install shorter duration bring-up/ring out times are available to provide baseline data on machine

Example:

±16G, 6400Hz sample frequency, 3200 LOR

Frequency Max = 2840Hz

Sampling Time (Samples / Sampling Frequency) = (24576 / 6400Hz) = 3.84 seconds

Bin Width (sampling frequency / 2.56) / LOR = (6400Hz / 2.56) / 3200 LOR = 0.781Hz per bin

6.2 ALARM THRESHOLDS

Two types of alarms exist for configuration within Machine Dossier: overall limits and spectrum band limits. Each alarm has two severity levels: warning and alarm.

When a measurement parameter exceeds a warning level a spectrum is sent to Machine Dossier.

When a measurement parameter exceeds an alarm limit a spectrum is sent and the measurement interval is reduced by a factor of 2 with a minimum measurement interval of 1 hour. This is true for measurements gathered in the warning state as well.

The set time limit interval assumes a potential limitation that a fleet of NANOs can experience when the connection between the machine and the server is interrupted. Due to this reason, it has been determined that an interval rate of no less than 1 hour is optimal for the machines, regardless of normal, warning, or alarm states. Furthermore, in the event of a communication interruption, the user can specify one of the following protocols.

1. **Hold gathered data collected by the machine. This process will ensure the latest measurement which did not get through the server will wait for the connection to be re-established.**
2. **Begin to overwrite data using the storage area in the NANO as a FIFO (Fist in → First out) buffer.**

Overall Limits – Overall limit threshold values are set at the machine level in Machine Dossier. The default threshold values are based on ISO 10816-1 revision 2012. The units for the available limits are velocity rms, velocity calculated peak, acceleration RMS, and acceleration true peak.

Spectrum Band Limits – Spectrum band frequency ranges are configured at the NANO level in Machine Dossier. These limits default to ratios of the machines operating frequency.

Example: Machine frequency is set at 3600 RPM which is equal to 3600RPM / 60 seconds per minute = 60Hz. CIV 1x RPM spectrum band limit defaults to a lower frequency limit of 0.8 would equate to 60Hz * 0.8 = 48Hz and an upper frequency limit of 1.2 or 60Hz * 1.2 = 72Hz. Any velocity peak inside this 48Hz – 72Hz range which exceeds the magnitudes defined by ISO 10816-1 revision 2012 will result in a warning / alarm event.

6.3 MEASUREMENT TRIGGER

Four events can trigger a measurement: acceleration magnitude, tap to wake, interval elapse, or a valid BLE connection request for measurement.

Acceleration Magnitude – Magnitude limits are configurable per axis. Any event which eclipses these limits will wake the unit and trigger a measurement. If this measurement following a magnitude limit exceeds the warning thresholds it will be stored to send to Machine Dossier.

Tap to wake – This feature relies on a built-in sensor that is always on and measuring at a very low threshold. Tapping near the device, or even on the mount of the device, should increase the measurements above the specified threshold, waking up the NANO. Upon wake, the NANO will start advertising and begin collecting measurements. Upon waking, a green LED is observed for 3 seconds.

Interval Elapse – Based on measurement configuration measurement interval the NANO will wake to make measurement. The NANO has the time between measurement intervals to offload this data to an X8II. If the X8II is unavailable or the network connection of the X8II is down between intervals the NANO will save the measurement and make a new one. The NANO will save 300 single axis measurements (100 3-axis triplets will be saved). When the X8II is available these saved measurements will be offloaded.

BLE Connection – An active BLE connection formed via X8II or a smartphone application can trigger a measurement via command. This means of triggering a measurement can be beneficial in installations where the unit is not easily accessible for Tap to Wake. The LED will illuminate for 3 seconds following a BLE connection commanded measurement trigger as an acknowledgement to the user.

6.4 MEASUREMENT

Following a measurement trigger the NANO will wake. The NANO will stop advertising or disconnect from an active connection. The NANO samples the integrated triaxial accelerometer based on the current measurement configuration. Following the sample acquisition, the NANO computes results including the Fast Fourier Transform (FFT).

These results are compared with the alarm thresholds to determine if the current vibration level warrants a change in measurement interval (a measurement parameter that exceeds an alarm limit will reduce the interval by a factor of 2 with a minimum interval of 1 hour). The same is true for warning and this measurement process is sequentially executed for all configured axis.

After the Zark NANO has been configured properly, it will begin to look for communication, indicating that it has data to send to Machine Dossier, or another configured location. To do so, the Zark NANO must effectively communicate with the X8II device. This occurs when the X8II scans for NANO devices that may have certain needs, whether that be sending data or updating the time. The Zark NANO can connect to any X8II device. A bundle of NANOs can all pass through one X8II as well. Therefore, it is imperative that the user must be able to know which NANO is passing through which X8II so that they can distinguish between measurements.

When proper communication is established, the X8II will connect with the NANO device and begin downloading data. When this occurs, the Zark NANO will delete its' collected data as soon as the X8II completes the download. Each packet of data that the NANO sends over to the X8II contains measurement values in all three axes: X, Y, and Z. Therefore, each measurement per axis is downloaded and deleted separately. The Zark NANO is capable of sending 500 Spectrum Peaks and 2048-point waveform data.

6.5 ADVERTISING

Each device has an assigned serial number that is unique from one device to another, preventing mismatch across devices. Having a specific serial number per device allows the user to seamlessly distinguish between one device and another. This allows the user to efficiently monitor which device is located where on an operating machine. The serial number of the Zark NANO can be located on the device. (Z2-XXXX) When downloading data, the X8II and the Zark NANO follow communication protocols, designed and developed by SEC. Any messages sent to the Zark NANO while violating the communication protocols will not be processed and completely disregarded.

The NANO is a Bluetooth Low Energy 5.0 peripheral. It is configured to advertise its status on an interval between 0.1 to 2.0 seconds. Advertisement interval is decreased to speed up the connection forming process with an X8II or smart phone application. Advertisement interval is increased to decrease power consumption. The NANO will advertise its device name, serial number; Z2-XXXX, and this will be visible in most BLE scanners commonly available on smart phone devices. **The NANO will not advertise while in an active connection or while taking a measurement.**

6.6 CONNECTION

A connection can be formed by a valid BLE central device which supports the NANO BLE service. Examples of valid devices would be the X8II and X8II smart phone application. A connection will be formed during an advertisement which occur at the

advertisement interval. The advertisement interval varies as previously detailed so the time to form connection is variable from as quick as a few hundred milliseconds to multiple seconds. X8IIs will actively scan and connect to NANOs based on the NANOs status. One X8II can maintain an active connection with multiple NANOs simultaneously. The connection process is automatic as the X8II will pair to any NANO that is actively advertising. The purpose of auto pairing is to allow for better efficiency when communicating between devices. The X8II will only pair with the Zark NANO if the device has measurements to transmit. Doing so improves battery life allowing the user to collect more data over time.

6.7 SLEEP

Being a battery powered device, the NANO needs to minimize its power consumption between samples. The NANO is designed to be in sleep mode as frequently as possible. Any measurement trigger or BLE connection will wake the NANO. There is no visible indicator the unit is in sleep as this mechanism would contribute heavily to the power consumption. The NANO still maintains periodic advertisements which are detailed previously and visible in BLE scanners.

6.8 WAKE UP

This NANO feature becomes activated upon the detection of a high magnitude event. However, for detection to occur, at least one measurement must be taken so that the Nano can understand the orientation that it is mounted in. The nano cannot go out into wake-up mode on boot because it does not know which orientation it has been positioned in. Furthermore, the wake-up magnitude cannot be triggered if the NANO is powered on while in alarm. The threshold level for the high magnitude event is specified by the user in units of G's. This threshold is applicable in both the positive and the negative magnitude level. For example, if the threshold is specified to be at 0.1 g, then the wake-up magnitude will be triggered at both, 0.9 g's and 1.1 g's. When such a threshold is reached, the NANO "wakes-up" and takes three measurements in alarm at 15-minute intervals. Upon completing those measurements after 45 minutes, the NANO returns to its normal interval state. **Figure 1** shows the trendline in Machine Dossier where a unit detected the high magnitude event, took three measurements at 15-minute intervals, and return to one hour interval sends.

Note: While in wake-up mode, the green LED will be blinking to indicate the user that the NANO is in wake-up mode. This feature was strictly intended for testing purposes only, and it will be removed upon the official release of the feature.

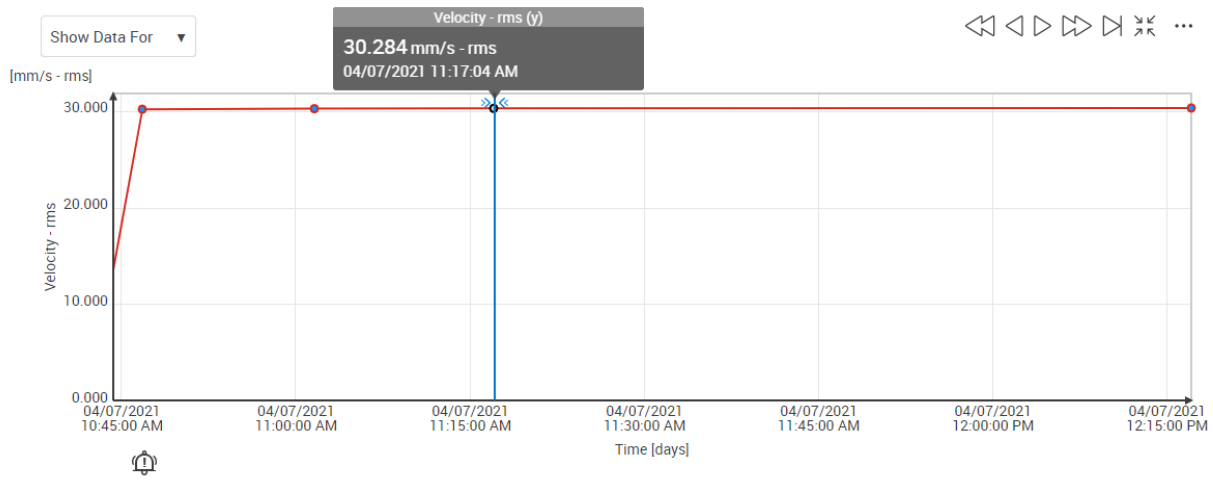


Figure 1: NANO behavior under a short high magnitude event.

If the high magnitude event persists upon completion of the first three 15-minute intervals, the NANO will wait until the halved normal interval is reached and take three more 15-minute interval measurements. For example, the normal interval is 12 hours, the NANO will send three 15-minute interval measurements every six hours. **Figure 2** shows the NANO functioning under a persistent high magnitude event.

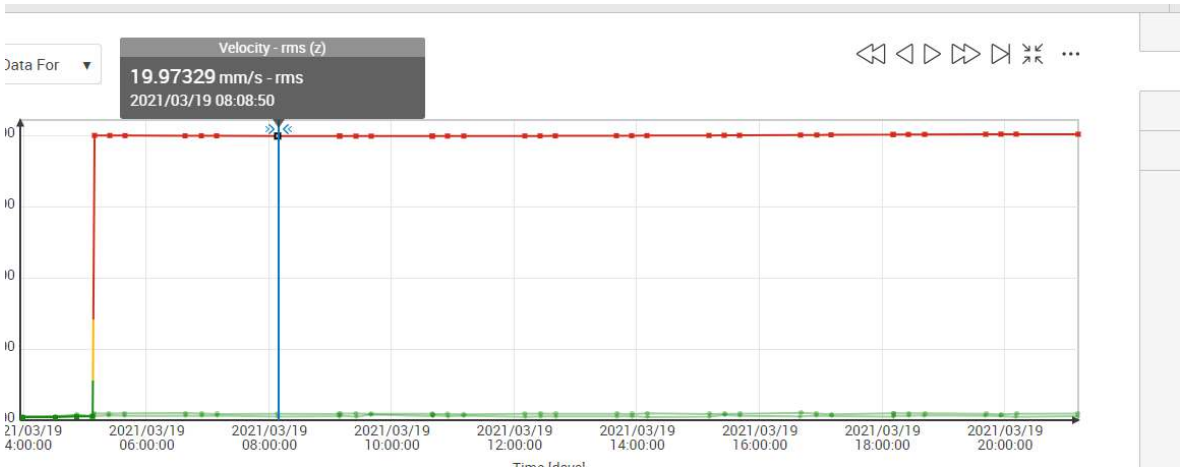


Figure 2: NANO behavior under a constant high magnitude event.

6.8.1 Configuring the Wake-Up Settings via UCT

After opening the port and retrieving from the X8II[1]. Click “SCAN For Nanos” and choose the NANO that you would like to configure. **Figure 3**

Figure 3: Scan for NANOs selection screen.

[1] See “*Getting Started with the UCT*” document for instructions.

Click “Configure Nano Device” after selecting the proper Serial number. A new window will be displayed, allowing the user to make changes on the NANO. **Figure 4**

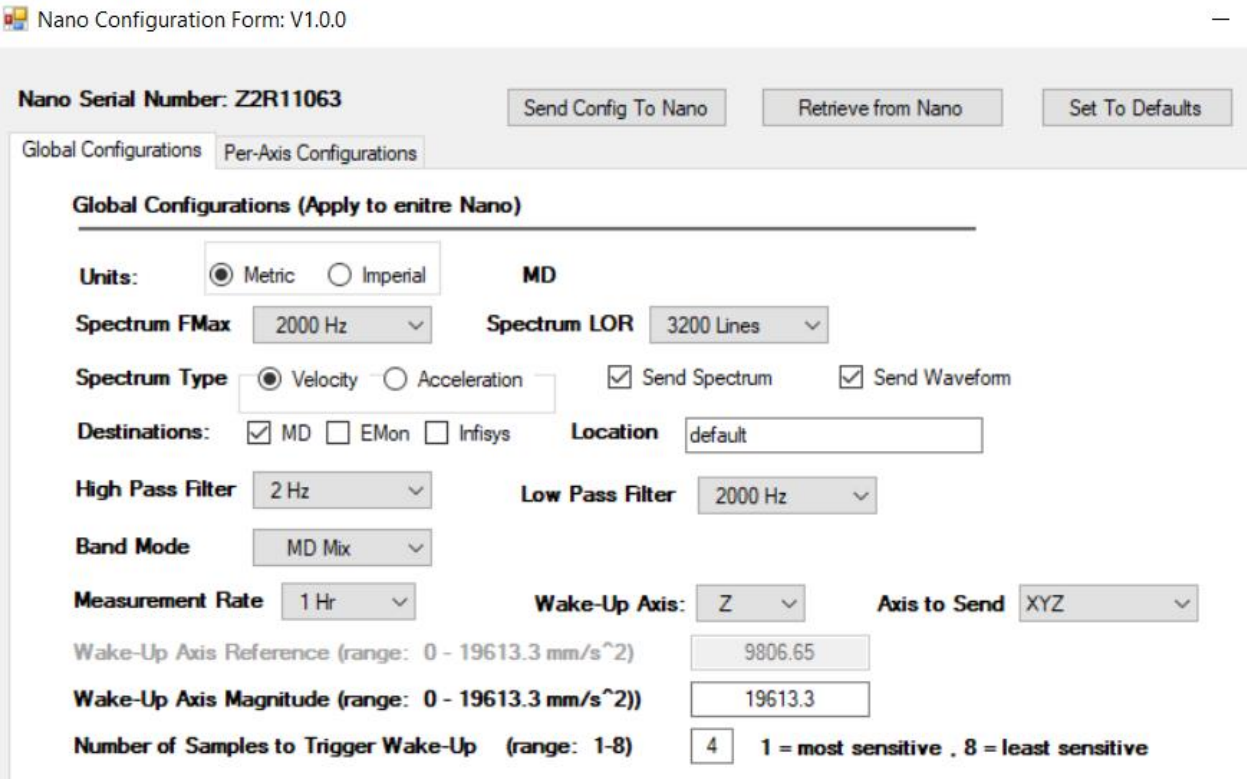


Figure 4: NANO configuration window.

Click “Retrieve From Nano”. The tool will populate all fields with what the NANO is currently set to. Once retrieved, the user cans et the Wake-Up Axis Magnitude range to a specified amount. Note that the units are in $\frac{mm}{s^2}$ so if you would like your threshold to be 0.1 g’s, then enter 9806.65 $\frac{mm}{s^2}$. Once the desired threshold is selected, click “Send Config to Nano”. Close out of the window and close the X8II port. The NANO should now have the new wake up threshold specified by the user.

The number of samples to trigger wake-up can also be specified by the user. The specified number of samples has a direct influence on the magnitude of vibration that is required to trigger a wake-up event. As seen on **Table 1** below, the shaker magnitude to trigger wake-up at 100 Hz shaking frequency varies from one to four number of samples.

Wake-up Magnitude Threshold in G's	Num of Samples to Trigger Wake-up	Shaker magnitude to trigger Wake-up @ 100 Hz (mm/s^2)
0.1 (981 mm/s^2)	1	475
	2	700
	3	875
	4	1550
0.11 (1079 mm/s^2)	1	500
	2	700
	3	950
	4	1800
0.12(1177 mm/s^2)	1	650
	2	800
	3	1100
	4	2050
0.13(1275 mm/s^2)	1	700
	2	900
	3	1150
	4	2150
0.14 (1373 mm/s^2)	1	725
	2	925
	3	1250
	4	2300
0.15 (1471 mm/s^2)	1	825
	2	975
	3	1350
	4	2500
0.2 (1961 mm/s^2)	1	1175
	2	1375
	3	1800
	4	3375
0.3 (2942 mm/s^2)	1	1850
	2	2150
	3	2800
	4	5250
0.4 (3923 mm/s^2)	1	2600
	2	2950
	3	3850
	4	6950
0.5 (4903 mm/s^2)	1	3200
	2	3600
	3	4750
	4	8750

Table 1: Relationship between number of samples and required magnitude for wake-up.

7 X8II BEHAVIOR

The behavior of the X8II is detailed below. **A NANO does not pair to a specific X8II and multiple X8IIs can be deployed in the same facility to increase coverage**. The X8IIs will service NANOs on an as needed basis based on their advertisement payload(s).

7.1 NANO COMMUNICATION

This section will introduce and define various forms of interaction that will occur between the NANO and X8II during service.

Scanning – The X8II is a BLE central device which scans for NANO advertisement packets detailed previously. Based on the content of the advertisement packet it will determine if a connection is needed.

BLE Connection – The X8II will connect to a NANO if it requires time service, has a new measurement configuration update, new NANO firmware image or data measurements are ready to download.

Time – The X8II maintains the time across the NANOs in range. This time is used to keep measurements in chronological order. Time is received from a time server polled via Wi-Fi. **If a time server is not available, any newly powered NANOs will not take measurements as they cannot time stamp their measurements. Units which have already been powered will time keep in the X8IIs absence and save measurements until a X8II can receive a time update.**

Wi-Fi Connection – The X8II stays in contact with Machine Dossier cloud servers. When a configuration update is made in Machine Dossier the X8II will relay this change to the NANO. The X8II will encrypt and transmit measurement data when available and transmit them as they become available.

Firmware Update – Firmware updates are hosted on Machine Dossier to update the X8II firmware and NANO firmware. Firmware updates are set to deploy by organization and are not mandatory. The X8II / NANO image is downloaded as one file and stored in the X8II. An X8II will connect to a NANO during downtime and upgrade its firmware. This is an Over-the-Air (OTA) upgrade feature where the NANO must request through the X8II, allowing the user to manually confirm a firmware update in MD.

7.2 DATA BUFFERING

The NANO device communicates with the X8II via Bluetooth. Upon taking measurements, the NANO waits for communication from the X8II, allowing it to send a measurement. Measurement rates are configured by the user in User Configuration Tool (UCT), with an interval of no less than one hour. Measurement rates are also halved when a NANO is measuring a signal that is specified to be above a certain

threshold. However, intervals cannot be halved when resulting in a new interval of less than an hour.

The X8II is a device that can perform multiple tasks at once. Rather than having a linear logic system, the X8II can perform multiple functions simultaneously. Therefore, measurements, sends, and buffers, are more reliable and time accurate.

The X8II communicates with Machine Dossier or EMonitor via a wireless network connection. The connection is specified via an IP address, allowing the user to collect data and send to virtually any supported platforms that can interpret and display the collected measurements. The sent measurements can either be measurement points, or spectra of frequencies.

For additional information regarding setup and operation of the X8II, please refer to the **X8II User Manual**.

8 MAINTENANCE AND TROUBLESHOOTING

8.1 BATTERY REPLACEMENT

The NANO comes with a ½ AA Lithium battery pre-installed. This unit was designed with battery replacement in mind and this section will provide detail on how to replace the factory battery.

⚠ **CAUTION**: REPLACE BATTERY IN NON-HAZARDOUS ENVIRONMENT ONLY!

8.1.1 Step 1: Cover Removal

Unscrew the blue cover by placing one hand on the metal hex base and one hand on the cover. Rotate the cover counterclockwise, and the hex base clockwise, until the cover is fully disengaged with the hex base and pull it straight up and off the unit.

If unit is installed in a severe environment and gasket sealer was applied during initial installation, the current seal will need to be removed with a knife and reapplied in step 5 of this section.

Figure 20: Cover Removal

8.1.2 Step 2: Battery Support Removal

Place your thumb and index finger on the tabs that go around the battery and lock into the sheet metal and gently push in toward the battery to release the tabs. Pull the battery support directly away from the battery (figures 21 and 22). Place this part to the side, we will re-install it before the unit goes into service. **DO NOT THROW THIS PIECE AWAY**, as the unit will not function correctly without it.

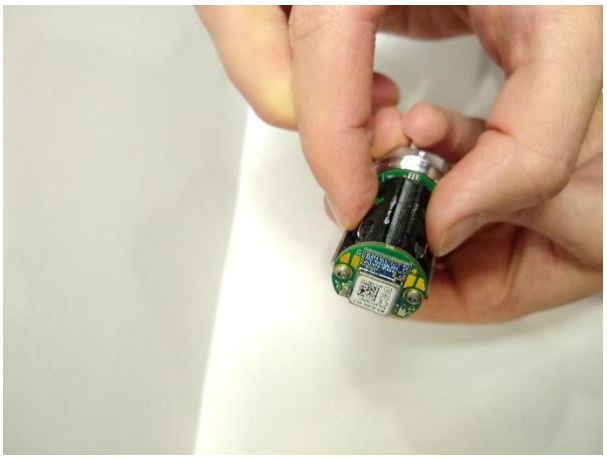


Figure 21: Clasp the Support by the Snap Arms with Thumb and Index Finger

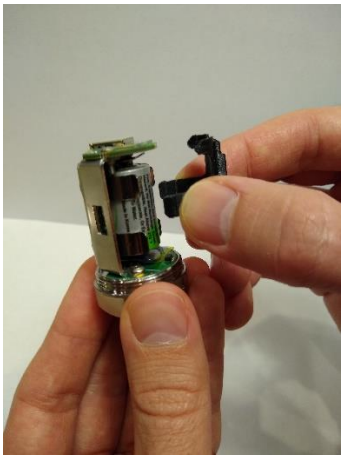


Figure 22: Push Snap Arms in Toward Battery and Pull Away from Unit

8.1.3 Step 3: Remove the Existing Battery

There are two small rectangular holes in the sheet metal on either side of the battery – these are the same holes used to attach the battery support taken out in the previous step – and will be used to safely remove the battery without damaging the unit. An appropriately sized flat head screwdriver can be used to pry the battery out of the unit by using these rectangular windows. An example of this can be found in figure 23. **Please be careful when you are performing this step, as the battery might be ejected from the unit.**

Figure 23: Place Flathead Screwdriver Head into Either Rectangular Cut-out and Pry Battery Away from Unit

8.1.4 Step 4: Install New Battery

Push new battery into unit where the old battery existed. Please take note of the positive and negative terminals and align battery appropriately before pressing into its final resting position. Positive end of the battery should face downward, toward the metal hex base.

On top of the unit, you should see an LED light up bright green (figure 3). This means you have established power and the unit is ready to be reassembled and re-installed. If the LED does not light up, check battery alignment. After the LED has successfully lit up, it should run through 7 self-tests and will respond with 7 LED flashes. Please see the LED Flash Codes/Troubleshooting section for more information on what these flashes mean.

8.1.5 Step 5: Reassemble

Re-install the battery support and blue cover that were removed in steps 1 and 2 of this section, following those steps in reverse. Cap should be seated at a torque value no greater than 15 in-lbs (2.63N-mm).

If the NANO is being installed in a “severe environment,” additional gasket seal will be supplied and should be applied before cap is installed. Please apply a thin bead of the supplied gasket seal on the lip around the metal hex base, where the cover and base contact when the cover is fully tightened. See figure 24 below.

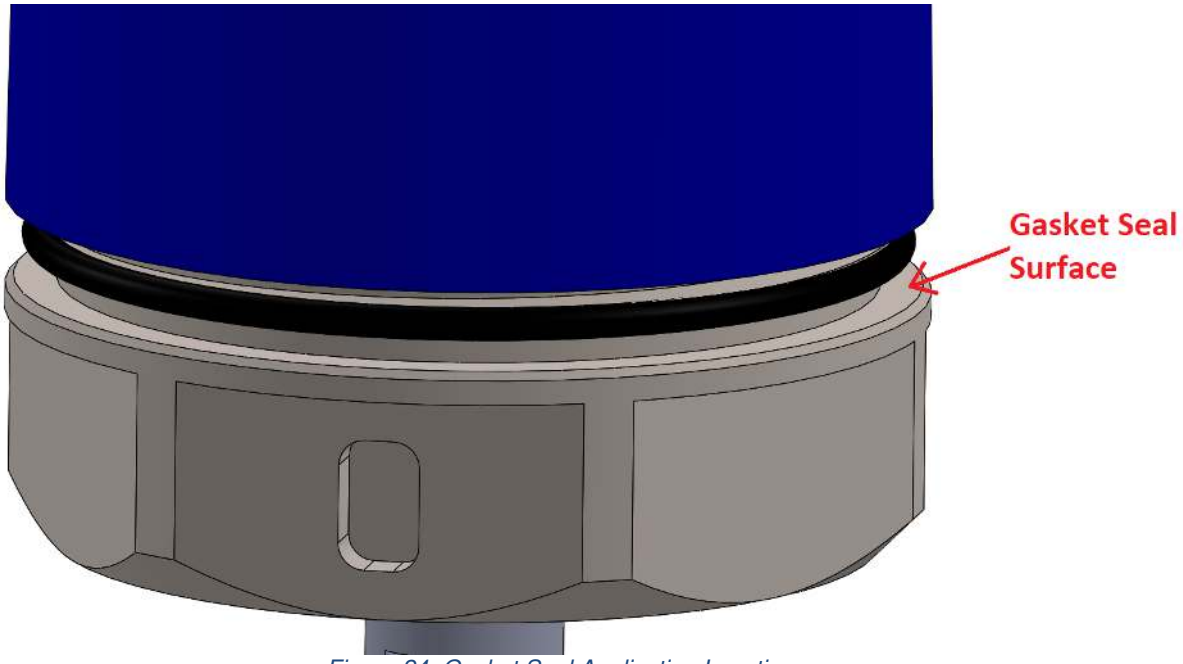


Figure 24: Gasket Seal Application Location

8.2 LED Flash Codes

Each NANO has an LED installed on the top PCB, which is visible once the cover has been removed. Refer to section 2, step 2.1.1 for cover removal. Figure 25 below shows the LED location on a unit with the cover removed.

Figure 25: LED Location

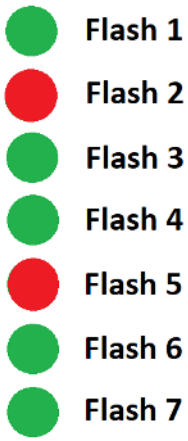
Once power has been established the LED will run 7 self-tests flashing either green or red, depending on whether the specified test condition has passed or failed. If the battery insulator tab is removed and the LED remains off check the orientation of the battery and ensure the battery's positive terminal is facing downward (away from the LED). If battery orientation is confirmed to be correct and the unit still does not power on, call customer service at 1-877-586-5690.

Provided power has been established and the LED is active, please follow the information below to better understand the LED flash codes and what they mean. For all the tests below, a green flash will indicate it passes and a red flash will indicate failure.

1. Flash #1 – Bootloader Present Check
2. Flash #2 – RTC Device Check
3. Flash #3 – BMA400 Device Check
4. Flash #4 – LIS2DS12 + SIP32431 + TPS7831 + 74AUP1T3 Device Check
5. Flash #5 – MX25R6435 + SIP32431 Device Check
6. Flash #6 – NRF52 ADC Battery Voltage Check
7. Flash #7 – TMP36GRTZ Device Check

If all 7 self-tests above pass and flash green, the program will launch, and the device will work normally. If any of the seven checks flash red, the program will not launch, and the LED will continue to run the self-test flashing seven times every 10 seconds.

An example of a failed test might look like the following:



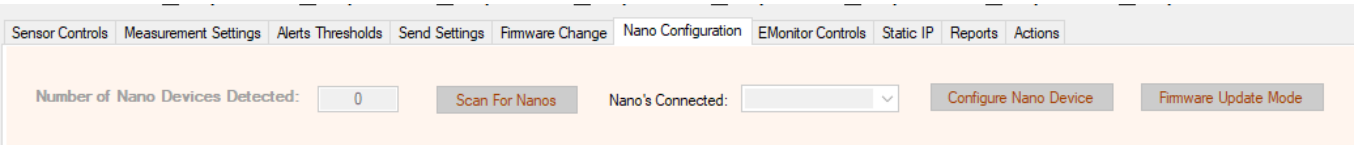
In the above flash code sequence, flashes 2 and 5 fail while all the rest pass. Referring to the flash code definitions, provided earlier in this section, we can see that a failure in flash #2 indicates an RTC device failure and a failure in flash #5 indicates a MX25R6435 + SIP32431 failure. Since at least one test failed, the program will not boot, and this flash sequence will continue every 10 seconds. If any of the tests fail, and the program fails to boot, please call customer service at XXX-XXX-XXXX.

8.3 FIRMWARE UPDATE

8.3.1 Set the NANO to “Firmware Update Mode”

The Wireless NANO device must be prepared to update its firmware. This requires the use of the User Configuration Tool (UCT). After opening the UCT, click on the “Nano Configuration” tab, then click “Scan for Nanos.”

After the scan is complete, use the drop-down menu labeled “Nano’s Connected” and select the NANO you wish to update. After you have selected the NANO you wish to update from the drop-down menu, click “Firmware Update Mode.” By placing the NANO in this mode, you can now update the Firmware by using an iOS or Android device. To update using an iOS device, see section 7.3.2. For Android devices, see section 7.3.3.



NOTE: Once a NANO is in "Firmware Update Mode," it will only remain in this mode for 2 minutes. You should read through the applicable operating system (iOS or Android) instructions below, and be ready to update, before you place a NANO into this mode.

8.3.2 Using IOS to Perform a Device Firmware Update (DFU)

8.3.2.1 Get the app from the Apple Store

On your iOS device, go to the App Store and search for nRF Toolbox.

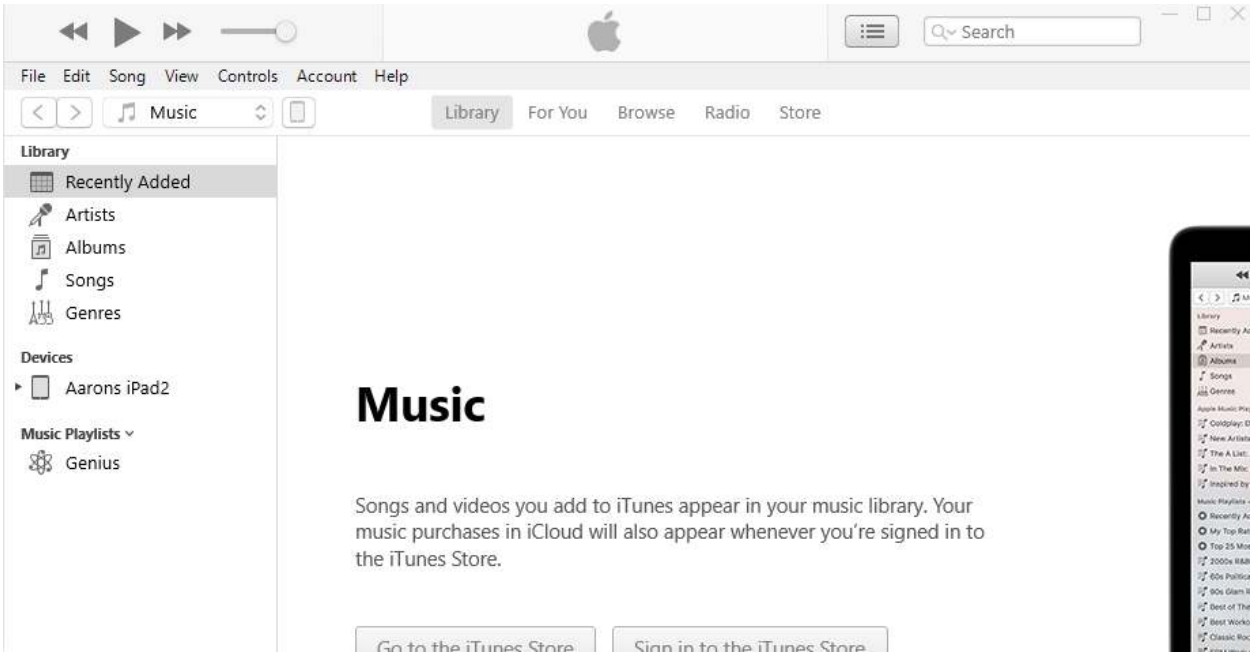
In the above, is shows "OPEN" because it's already been downloaded and installed, but you will see "GET". Click the GET button and allow the "nRF Toolbox" to install.

8.3.2.2 Transferring the Firmware .zip file onto the iOS Device

It is important that the firmware update file be kept in zipped format. The "nRF Toolbox" application expects the file to be zipped. If you can receive this file by email or some other method onto the iOS device, you can skip this section.

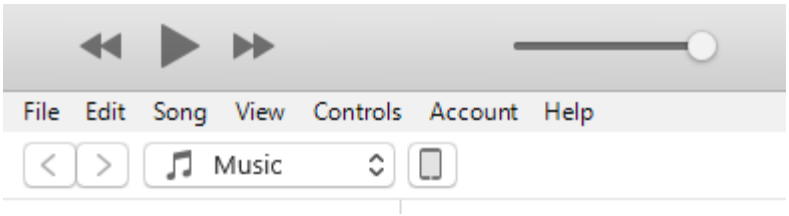
If you only have the zipped file on a separate Windows PC, you will need to connect the iOS device to the PC using a USB cable. As soon as you connect it, the iOS device will recognize that it is connected to a PC and prompt you for whether to "trust" the PC. Tap "Trust".

If you do not already have Apple iTunes installed on your PC, you will need to do download it from either Apple or Microsoft. Install it and then run the iTunes program on your PC:

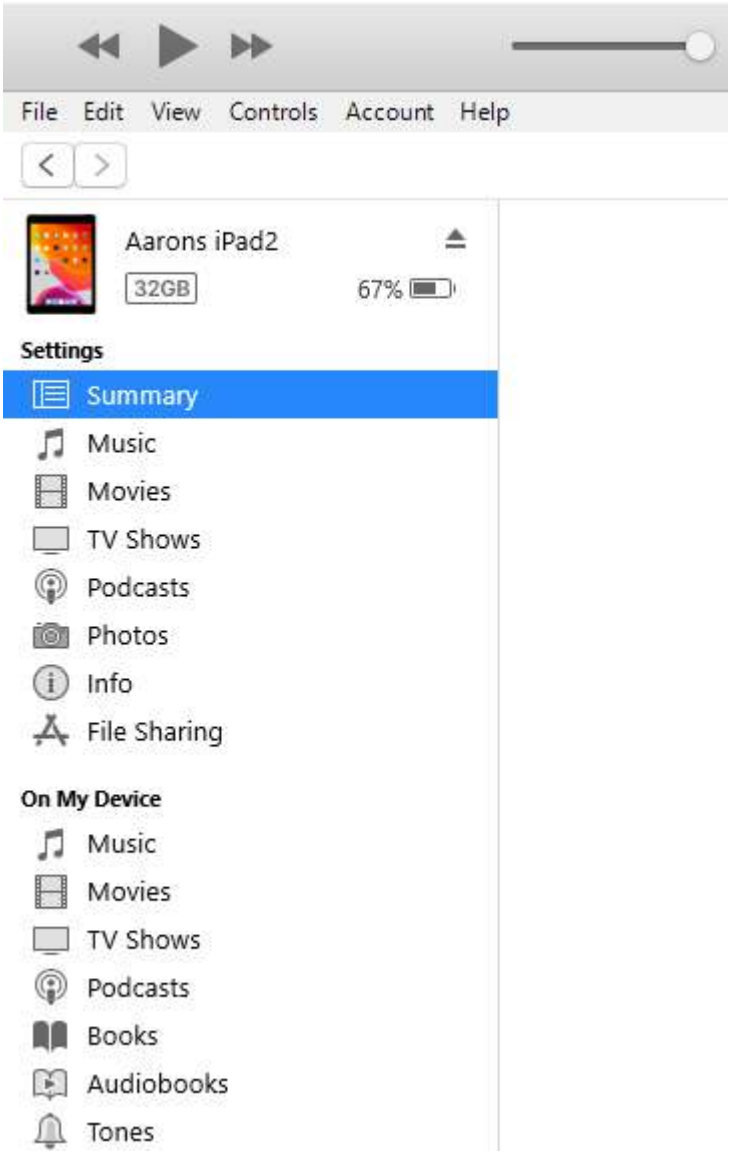


If you have the iOS device connected, and trusting, then you should see the iOS device under the “Devices” section on the left panel.

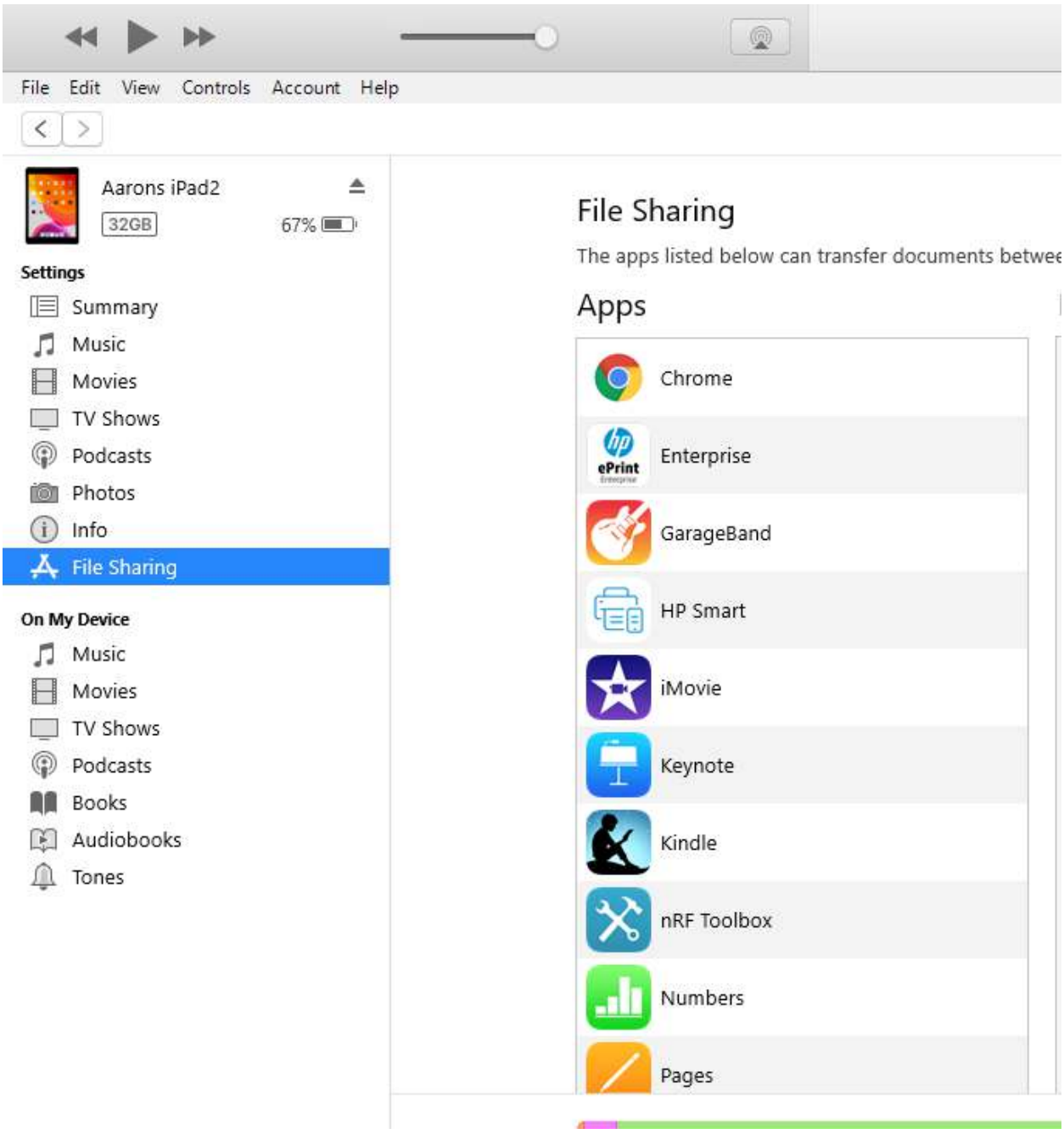
In the upper left, in the 3rd row down, you should see an Icon that looks like a tablet, just to the right of the “Music” selector:



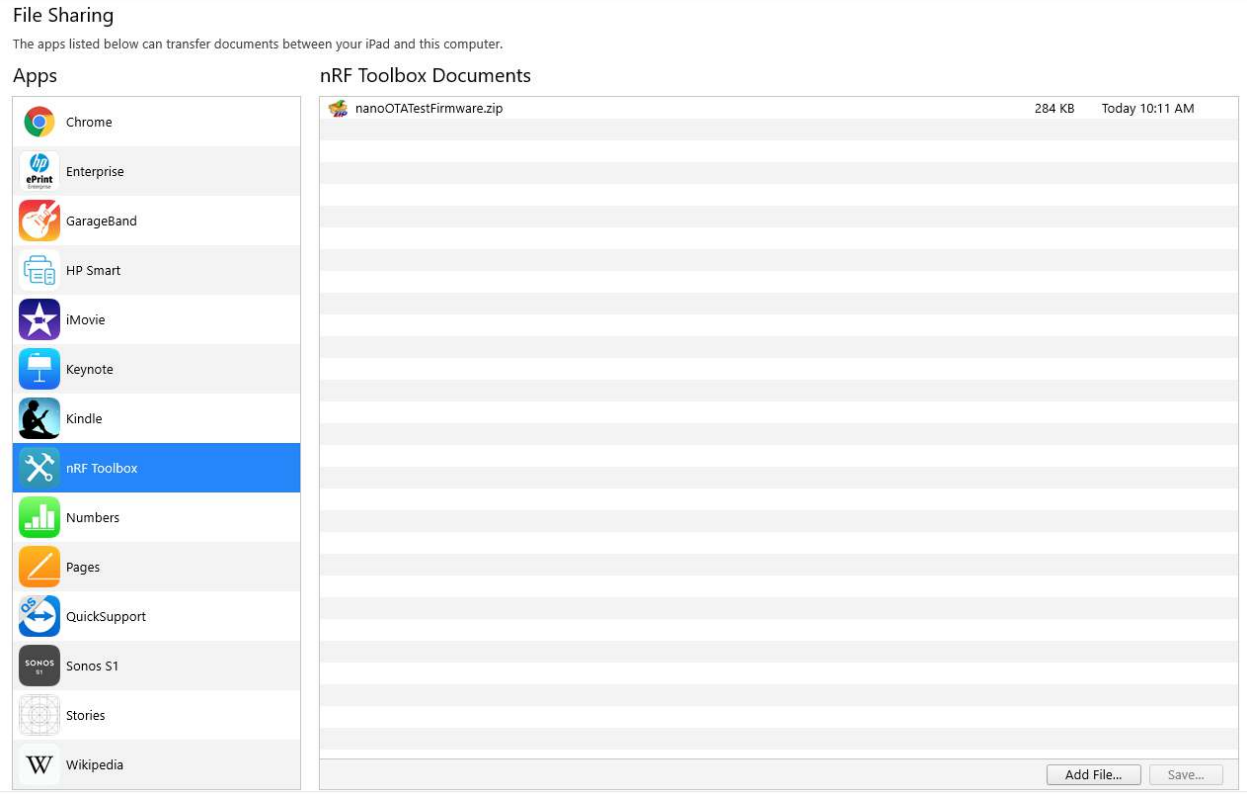
Click that tablet icon, and the iTunes application should change to look like this:



Click the “File Sharing” link:



Look in the list of Apps for the “nRF Toolbox” icon, shown above. Click on that icon.

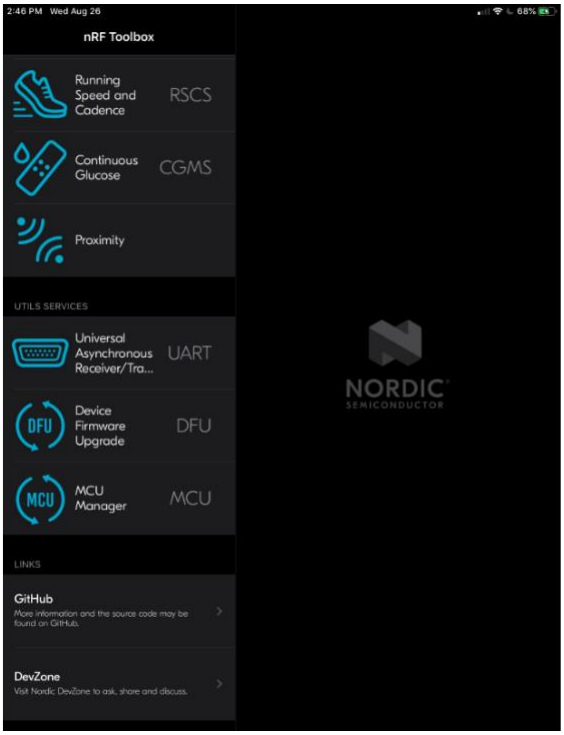


Make sure you are scrolled all the way down in the Apps list. You should see a button "Add File…" in the lower right corner:

Click the "Add File…" button, and navigate your way to the .zip file, select it, and click "Open". This should place the file where it needs to go for the "nRF Toolbox" Application to find the file when it is time to use it to Update the firmware in the NANO wireless device.

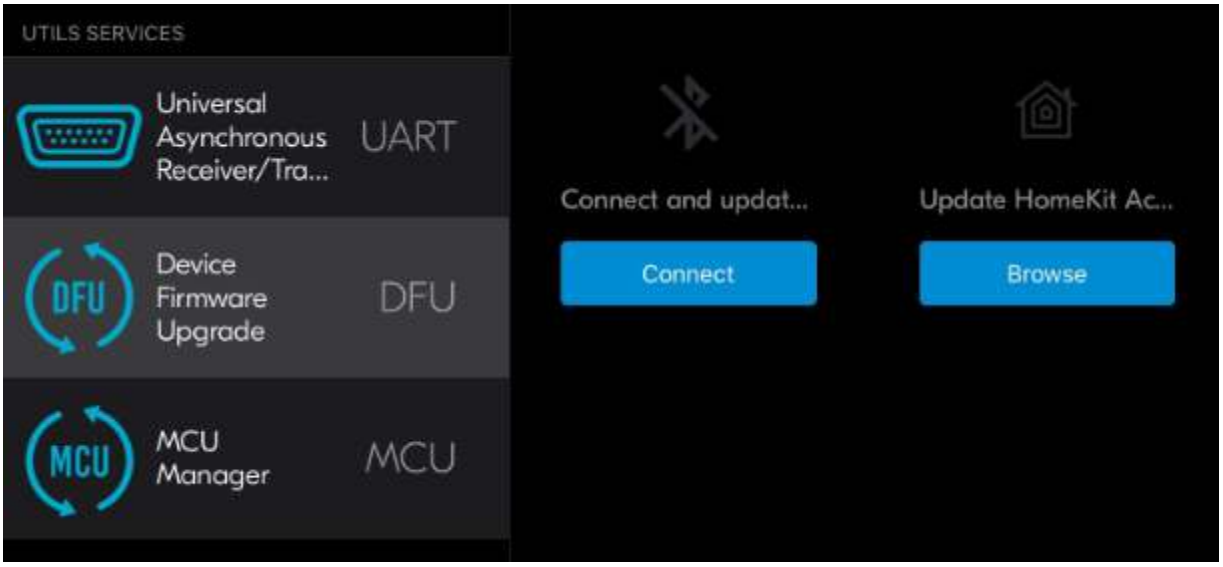
8.3.2.3 Using the iOS "nRF Toolbox" Application

Open the "nRF Toolbox" application on your iOS device, where you will find a column on the left that is scrollable. Scroll that column down to the bottom. You should see this:



Look for the DFU section ("Device Firmware Upgrade"):

Click on it.



Click the “Connect” button.

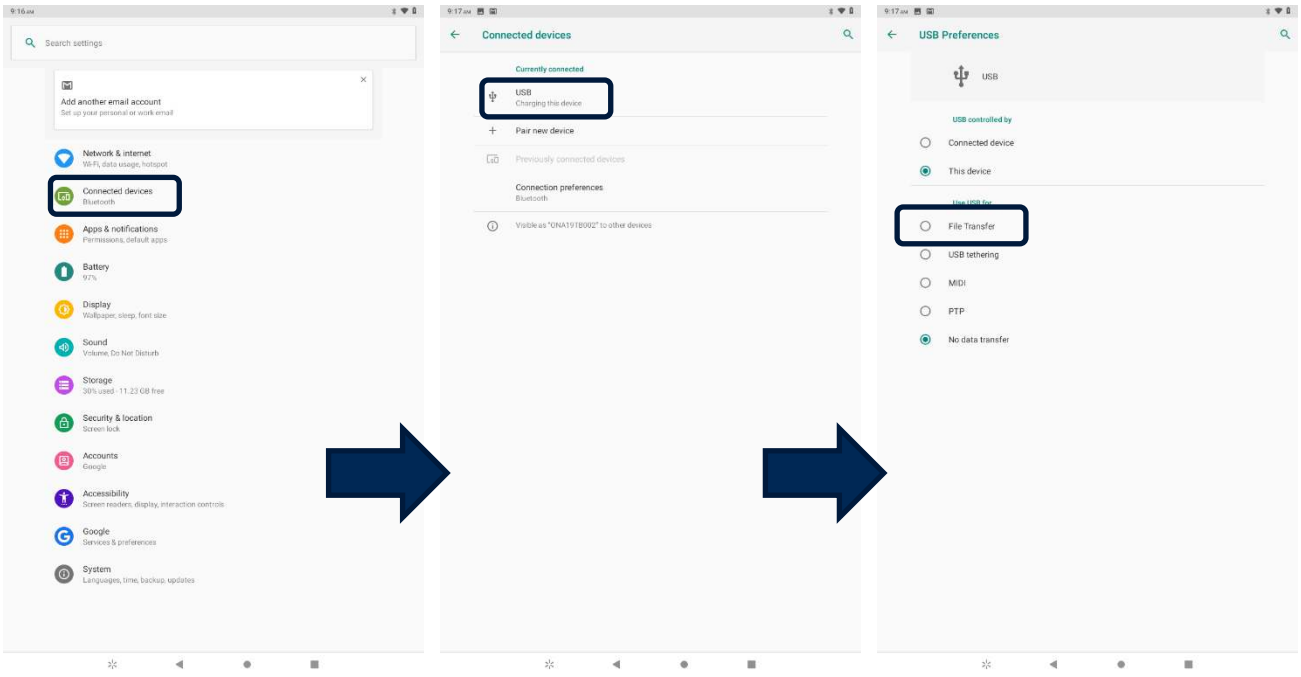
The nRF Toolbox application will scan for devices. If you have prepared the NANO Wireless Device using the BOOTZ2,XXXX command, the NANO Wireless device should be broadcasting as “Z2Bootloader”. Tap on it and confirm the update. You should see a blue circle that is spinning while it is transferring the file. You should also see a blue progress bar.

Confirm that the application indicates that the upgrade was successful.

You have successfully updated the NANO Wireless device!

8.3.3 Using Android to Perform a DFU

Android devices do not automatically allow for file transfer via USB. This feature must be enabled in the settings of the android device. Follow the instructions below to enable USB file sharing.

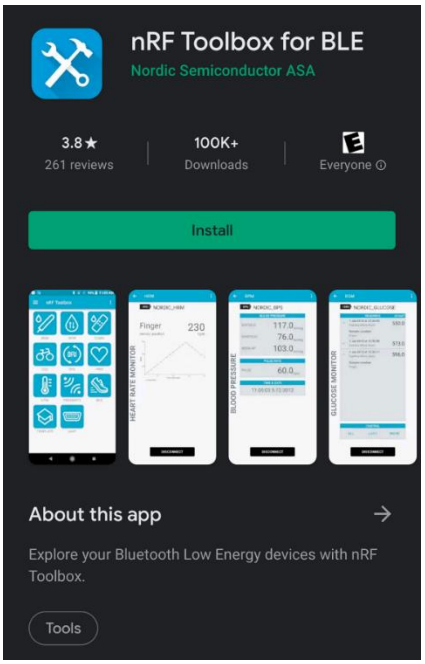


Connect android device to a PC via USB. (2.0/3.0/micro/Type-C) Navigate to the settings, tap “Connected Devices”→ “USB” → “File Transfer”

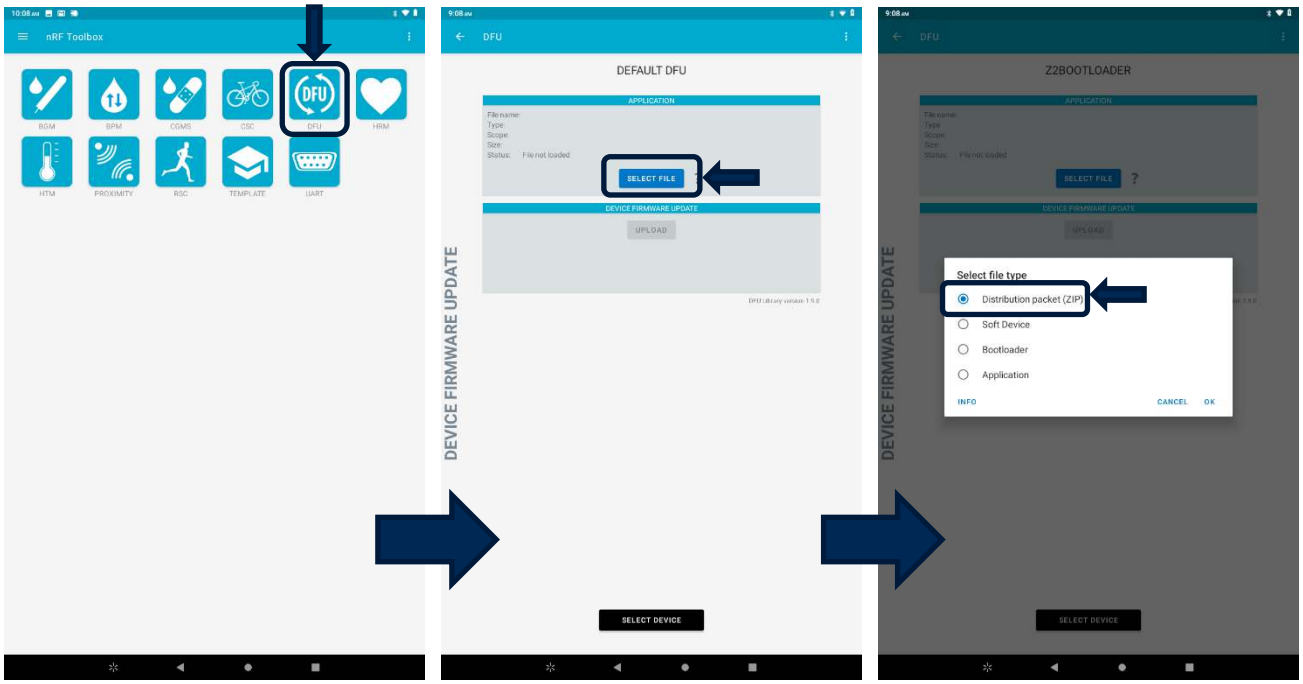
Once file transfer is selected, the user may navigate to the desired file on their PC, copy it, and place it into the file system of the android device, accessed by navigating into my computer section of windows. A common location, and the location chosen for the purpose of creating this document, is the “Downloads” folder located in the android file system. Place the DFU.zip file in that location.

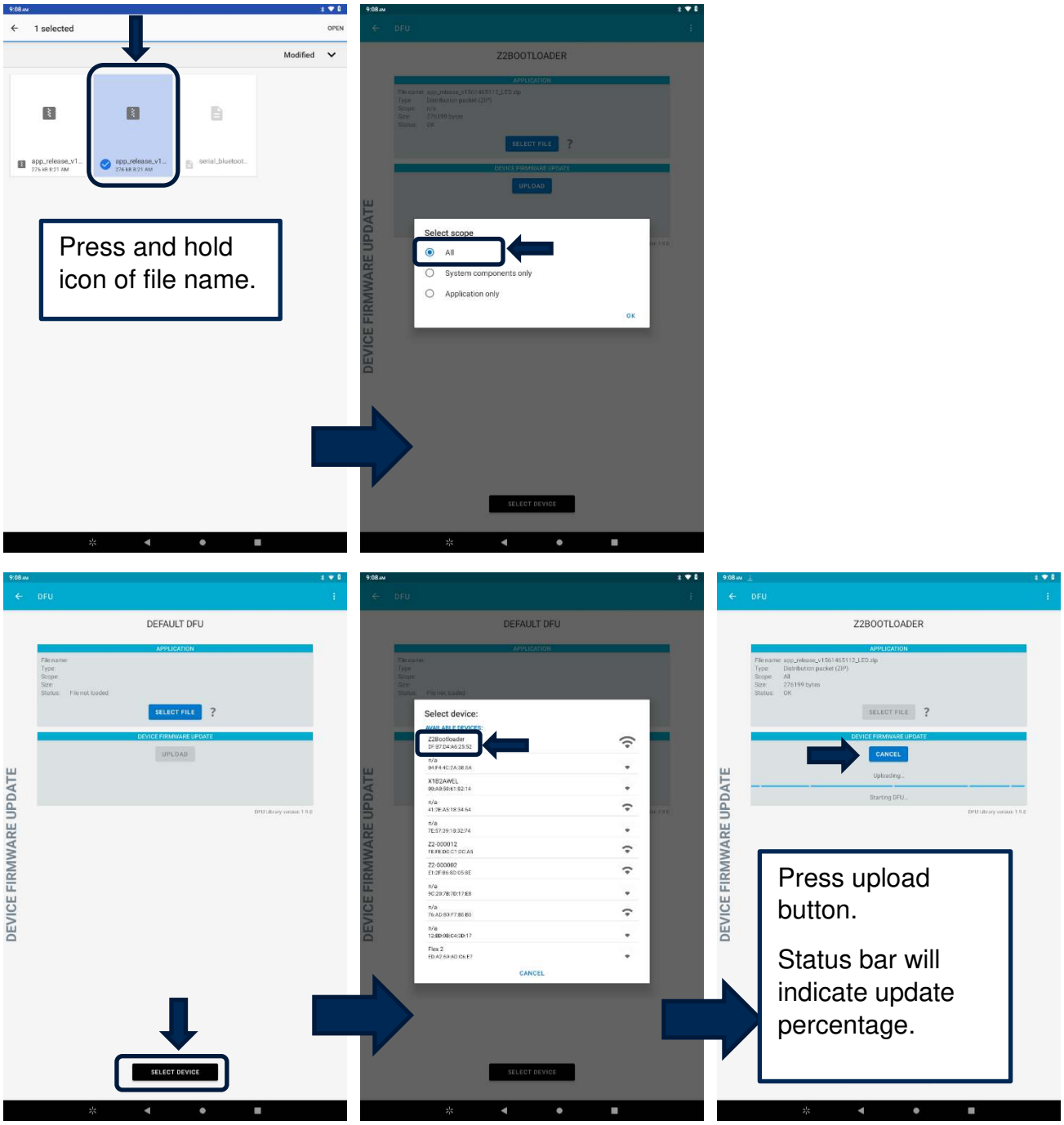
8.3.3.1 Using the nRF Toolbox

Navigate to the play store on your android device and search for “nRF Toolbox”. The image below shows the application, tap “Install”.



Follow the instructions below to upload a firmware to the NANO.





Select Device. Andromeda in bootloader will advertise with name “Z2Bootloader”. This may change in the future to display the unit serial number. Press upload button. The bootloader will reflash the application image and launch.

9 GLOSSARY

Advertisement: Signal sent by NANOs letting all X8IIs in range know it is ready to offload measurement data.

Alarm Thresholds: User specified values that dictate when alert notifications will be sent. These values can be set using the X8UserConfigurationTool.

MachineDossier.net (MD): This is our cloud-hosted application in which authorized users can view their organization's X8II collected data, update, and change X8II data collection schedules and collaborate with others to diagnose machinery problems.

Measurement Interval: Time between sampling rate of sensors. Once a day is a typical sampling rate for these sensors, but if this is increased it could burden the system.

NANO: Sensor that is mounted on the machines being monitored. These sensors are programmed to sample at certain times and communicate with a nearby X8II to offload the data.

Over-The-Air (OTA): Any type of wireless transmission.

RTC: Real-time-clock, which is internal to the X8II and is what is used to accurately take timestamped measurements. The RTC Clock will sync with your PC to calibrate and can also be manually updated, if necessary.

RF: A frequency or band of frequencies in the range 10^4 to 10^{11} or 10^{12} Hz, suitable for use in telecommunications

Self-Test: Consists of 7 different hardware tests. When it completes the last test, the NANO will indicate the result of the self-test with a series of single-LED flashes. It will flash once for each of the 8 tests, in sequence. If the test passes, it will flash green. If the test fails, it will flash red, and have a slightly longer duration. See section 7 for more information.

X8II: The X8II is a BLE central device which scans for NANO advertisement packets detailed previously. One X8II can communicate with up to 16 NANOs. For more information on X8II behavior see section 6.

10 INDEX

A

Acceleration Magnitude, 32
advertisement signal, 56
Android, 52

B

Battery, 7
Battery Support, 40
Battery Tab, 8
BLE Connection, 32, 38

D

DFU, 46
Difficult-to-Reach Locations, 17
Dimensions, 7

F

Fast Fourier Transform, 32
FIFO, 31
Firmware, 45
Firmware Update, 38

G

gasket seal, 10
G-Force Maximum, 7

H

Humidity Range, 7

I

Interval Elapse, 32
iOS, 46

L

LED, 9, 44
LED Location, 44

M

Machine Dossier, 18
measurement parameter, 31

N

New Measurement Point, 19
nRF Toolbox, 51

O

Overall Limits, 31

R

RF Interference, 17

S

Scanning, 38
self-tests, 9, 44
serial number(SN), 18
set time limit interval, 31
single-LED flashes, 56
sleep mode, 34
Spectrum Band Limits, 32
Spectrum Resolution, 18

T

Tap to wake, 32
Temperature Range, 7
Time, 38

W

Weight, 7
Wi-Fi Connection, 38

X

X8II, 38
X-axis Indicator, 13