AV200

xNAV650

USER MANUAL

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Contact details

OXTS

Park Farm Business Centre
Middleton Stoney
Oxfordshire
OX25 4AL
United Kingdom

Tel: +44 (0) 1869 814 253
Fax: +44 (0) 1869 251 764

Web: http://www.oxts.com
Email: support@oxts.com

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Introduction

Thank you for choosing an OXTS inertial navigation system (INS). This manual covers two products: the AV200 and the xNAV 650, which operate very similarly. Both devices combine dual GNSS receivers and a multi-core tactical-grade IMU into one self-contained package. This document covers the technical information and hardware design instructions for the AV200 and xNAV650 modules to enable you to successfully integrate it into your system. Specific instructions for either model are noted throughout the manual.

Please note that drawings in this manual may be of the xNAV650 or the AV200; unless otherwise states, the details show in the drawings are the same for both models.

> Important information is highlighted throughout this manual in these boxes.

Intended use

The AV200 and xNAV650 inertial navigation systems are designed to precisely measure position, time, orientation, and dynamics for localisation, georeferencing, and validation applications. They are capable of logging navigation and localisation data as a passive measurement device, and/or outputting the data in real-time with low latency for use in active systems. If the outputs are used in any way as part of a control system, appropriate steps should be taken by the System Integrator to ensure that the control system as a whole meets the required functional safety standards, with additional independent and redundant sensors and modules.

The enclosure used for the AV200 and xNAV650 is not IP rated so should not be exposed to dust or water ingress. It is intended for use in pollution degree 2 locations.

Related documents

This manual covers the installation and operation of the AV200 and xNAV650, but it is beyond its scope to provide details on service or repair. Please contact OxTS support or your local representative for customer service-related enquiries.

Additional manuals provide further information on some of the software and communication types mentioned in this manual. Table 1 lists related manuals and where to find them.

The xNAV650 and AV200 Quick Start Guides are also useful tool for using your INS system.

Document	Description
Product disclaimer	Safety considerations and liability disclaimer. AV200_disclaimer.pdf (oxts.com)
OxTS Georeferencer	Use OxTS Georeferencer to calibrate your setup and create point clouds. https://support.oxts.com/hc/en-us/articles/360016436060
ROS2 driver	Allows an OxTS INS to interact with a wider ROS network. https://github.com/OxfordTechnicalSolutions/oxts_ros2_driver
NAVconfig	Use NAVconfig to configure the settings on your INS and to tell it what the physical and hardware setup is that you are using. https://support.oxts.com/hc/en-us/articles/360018688799
NAVsolve	Use NAVsolve to process your raw data into NCOM navigation data. https://support.oxts.com/hc/en-us/articles/360000225449-NAVsolve-manual
NAVgraph	Use NAVgraph to display your navigation data and diagnostics after processing. https://support.oxts.com/hc/en-us/articles/115002433465-NAVgraph-Online-manual
NAVdisplay	Use NAVdisplay to view your navigation data in real time. https://support.oxts.com/hc/en-us/articles/115002433285-NAVdisplay-Online-manual
NCOM Manual	Use this manual to decode and use the OXTS NCOM format. https://support.oxts.com/hc/en-us/articles/360011890040-NCOM-Manual
NCOM C Decoder	A collection of C functions that can be used to decode the binary protocol NCOM format. https://github.com/OxfordTechnicalSolutions/NCOMdecoder
CAN Interface Manual	Manual describing the CAN format and outputs. CAN_man.pdf (oxts.com)
NMEA 0183 Description	NMEA description manual for the NMEA outputs. NMEA_man.pdf (oxts.com)https://support.oxts.com/hc/en-us/articles/360011890180-NMEA-Manual

Table 1:
Supplementary manuals

Scope of delivery

The AV200 can be supplied in two variations: base kit or evaluation kit. The evaluation kit includes additional items that allow users to quickly and easily set up and evaluate the system. Table 2 shows what is included in each kit variation.

The xNAV650 is supplied with the items listed below in the basic kit. Other items such as antennas and antenna cables are provided separately.

Item	AV200 standard kit	xNAV650 standard kit
Part number	109-01217	109-01216
Inertial navigation system device	✓	✓
14C0230 user cable		✓
14C0241 user cable	✓	
Ethernet cable	✓	✓
Ethernet coupler	✓	✓
Software USB	✓	✓
Quick start guide	✓	✓

Table 2:
AV200 and NAV650 scope of delivery

Conformance notices

The AV200 and xNAV650 comply with the radiated emission limits for 47 CFR 15.109:2020 class A of part 15 subpart B of the FCC rules, and with the emission and immunity limits for class A of EN 55022. These limits are designed to provide reasonable protection against harmful interference in business, commercial and industrial uses. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or both of the following methods:

+ Re-orient or relocate the receiving antenna.
+ Increase the separation between the equipment and the receiver.

The AV200 and xNAV650 incorporate GNSS receivers. No GNSS receiver will be able to track satellites in the presence of strong RF radiations within 70 MHz of either the L1 GPS frequency (1575 MHz) or L2 (1228 MHz).

The AV200 and xNAV650 conform to the requirements for CE. Do not remove the label from the device.

Regulator testing standards

EMC

+ BS EN 61326-1:2021 - Electrical equipment for measurement, control and laboratory use.

LVD

+ BS EN 61010-1:2010+A1:2019 - Safety requirements for electrical equipment for measurement, control, and laboratory use.

RED

+ BS EN 301 489-19 v2.2.1 (2022-09) – Electro Magnetic Compatibility (EMC) standard for radio equipment and services; Part 19: Specific conditions for Receive Only Mobile Earth Stations (ROMES) operating in the 1,5 GHz band providing data communications and GNSS receivers operating in the RNSS band (ROGNSS) providing positioning, navigation, and timing data.
+ BS EN 303 413 V1.2.1 (2021-04) - Global Navigation Satellite System (GNSS) receivers. Radio equipment operating in the 1 164 MHz to 1 300 MHz and 1 559 MHz to 1 610 MHz frequency bands.

RoHS

+ BS EN 63000:2018 – Technical documentation for the assessment of electrical and electronics products with respect to the restriction of hazardous substances. (AV200 only)

FCC

+ 47 CFR 15.109 – Code of Federal Regulations – Title 47 (Telecommunication): Part 15 (Radio Frequency Devices) – Subpart B (Unintentional Radiators) – Section 15.109.
+ ICES-003 Issue 7 January 2020 – Information Technology Equipment (Including Digital Apparatus) – Limits and Methods of Measurement.

Hardware description

Overview

The AV200x and NAV650 are miniature GNSS-aided inertial navigation systems. They combine dual multi-constellation, multi-frequency RTK GNSS receivers with a tactical-grade quad IMU array to provide a compact centimetre-level navigation solution. Additionally, the system includes 32 GB data storage and an on-board processor running the real-time strapdown navigator and Kalman filter.

The dual receiver integration allows greater heading accuracy with wider antenna baselines and ensures stable heading performance even when stationary and during low dynamics. The custom built quad IMU array consists of four individual IMU sensors that each combine 6-axis MEMS gyros and accelerometers, providing improved performance, noise reduction and redundancy. The sensor fusion between the GNSS receivers and inertial sensors is done seamlessly in real time for a continuous 100 Hz navigation output. Data is automatically logged to the 32 GB eMMC for added data protection.

Figure 1 and Figure 2 show the key points of note on the AV200and xNAV650. The numbered labels are described in Table 3.

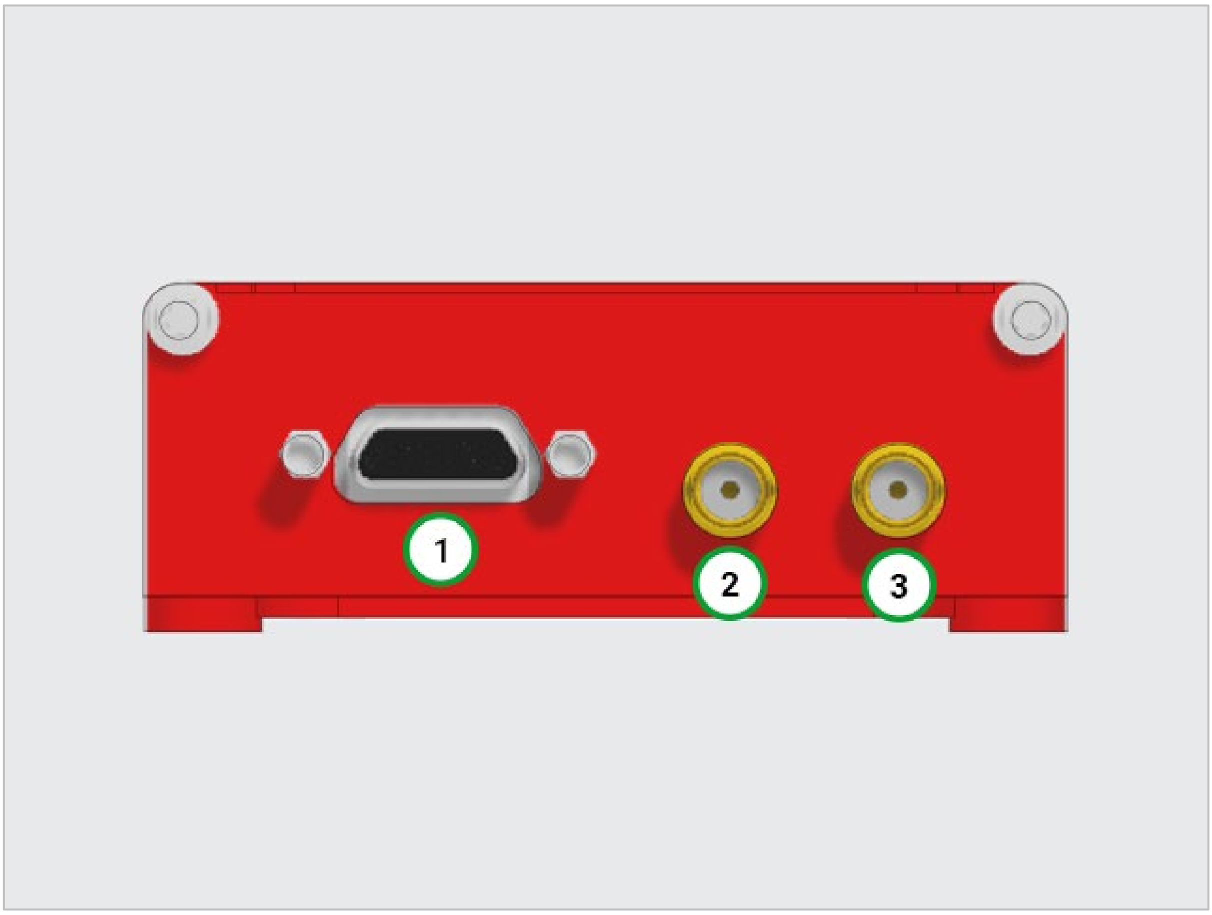


Figure 1:
AV200x and xNAV650 front view

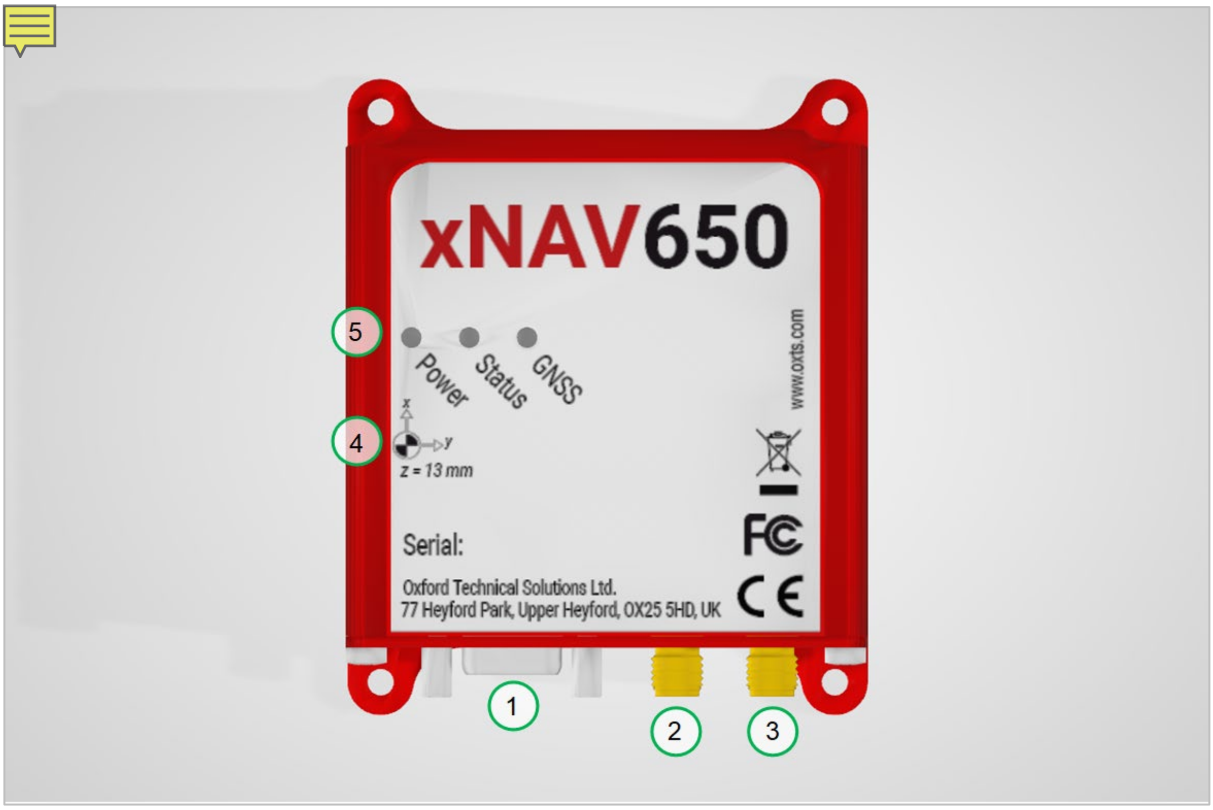


Figure 2:
AV200 and xNAV650 top view

Label number	Description
1	Main I/O connector (15-way Micro-D) • Power • Ethernet • PPS • Digital I/O signal 1/2 (configurable) • CAN (AV200 only) • Serial TX/RX (xNAV650 only)
2	Primary GNSS connector (SMA)
3	Secondary GNSS connector (SMA)
4	Measurement origin point
5	LEDs

Table 3:
AV200 and xNAV650 points of interest

Dimensions

Figure 3 shows the outer dimensions of the AV200 and xNAV650, the mounting points, and the measurement origin point. When making measurements required in the configuration files, measurements should be made from the origin point.

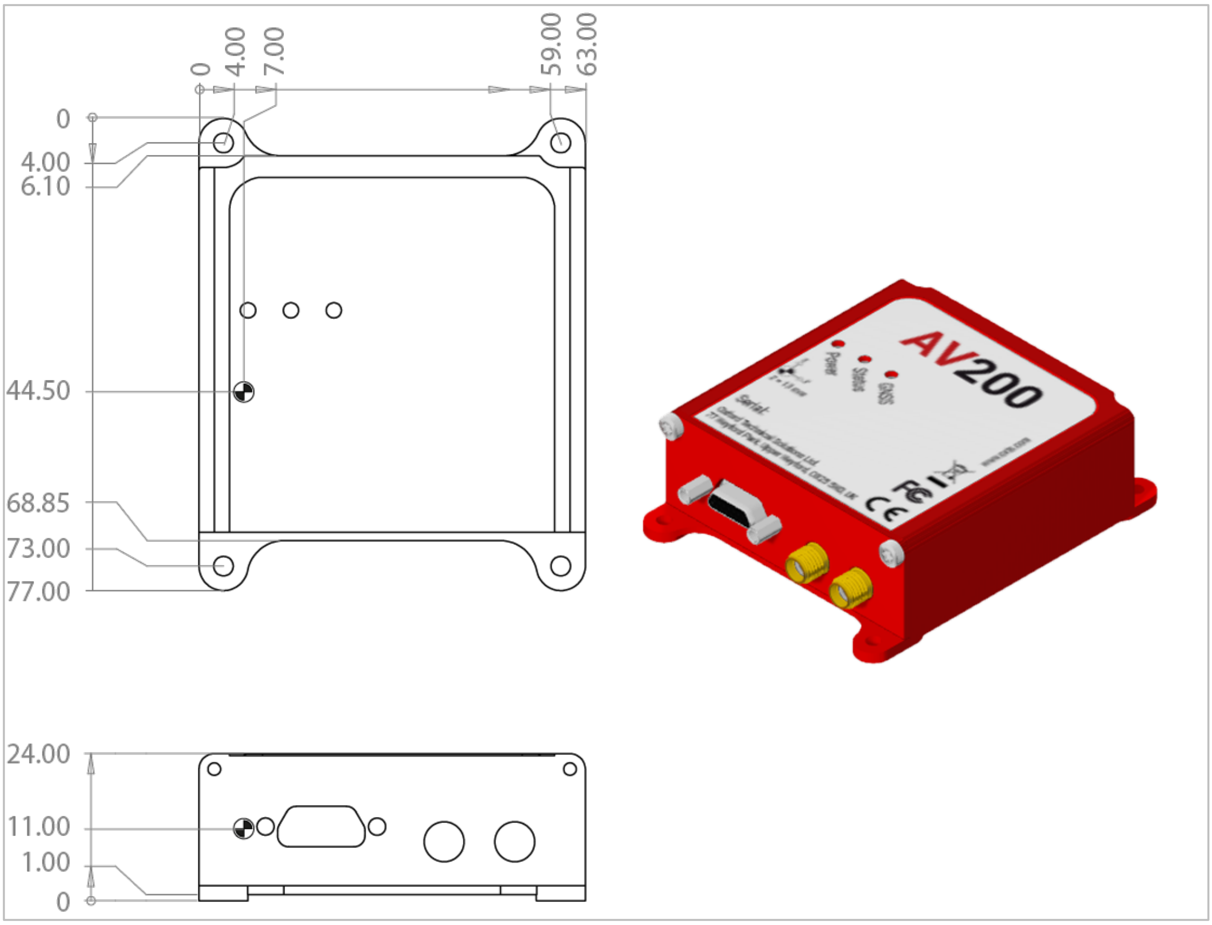


Figure 3:
AV200 and xNAV650 dimensions and measurement origin point (mm)

LED definitions

Table 4, **Table 5**, and

Table 6 show the descriptions for each of the LED functions.

Colour	Description
Off	There is no power to the system or the power supply has failed.
Green	Power is applied to the system.
Orange	The system is powered and an Ethernet link is present.

Table 4:
Power LED

Colour	Description
Off	The operating system has not yet booted (this occurs at start-up).
Red-green flash	The system is asleep. Contact OxTS support for further information.
Red flash	The operating system has booted but the GNSS receiver has not yet output a valid time, position, or velocity.
Red	The GNSS receiver has locked-on to satellites and has adjusted its clock to valid time (1PPS output now valid). The INS is ready to initialise.
Orange	The INS has initialised and data is being output, but the system is not yet real time (the Kalman filter delay is a few seconds). It takes ~10 seconds for the system to become real-time.
Green	The INS is running and the system is real-time.

Table 5:
Status LED

Colour	Description
Off	The GNSS receiver has a fault (valid only after start-up).
Red flash	The GNSS receiver is active but has not yet determined heading.
Red	The GNSS receiver has a differential heading lock.
Orange	The GNSS receiver has a floating (poor) calibrated heading lock.
Green	The GNSS receiver has an integer (good) calibrated heading lock.

Table 6:
GNSS LED

Coordinate frame

The IMU reference frame shown in Figure 4 is popular with navigation systems – where the positive X-axis points forwards, the positive Y-axis points right and the positive Z-axis points down.

The AV200 and xNAV650 can be mounted in any orientation, it is not necessary for its axes to match those of the host vehicle. The configuration file will specify the transformation from the IMU frame to the vehicle frame.

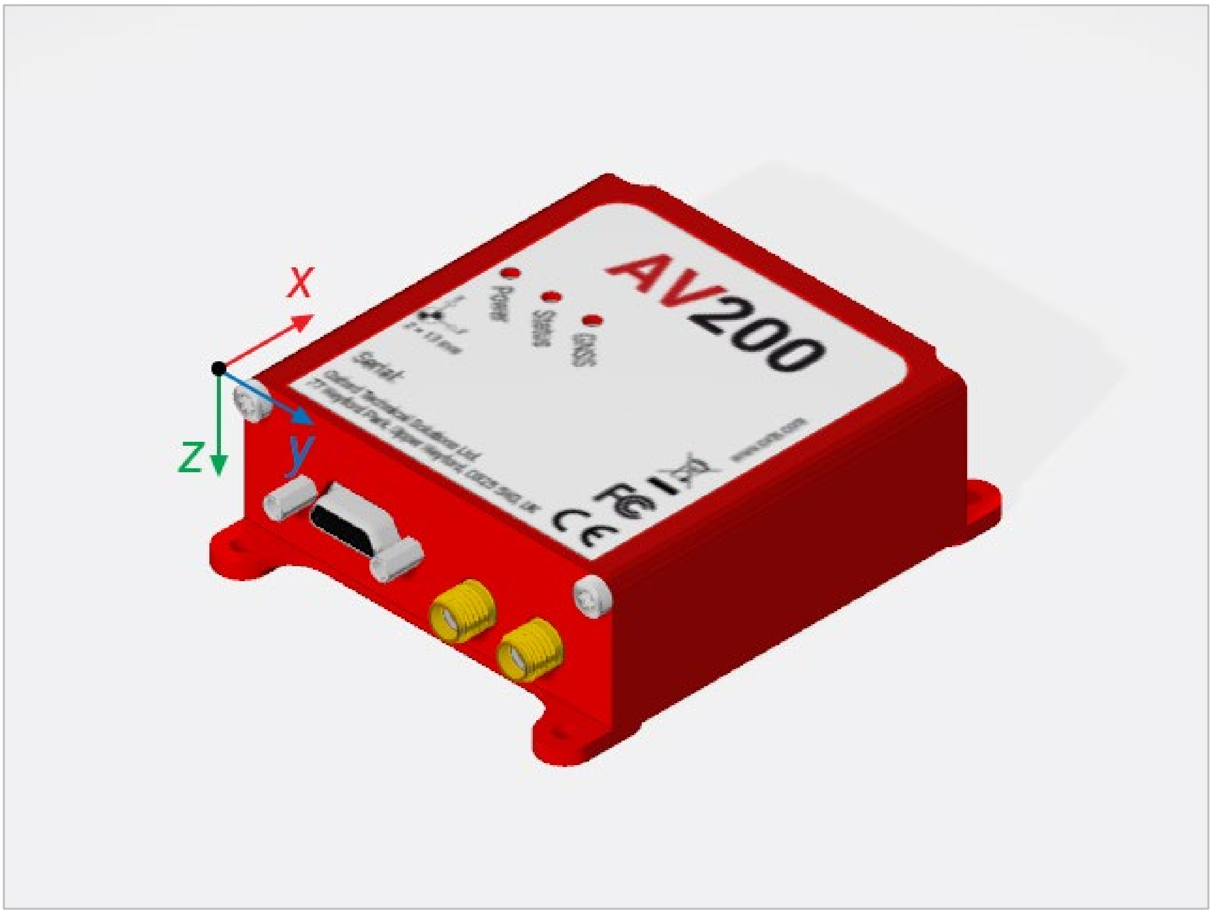


Figure 4:
AV200 and xNAV650 coordinate frame axes

Design-in

Main connector

The main I/O connector on the AV200 and xNAV650 is a 15-way Micro D-sub. Figure 5 shows the pin layout.

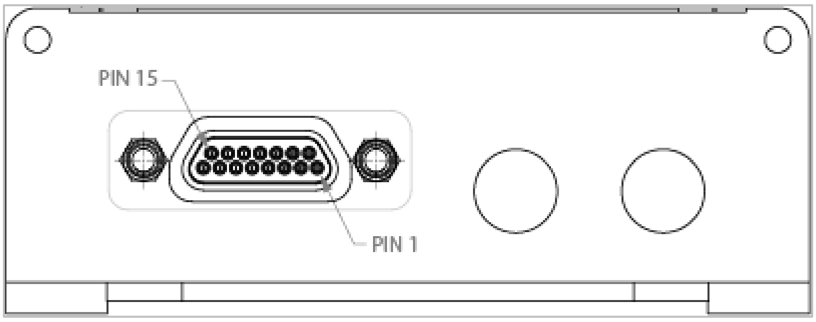


Figure 5
AV200 and xNAV650 main connector pin layout

Table 7 shows the pin descriptions.

Pin #	Name (function)	I/O type	Description
1	Supply+	P	Power supply +
2	Supply+	P	Power supply +
3 (AV200)	CAN+	I/O	CAN bus high
3 (xNAV650)	Serial	I/O	Serial RS232 RX
4 (AV200)	CAN-	I/O	CAN bus low
4 (xNAV650)	Serial	I/O	Serial RS232 TX
5	ERX-	I	Ethernet receive -
6	ERX+	I	Ethernet receive +
7	ETX-	O	Ethernet transmit -
8	ETX+	O	Ethernet transmit +
9	I/O signal 2	I/O	Configurable I/O. Contact OxTS for options
10	I/O signal 1	I/O	Configurable I/O. Contact OxTS for options
11	Signal ground	P	Signal ground
12	PPS	O	Pulse per second synchronisation output
13	Signal ground	P	Signal ground
14	Supply-	P	Power supply -
15	Supply-	P	Power supply -

Table 7:
Main connector pin description

PPS

The PPS output is a pulse generated by the GNSS receiver. Note the output will **not** be active when the GNSS receiver has no valid position measurement. The falling edge of the pulse is the exact transition from one second to the next in GPS time. The pulse is low for 1 ms, then high for 999 ms and repeats every second. The output is a low-voltage CMOS output, with 0.8 V or less representing a low and 2.4 V or more representing a high. No more than 10 mA should be drawn from this output.

The signal is configurable to the rising or falling edge. For details, please refer to the support article for NAVconfig or check the hardware section of this manual.

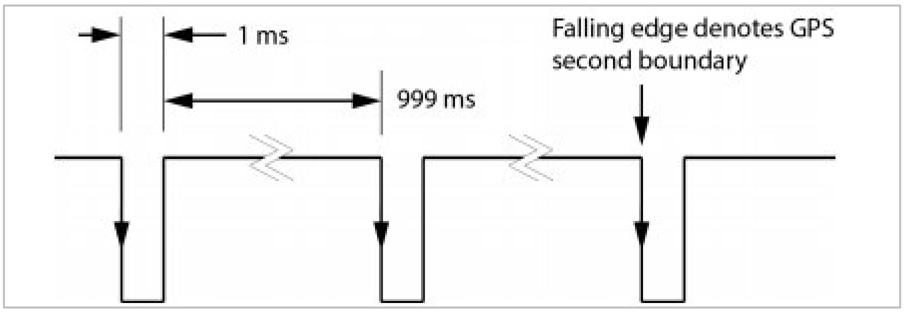


Figure 6:
PPS waveform

Serial (xNAV650 only)

The serial interface uses a standard 5V logic RS232. The exact transceiver used is the SN65C3221EPWR. For full details you can read the datasheet from Texas Instruments:

https://www.ti.com/lit/ds/symlink/sn65c3221e.pdf?ts=1612353780873&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FSN65C3221E

Digital I/O

I/O	Typical	Min	Max
Input Low Voltage (V)	-	-20	0.5
Input High Voltage (V)	-	2	20
Output Voltage high (V)	3.3	2	3.3
Output Voltage Low (V)	0	-	0.8
Output Current (mA)	-	-	4

Table 8:
Digital I/O electrical specifications

Note that triggers are pulled up internally to allow a switch to be used to short them to GND.

User cable

The AV200 evaluation kit and the xNAV 650 are supplied with a standard user cable for quick access to the main interfaces. Figure 7 shows the cable diagram for the AV200 cable, while Figure 8 shows the cable diagram for the xNAV650. **Table 9** shows the pin descriptions for the interface connectors. At the end of this manual there is a full page drawing of both user cables provided.

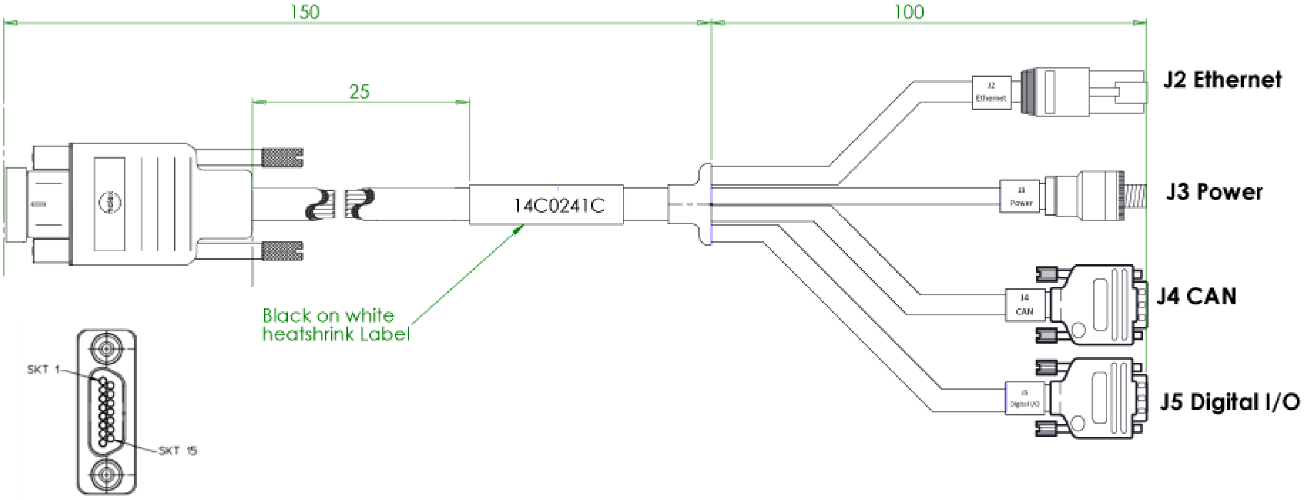


Figure 7:
AV200 user cable

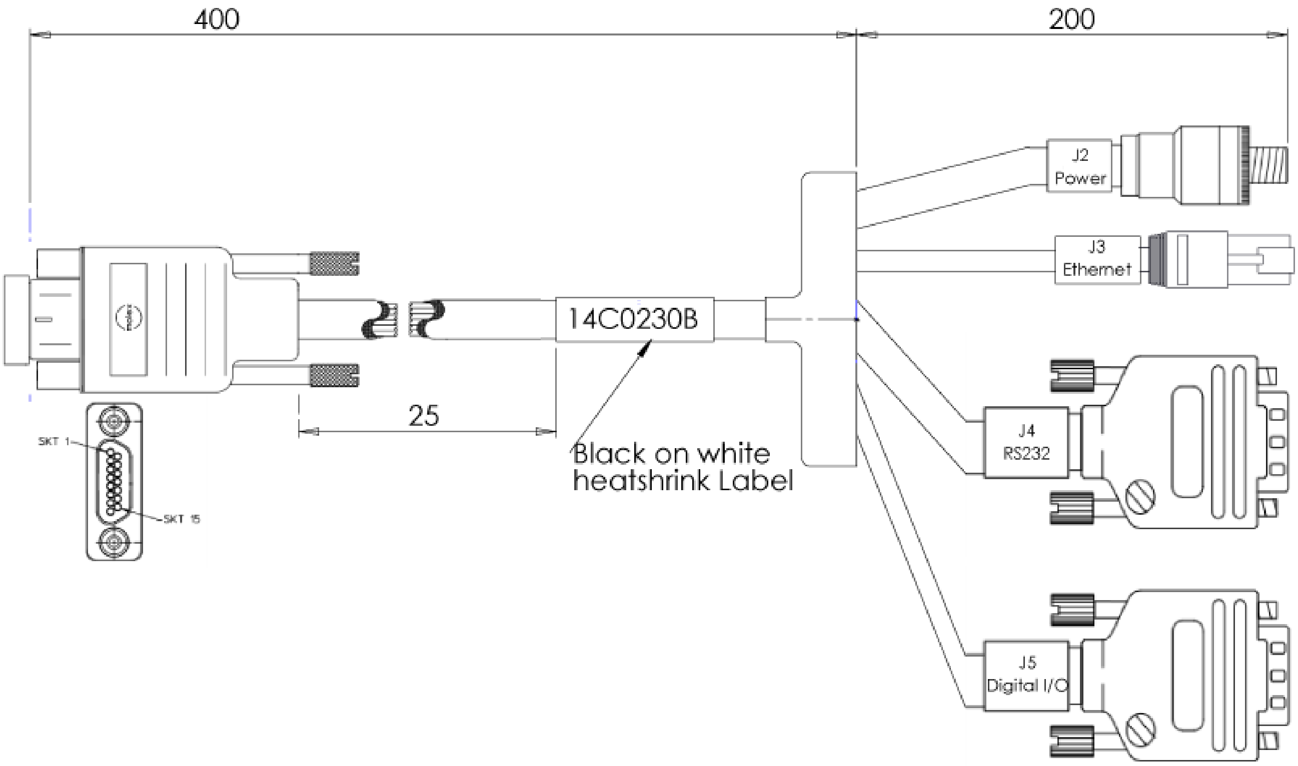


Figure 8:
xNAV650 user cable

The CAN interface does not include a termination resistor. Appropriate termination must be used, e.g. if used in a single device connection, a 120 Ω terminating resistor must be added between the CAN+ and CAN- pins.

J1 Pin	Wire colour from J1	Description	Terminate to
1	Black	Supply+	J3-1, Red
2	Brown		
3	Red	CAN+ (AV200), Serial RX (xNAV650)	J4
4	Orange	CAN- (AV200), Serial TX (xNAV650)	
5	Yellow	ERX-	J2-6, Green
6	Green	ERX+	J2-3, White/Green
7	Blue	ETX-	J2-2, Orange
8	Violet	ETX+	J2-1, White/Orange
9	Grey	I/O signal 2	J4
10	White	I/O signal 1	
11	White/Black	Signal ground	
12	White/Brown	PPS	
13	White/Red	Signal ground	
14	White/Orange	Supply-	J3-2, Black
15	White/Yellow		
Shield	Braid	Earth	

Table 9:
AV200 and xNAV650 user cable pin description

Power lines should be correctly terminated and insulated and wired up with a fuse somewhere between the unit and power source before being connected to a power source.

The AV200 and the xNAV650 are not IP rated so should not be mounted where they will be exposed to rain. Suitable for pollution degree 2 locations.

Mounting

It is essential to mount the INS rigidly in the vehicle. It should not be able to move or rotate compared to the GNSS antennas, otherwise the performance will be reduced. In most circumstances the INS should be mounted directly to the chassis of the vehicle. If the vehicle experiences high shocks, then vibration mounts may be required.

Figure 9 shows the mounting points for the AV200 and xNAV650. The mounting holes are suitable for M3 threaded screws.

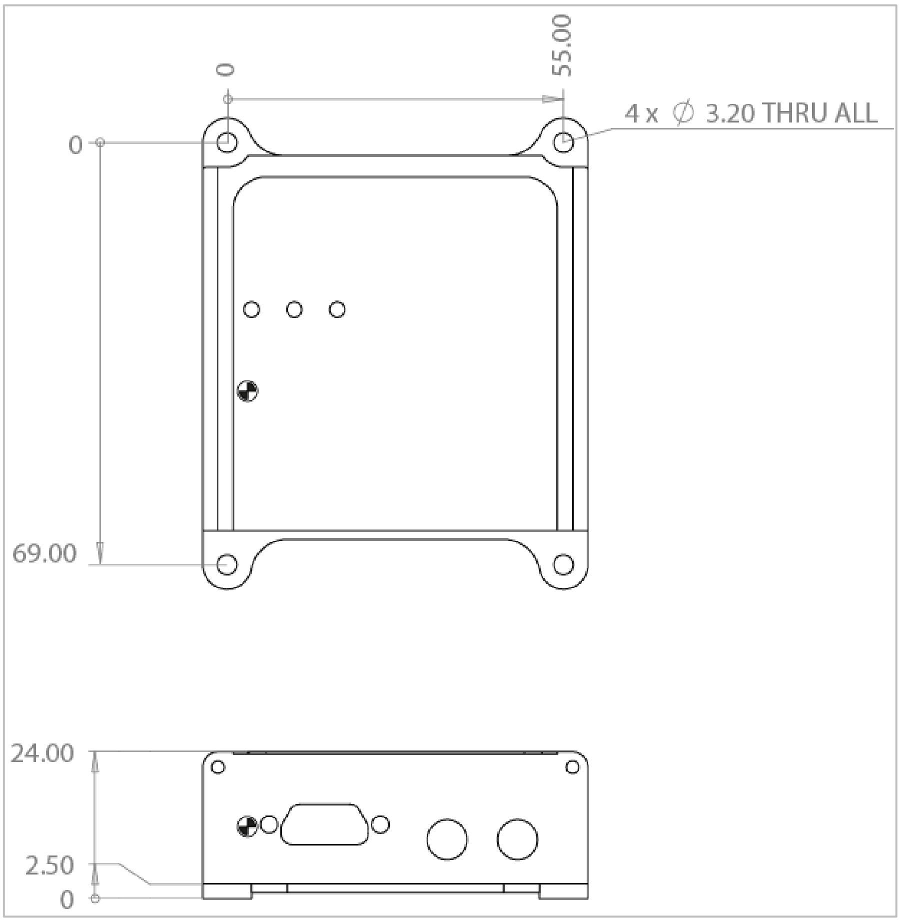


Figure 9:
AV200 and xNAV650 mounting points (mm)

Do not install the INS where it is in direct sunlight as this may cause the case to exceed the maximum temperature specification. Do not mount near sources of significant heating or cooling as sudden changes in temperature can adversely affect satellite signal tracking.

The user should perform a visual inspection of the equipment before use to ensure there is no damage.

Orientation and alignment

The orientation of the INSE in the vehicle is normally specified using three consecutive rotations that transform the system to the vehicle's co-ordinate frame. The order of the rotations is:

1. Heading (z-axis rotation);
2. then pitch (y-axis rotation);
3. then roll (x-axis rotation).

It is important to get the order of the rotations correct.

The AV200 and xNAV650 can be mounted at any angle in the vehicle as long as the orientation is described in the configuration. This allows the outputs to be rotated based on the settings entered to transform the measurements to the vehicle frame.

Antennas

The AV200 and xNAV650 have SMA connectors for the primary and secondary GNSS antennas. Antennas used with the AV200x and NAV650 must at least be capable of tracking the GPS L1 signal for operation and additionally the GPS L2 signal for RTK performance. Antennas capable of tracking L1 and L2 GLONASS signals, E1 and E5b Galileo signals, and B1 and B2 Beidou signals should be used for optimal performance and improved reliability.

The AV200 and xNAV650 are both certified for use with GNSS antennas with a gain of <= 35 dB.

When using the INS in a dual antenna configuration, it is recommended to use the same type of antenna with the same cable lengths for both the primary and secondary receivers.

A suitable ground plane is required for the antennas to achieve good performance.

Antenna placement and orientation

For optimal performance it is essential for the GNSS antenna(s) to be mounted where they have a clear, uninterrupted view of the sky and on a suitable ground plane, such as the roof of a vehicle. They should be mounted away from any potential sources of interference, such as LiDAR systems.

For dual antenna systems, the secondary antenna should be mounted in the same orientation as the primary antenna, as shown in Figure 10. The antenna baseline should also be aligned with one of the vehicle axes where possible, either inline or perpendicular to the vehicle's forward axis. In the default configuration the primary antenna should be at the front of the vehicle and the secondary antenna should be at the rear and they should be as far apart as possible.

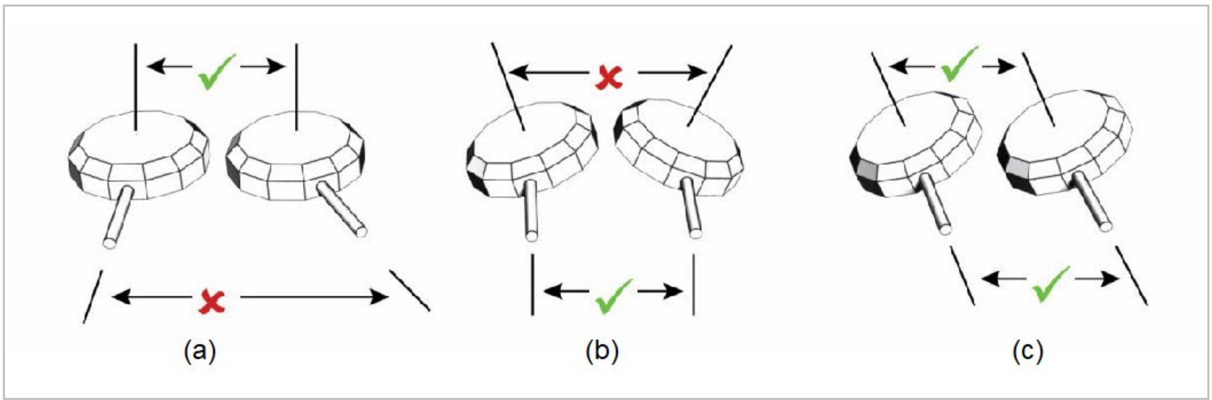


Figure 10:
Dual antenna orientation

a) The bases of the antennas are parallel, but the cables exit in different directions.

b) The cables exit in the same direction but the bases of the antennas are not parallel.

c) The bases of the antennas are parallel and the cables exit in the same direction. This configuration will achieve the best results.

Ethernet configuration

To configure the AV200 and xNAV650 for unrestricted data transmission it is necessary to use the Ethernet connection. The operating system at the heart of the AV200 and xNAV650 allows connection to the unit via FTP. The use of FTP allows the user to manage the data logged to the unit; transferring or deleting files. Configuration files for alternative configurations require FTP to put the configuration files on to the AV200 or xNAV650. The default username and password are both “user”.

The AV200 and xNAV650 output data over Ethernet using a UDP broadcast. The use of a UDP broadcast allows everyone on the network to receive the data sent by the INS. The data rate of the UDP broadcast is 100 Hz.

Each INS is configured with a static IP address, to enable communication by Ethernet. The default IP address will have the following format:

```
192.168.196.1xx
```

Where xx is the last two digits of the unit’s serial number.

The IP address of the computer being used to communicate with the INS may need to be changed so it matches the subnet. For example, 192.168.196.22 should be available since this IP address is never used by the INS by default.

Connection details for ethernet configuration

The RJ-45 connector on the 14C0222x user cable is designed to be connected directly to a network hub. To extend the cable it is necessary to use an in-line coupler. This is two RJ-45 sockets wired together in a straight-through configuration. Following the in-line coupler, a normal, straight UDP Cat 5e cable can be used to connect the coupler to the hub.

The AV200 and xNAV can be connected directly to an ethernet card in a computer. To do this a crossed in-line coupler must be used.

Internal storage

The AV200 and xNAV650 use a 32 GB eMMC for storage of hardware information, configuration files, and navigation data. Files can be sent to, or retrieved from, the card via FTP or with the software utilities provided (NAVconfig for configuration files and NAVsolve for data files).

The AV200 and xNAV650 start logging data automatically on power-up. Each individual raw data file (*.rd) can be a maximum of 2 GB, equivalent to around one full day of logging at 100 Hz data rate with four GNSS constellations. Once the 2 GB file limit is reached, a new file is started automatically to continue logging. If the 32 GB storage limit is reached, the system will start overwriting existing RD files, starting from the oldest first.

Data from other devices can be logged directly onto the AV200 and xNAV650 with the Generic Ethernet Logging feature code. LiDAR units with data rates similar to the VLP-16 LiDAR or less are able to log directly onto the INS. When data is recorded in this way the LiDAR data is recorded as a .lcom file. The data is stored without ethernet headers so is not identical to a traditional PCAP file. The limit for recording data can be as high as 5MB/s but 3MB/s is the specification given for reliable operation. This is more than enough for a VLP16 LiDAR for example but not for a VLP32.

Electrical specifications

This section lists the recommended electrical operating conditions for the AV200 and xNAV650.

I/O signal	Min	Typ	Max
Input voltage low (V)	-20		0.5
Input voltage high (V)	2.5		20
Output voltage low (V)	0	0	0.5
Output voltage high (V)	2.5	3.3	3.5
Output current (mA)			4

Table 10:
I/O interface electrical specifications
Note: triggers are pulled up internally to allow a switch to be used to short them to Ground.

PPS	Min	Typ	Max
Output voltage low (V)	0	0	0.5
Output voltage high (V)	3	3.3	3.5
Output current (mA)			2

Table 11:
PPS electrical specifications

Specifications

Specifications for xNAV650 can be found in
Table 12,
Table 13, and

Table 14. These specifications are listed for operation of the system under the following conditions:

- After a warm-up period of three minutes' continuous operation.
- Using combined post-processing the highest specification can be achieved effectively instantly for the entire duration of the dataset but the warm-up manoeuvres should always be performed.
- Open-sky environment, free from cover by trees, bridges, buildings or other obstructions. The vehicle must have remained in open sky for at least five minutes for full accuracy.
- The vehicle must exhibit some motion behaviour which should be achieved during the warmup. Acceleration of the unit in different directions is required so the Kalman filter can estimate any errors in the sensors. Without this estimation, some of the specifications degrade.
- The distance from the xNAV measurement point to the primary GNSS antenna must be known by the system to a precision of five millimetres or better. The vibration of the system relative to the vehicle cannot allow this to change by more than five millimetres. The system will estimate this value itself in dynamic conditions.
- For dual antenna systems, the system must know the relative orientation of the two antennas to 0.05° or better (the system will estimate this value itself under dynamic conditions).
- For single antenna systems, the heading accuracy is only achieved under dynamic conditions. Under benign conditions, such as motorway driving, the performance will degrade. The performance is undefined when stationary for prolonged periods of time.

Parameter	Value
GNSS tracking	GPS L1, L2 GLONASS L1, L2 BeiDou B1, B2 Galileo E1, E5b
Position accuracy[1]	1.5 m CEP SPS 0.4 m DGPS 0.02 m RTK
Velocity accuracy	0.1 km/h RMS
Roll/pitch accuracy	0.05° 1σ
Heading accuracy[2]	0.1° 1σ

Table 12:
AV200 and xNAV650 performance specifications
1Typical values, subject to ionospheric/tropospheric conditions, satellite geometry, baseline length, multipath. Requires clear view of the sky and appropriate differential corrections to achieve full specification.
2Using dual antenna with 1 m separation baseline. Higher accuracy can be achieved with wider antenna separation.

Accelerometers	Value
Full range	±8 g
In-run bias stability	0.08 mg
Scale factor	0.08%
VRW	0.06 m/s/√hr
Gyros	**Value**
Full range	±480°/s
In-run bias stability	5°/hr
Scale factor	0.3%
ARW	0.48°/√hr

Table 13:
AV200 and xNAV650 inertial sensor specifications

Parameter	Value
Input voltage[c]	5-30 V dc
Power consumption	4 W
Dimensions	77 × 63 × 24 mm
Mass	0.13 kg
Operating temperature	-40° to 70°C
Calibration temperature	-20° to 70°C
Vibration	10-500 Hz 1.42 g RMS
Shock	15 g 11 ms half sine
Internal storage	32 GB
Data logging rate	3 MB/s
Data output rate	100 Hz with 200 and 250 Hz options

Table 14:
AV200 and xNAV650 physical characteristics
[1]Voltage range of connected devices such as radio modems must be considered.

Notes on specifications

+ Full specification accuracy will be achieved after a short warm-up period during which motion inputs will be used by the navigation system to estimate sensor error characteristics.
+ The heading accuracy that can be achieved by the dual antenna system is 0.2° 1σ per metre of separation in ideal, open sky conditions. Increasing the separation improves the performance linearly. The system can provide these accuracies in static and dynamic conditions.
+ For single antenna systems, the heading is calculated from the inertial measurements and requires dynamic conditions to achieve the best performance.
+ Non-ideal mounting of the GNSS antennas will reduce the heading accuracy, particularly for dual antenna systems.

Export control classification number

Export control regulations are subject to change, and so the classification number of the AV200 and xNAV650 may also change. The information presented here is correct at the time of publishing.

The accelerometer and gyro sensors used in the AV200 and xNAV650, as well as the AV200 and xNAV650 navigation systems as a whole, do not fall under the requirements for controlled items on the Commerce Control List (CCL). As such the AV200 and xNAV650 is designated ECCN 7A994 meaning no licence is required for export or reexport.

Software installation

Included with every OXTS INS is a USB stick containing the software package NAVsuite. This package contains several programs required to take full advantage of the INS' capabilities.

Table 15 lists the contents of NAVsuite.

Icon	Software	Description
	NAVstart	A menu from which you can navigate between OxTS applications. This opens automatically when you are connected to a unit.
	NAVconfig	Used to create, send, and receive configurations from OxTS products. As configurations vary between products there is no manual for NAVconfig.
	NAVdisplay	Used to view real-time data from OxTS products via Ethernet or a serial port. It can also be used to transmit special commands and replay logged data.
	NAVsolve	Used to download raw data files from the RT and post-process the data. The configuration can be changed and differential corrections can be applied before the data is reprocessed. It can export NCOM, XCOM and CSV file formats.
	NAVgraph	Used to graph NCOM, XCOM and RCOM files created in post-process. It can display graphs, cursor tables and map plots and data can be exported in CSV or KML (Google Earth) format.
	NAVbase	Used to configure and manage RT-Base S and GPS-Base base stations, which can be used to achieve RTK integer level position accuracy.
	Manuals and documents	This folder contains PDF versions of relevant OxTS manuals. Other manuals can be downloaded from the OxTS website.

Table 15:
NAVsuite components

To install NAVsuite, insert the USB stick into your PC and run **NAVsetup.exe**. Follow the onscreen instructions to install the software. By default, the installer creates the program files in C:\Program Files (x86)\OxTS on 64 bit operating systems or C:\Program Files\OxTS on 32 bit operating systems.

The first time some OxTS applications are run, a firewall warning message similar to that shown in **Figure 11** may be triggered. This is because the program is attempting to listen for, and communicate with, OxTS devices on the network. The firewall must be configured to allow each program to communicate on the network, or programs will not work as intended.

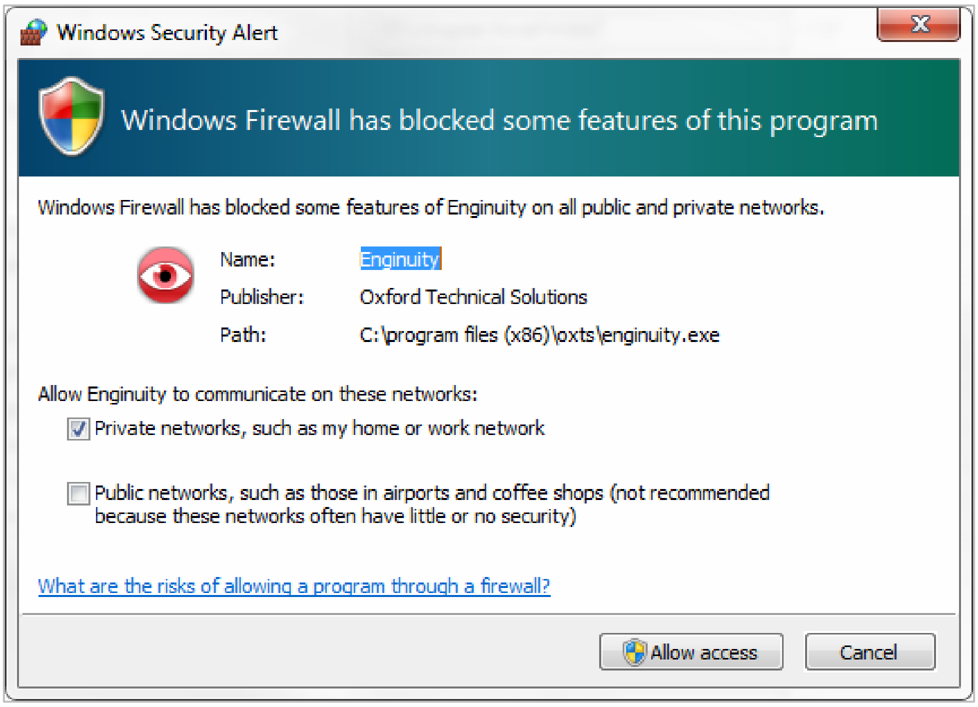


Figure 11:
Windows Firewall warning message

Ensure both Private and Public networks are selected to ensure the software can continue functioning when moving from one type to another.

Operating principles

This section gives some background information on the components in the xNAV650 and how they work together to give the outputs. A short overview of the algorithm is given and some explanation of how the software works. This section is provided as “interesting information” and is not required for normal operation.

Strapdown navigator

The outputs of the system are derived directly from the strapdown navigator. The role of the strapdown navigator is to convert the measurements from the accelerometers and angular rate sensors to position. Velocity and orientation are also tracked and output by the strapdown navigator.

Figure 12 shows a basic overview of the strapdown navigator. Much of the detail has been left out and only the key elements are shown here.

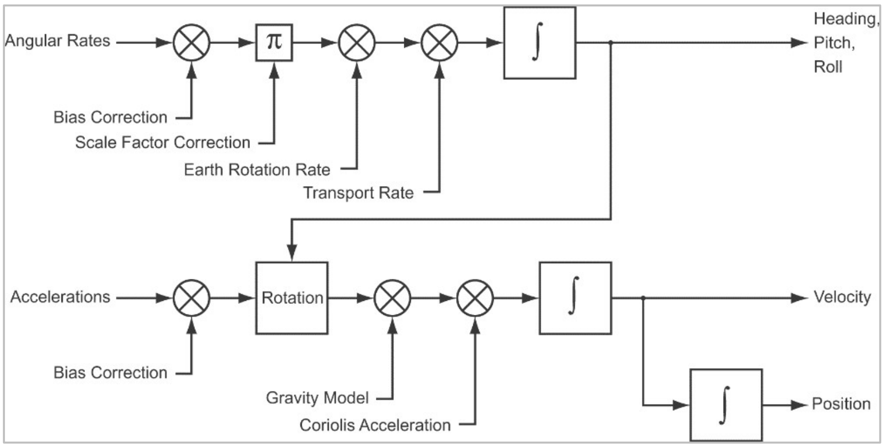


Figure 12:
Schematic of the strapdown navigator

The angular rates have their bias and scale factor corrections (from the Kalman filter) applied. Earth rotation rate is also subtracted to avoid the 0.25° per minute rotation of the Earth. The transport rate is also corrected; this is the rate that gravity rotates by due to the vehicle moving across the earth’s surface and it is proportional to horizontal speed. Finally, the angular rates are integrated to give heading, pitch and roll angles.

The accelerations have their bias corrections (from the Kalman filter) applied. Then they are rotated to give accelerations in the earth’s co-ordinate frame (north, east, down). Gravity is subtracted and Coriolis acceleration effects removed. The accelerations are integrated to give velocity. This is integrated to give position.

The strapdown navigator uses a WGS 84 model of the earth, the same as GPS uses. This is an elliptical model of the earth rather than a spherical one. The position outputs are in degrees latitude, degrees longitude and altitude. The altitude is the distance from the model’s earth sea level.

Extended Kalman filter

Kalman filters can be used to merge several measurements of a quantity and therefore give a better overall measurement. This is the case with position and velocity in the AV200 and xNAV650; the Kalman filter is used to improve the position measurement made from two sources, inertial sensors and GNSS.

The Kalman filter used in the INS is able to apply corrections to several places in the strapdown navigator, including position, velocity, heading, pitch, roll, angular rate bias and scale factor and acceleration bias.

Using a model of how one measurement affects another, the Kalman filter is able to estimate states where it has no direct measurement.

Position and velocity are compensated directly, but other measurements like accelerometer bias, have no direct measurements. The Kalman filter tunes these so the GNSS measurements and the inertial measurements match each other as closely as possible.

Use with survey hardware

NOTE that while the instructions below are applicable to both the AV200 and the xNAV650, the xNAV650 has been optimised for use with survey equipment. As such, the instructions below refer to the xNAV650.

For using your xNAV650 with a range of different surveying devices we have online support manuals. This is by no means exhaustive, the xNAV650 is compatible with almost any LiDAR or camera when it is configured correctly, and the correct interfaces are created between the devices.

Manual	Description
Hesai LiDAR	Hesai hardware integration guide https://support.oxts.com/hc/en-us/articles/360017030840
Ouster LiDAR	Ouster hardware integration guide https://support.oxts.com/hc/en-us/articles/360017072719
Phase One Camera	Phase One Camera User Guide https://support.oxts.com/hc/en-us/articles/360000099345-Phase-One-Camera-User-Guide
Velodyne LiDAR	Hardware integration with Velodyne LiDAR https://support.oxts.com/hc/en-us/articles/360017123620
Z&F Profiler	Hardware integration with Z&F 9012 Profiler https://support.oxts.com/hc/en-us/articles/360002379180-Hardware-integration-with-Z-F-9012-Profiler
PTP	Procedure for configuring PTP for a time synchronisation method over ethernet https://support.oxts.com/hc/en-us/articles/360016515759-PTP-Quick-Start-Guide-Beta-

Table 16:
Hardware integration manuals for surveying devices

For information on setting up a configuration for your INS to work with survey devices you can follow the guides above and the NAVconfig support guide.

Many devices will require to receive NMEA messages and a time synchronisation. For the xNAV650, time synchronisation can be done using PPS or using PTP. See the manual at the hyperlink above to configure your INS to use PTP. PTP messages are sent over ethernet whereas PPS will require a suitable cable connection to be made. NMEA messages can be configured to be sent over serial or over ethernet using NAVconfig. For the serial connection, there must again be a suitable cable connection made.

Using NAVconfig you can also configure input and output triggers and a displaced output if you want the navigation data to be representative of the survey device instead of the INS.

Data logging

A Feature Code can be purchased to allow your xNAV650 device to log ethernet traffic directly onto the unit. This allows you to bypass the need to monitor and record your files in real time. Files can be retrieved from the device in the same way as RD files via FTP interfacing.

When LiDAR data is logged in this way it is recorded as .lcom which is identical to a .pcap except without ethernet headers. LCOM and PCAP files work identically in OxTS Georeferencer.

Please note that data logging does not work for all LiDAR. Data rates from LiDAR devices can be very large which can be overbearing for the CPU of the xNAV650. For Velodyne LiDAR usage, a 16 laser LiDAR will log comfortably onto the xNAV but a 32 laser LiDAR will not log correctly onto the xNAV. 3MB/s is the given specification for data recording reliably.

This setting can be enabled or disabled in the LiDAR Scanner tab of the Hardware Setup in NAVconfig. Select the Velodyne VLP-16 as your scanner type (regardless of your device) and then select 'Log data' and 'Log telemetry'.

PPS and NMEA

Many survey devices require to receive PPS synchronisation and NMEA data. This can be easily configured using NAVconfig. The hardware setup will also have to be made to support this via a suitable cable. Furthermore, ensure that the PPS requirements for the device are the same as the INS output. If you require TTL input, for example, you will need an adapter between the two devices.

In NAVconfig PPS and NMEA can be set in the LiDAR Scanner tab of the Hardware Setup section. Choosing Velodyne VLP-16 (regardless of your device) will allow you to choose NMEA settings. Depending on the cabling setup you have used you are able to send NMEA messages over either ethernet or serial. For example, when using a PTP setup you will want NMEA and PTP messages to both be sent over ethernet to the device.

There are further PPS options in the PPS/Triggers section.

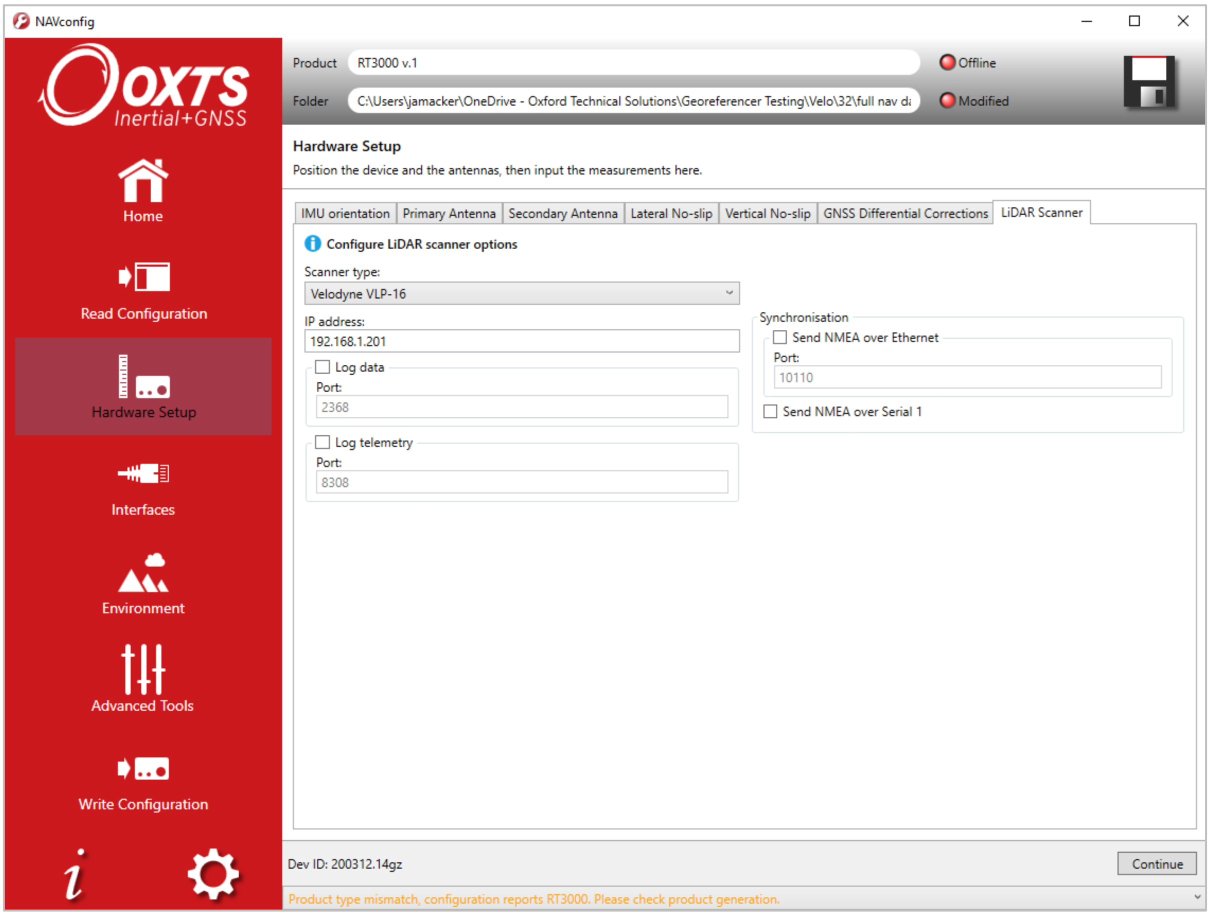


Figure 13:
NAVconfig LiDAR Scanner tab

PPS/Triggers

NAVconfig allows users to easily configure trigger inputs for cameras within the PPS/Triggers tab of the Interfaces section. These are set on the right-hand side and can be input, output triggers or IMU sync triggers.

PPS signals can be set to have the active edge in the falling or rising edge in this tab also. Check your device's manual to determine which is required.

NCOM (navigation data) packets can be set to output on triggers in the ethernet tab.

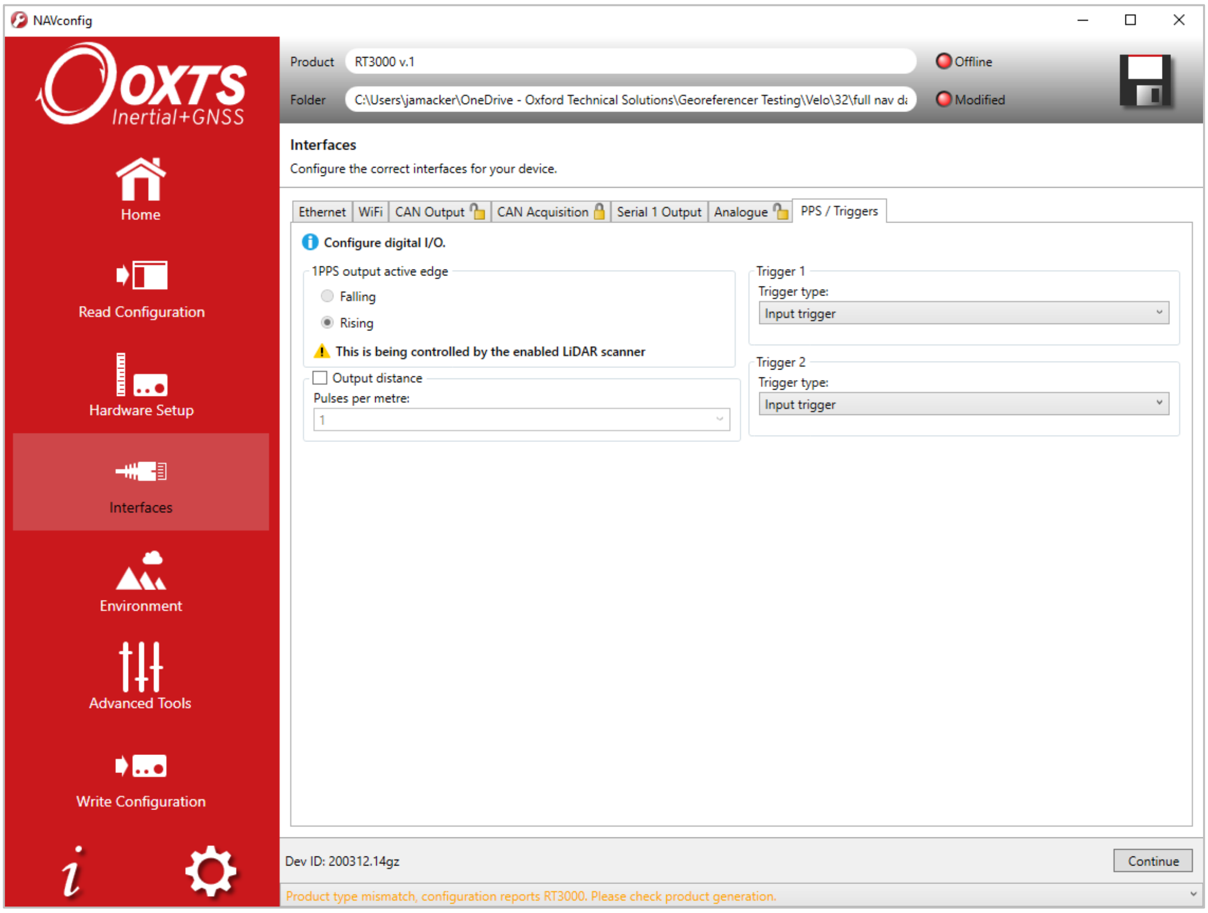


Figure 14:
The PPS/Triggers tab in NAVconfig.

PTP

Precision Time Protocol (PTP) is supported according to both the IEEE 1588 standard and the 802.1AS (gPTP) and AUTOSAR profiles of PTPv2. The AV200 and xNAV650 can be configured as either a PTP Grandmaster (synced to GPS time), a PTP slave, taking time from an alternative PTP master clock or as a PTP master taking time from an alternative grandmaster and acting as an intermediate master clock to other time slave devices..

To configure, first select the PTP Mode (PTP, gPTP or gPTP AUTOSAR), from the dropdown and then the System Mode (Master, Slave or MasterSlave). NB: MasterSlave is not available under the AUTOSAR implantation.

Different time epochs can then be configured by selecting the "Time Epoch" checkbox and then selecting from PTP, GPS, UNIX or UTC from the dropdown list.

If gPTP AUTOSAR is selected, additional message extensions can be added in the Data Id List. If the xNAV650 is to be used as a Master clock using the gPTP AUTOSAR mode, additional User data can be provided as a follow up message. Select the length of the User data from the dropdown and choose which Sub-TLVs and CRC flags are required.

gPTP AUTOSAR also supports using standard gPTP compliant messages where the sync and follow up format are supported according to 802.1AS. Select this mode by enabling the message compliance checkbox.

The use of a Cyclic Redundancy Checksum (CRC) can also be enabled via a checkbox.

If the INS is to be used as a time slave in the gPTP AUTOSAR implementation, a static delay can also be applied by typing the value (in nanoseconds) in the relevant box.

During internal testing of the PTP feature, a data was collected with a Hesai Pandar40P and an RT3000 v3. Time synchronisation was achieved using PTP. The RT3000 v3 was in GPS mode but the Hesai Pandar40P was expecting timestamps in UTC. The following command was required to generate an accurate point cloud:

```
lidar_time_offset=315964785000000000
```

If the RT3000 v3 was instead in Unix time mode, the following command would be required:

```
lidar_time_offset=-18000000000
```

Finally, ensure that your survey device is correctly configured to anticipate PTP time synchronisation.

Appendix A – Ensuring optimal operation

In order to maximise performance and ensure optimal operation, there are a number of areas to consider during installation and operation of the AV200 and xNAV650 system.

Table **17** lists the topics to pay attention to.

Topic	Consideration
Installation	Antennas installed with same orientation
	Antennas installed clear of obstructions
	Antennas able to see same constellation of satellites
	Antennas and cables routed clear of sources of EMI
	Unit mounted rigidly in vehicle
	Unit and antennas unable to move independently
	Appropriate antivibration mounts used if necessary
	Unit has a stable, uninterrupted power supply
	Appropriate CAN isolation is used
Configuration	Dual antenna set up as per OxTS guidelines
	CAN output configuration below suggested maximum message limit and lowered appropriately for other messages on the CAN bus
	Differential corrections enabled and configured
	Secondary antenna separation distance measured as accurately as possible
	Ethernet output enabled and monitored during vehicle operation
	Vibration levels are set to normal (higher levels will reduce confidence in IMU error models)
	GNSS environment set to Open skies (lower settings will reduce confidence in GNSS error models)
	A good warm up as been performed in RTK and an improved configuration committed to the unit
Pre-drive checks	Ensure all equipment is mounted securely
	Differential corrections are being received and the unit is in RTK position mode
	Position accuracy is being received over ethernet
	All cable connections are secure
Initialisation	Good GNSS conditions for dual antenna static initialisation (open skies, no multipath)
	Able to drive in a straight line and exceed speed threshold for kinematic initialisation
	Care not to exceed initialisation speed while reversing or turning
Vehicle operation	Device status is monitored – see Product Disclaimer for recommended status messages
	Avoid extended periods in blocked or obstructed GNSS environments without additional aiding sources such as a wheel speed

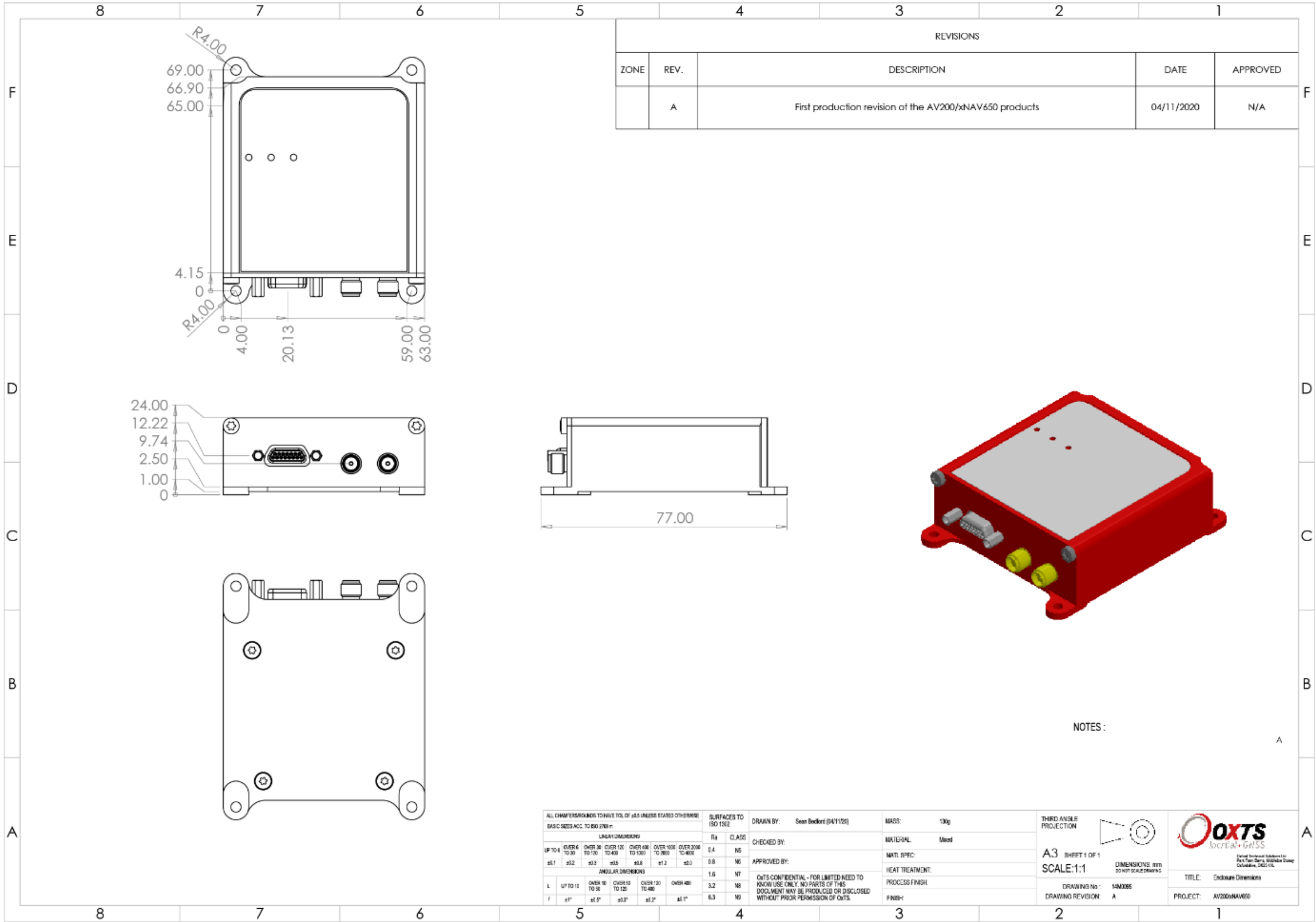
Table 17:
Optimal operation checks

Appendix B – Drawings

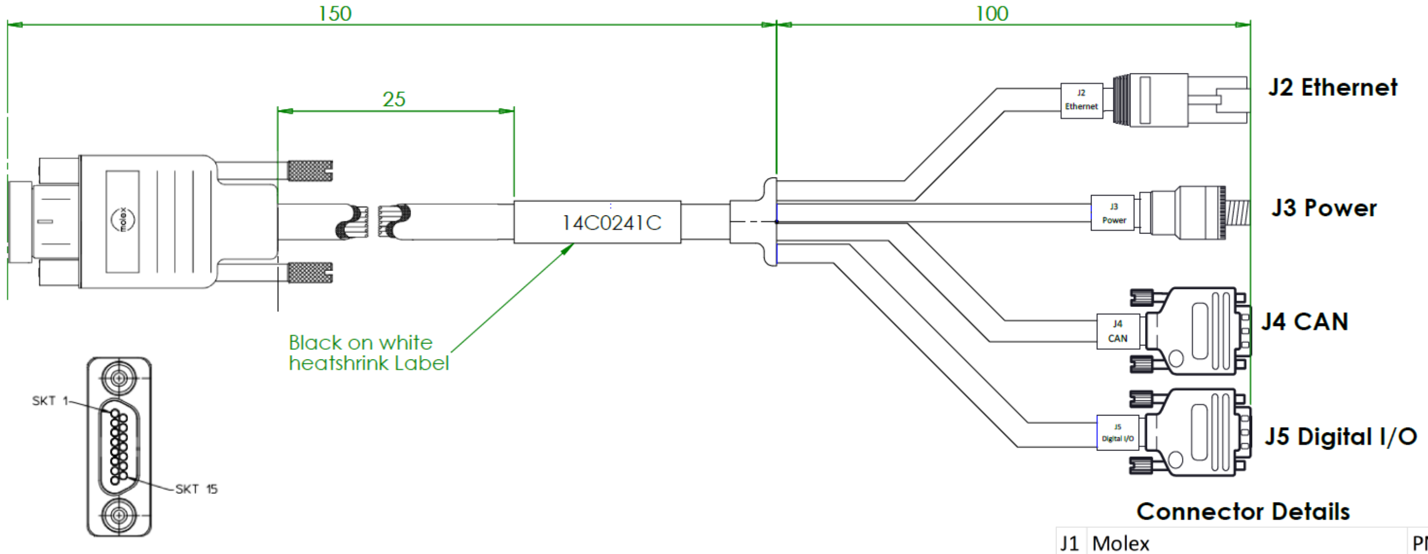
Table **18** lists the available drawings that describe components of the xNAV650 system. If you require a drawing, or different revision of a drawing, that is not here then contact OXTS.

Drawing Number	Revision	Description
14M0066A	A	AV200/xNAV650 system outer dimensions drawing
14C0241C	C	AV200 terminated user cable
14C0230B	B	xNAV650 mobile mapping cable

Table 18.
List of available drawings


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
A
First production revision of the AV200/xNAV650 products
04/11/2020
N/A
R4.00
69.00
66.90
65.00
4.15
0
R4.00
0
4.00
20.13
59.00
63.00
24.00
12.22
9.74
2.50
1.00
0
77.00
NOTES :
SURFACES TO ISO 1302
Ra
CLASS
0.4
N5
0.8
N6
1.6
N7
3.2
N8
6.3
N9
DRAWN BY:
CHECKED BY:
APPROVED BY:
OxTS CONFIDENTIAL - FOR LIMITED NEED TO KNOW USE ONLY. NO PARTS OF THIS DOCUMENT MAY BE PRODUCED OR DISCLOSED WITHOUT PRIOR PERMISSION OF OxTS.
MASS:
MATERIAL:
Mixed
MATL SPEC:
HEAT TREATMENT:
PROCESS FINISH:
FINISH:
THIRD ANGLE PROJECTION
A3
SHEET 1 OF 1
SCALE:1:1
DIMENSIONS: mm
DO NOT SCALE DRAWING
DRAWING No.:
DRAWING REVISION:
A
TITLE:
Enclosure Dimensions
PROJECT:

J1 Molex PN 834229007



Connector Details

J1	Molex	PN 834229007
J2	RJ45 FTP Patch Lead	
J3	5-Way M12 male plug connector	Lutze PN:456202
J4	9-Way Male D-type and shell	RS 180-7206
J5	9-Way Female D-type and shell	RS 180-7206

J1 Pin no.	Wire colour from J1	Signal Description	Terminate to	Assembly Notes
5	YEL	ERX-	J2-6, GRN	Pre-moulded shielded FTP Ethernet cable to be used for J2 and joined to wires from J1 in centre joint. Part should be selected with similar look to that of cable from J1.
6	GRN	ERX+	J2-3, W/GRN	
7	BLU	ETX-	J2-2, ORG	
8	VIO	ETX+	J2-1, W/ORG	
1	BLK	Supply +	J3-1+2, RED	2 core 7/32 shielded cable to be terminated to J1 wires at centre join. Must have red and black insulation on inner cores (red for supply +). Outer insulation to have similar look to cable from J1.
2	BRN			
14	W/ORG	Supply -	J3-3+4, BLK	
15	W/YEL			
3	RED	CAN+	J4-7	Wires 3 and 4 from J1 should be a twist-ed pair (TP). Outer insulation to have similar look to cable from J1.
4	ORG	CAN-	J4-2	
11	W/BLK	Signal Ground	J4-3+6	
12	W/BRN	PPS	J5-1	Outer insulation to have similar look to cable from J1. No shielding required.
13	W/RED	Signal Ground	J5-6 - 9	
9	GRY	I/O Signal 2	J5-4+5	
10	WHT	I/O Signal 1	J5-2+3	
Shield	Braid	Earth	Shields from J2&3's moulded cables to be joined to that of J1 at the centre join. Join should also be shielded.	

Notes:

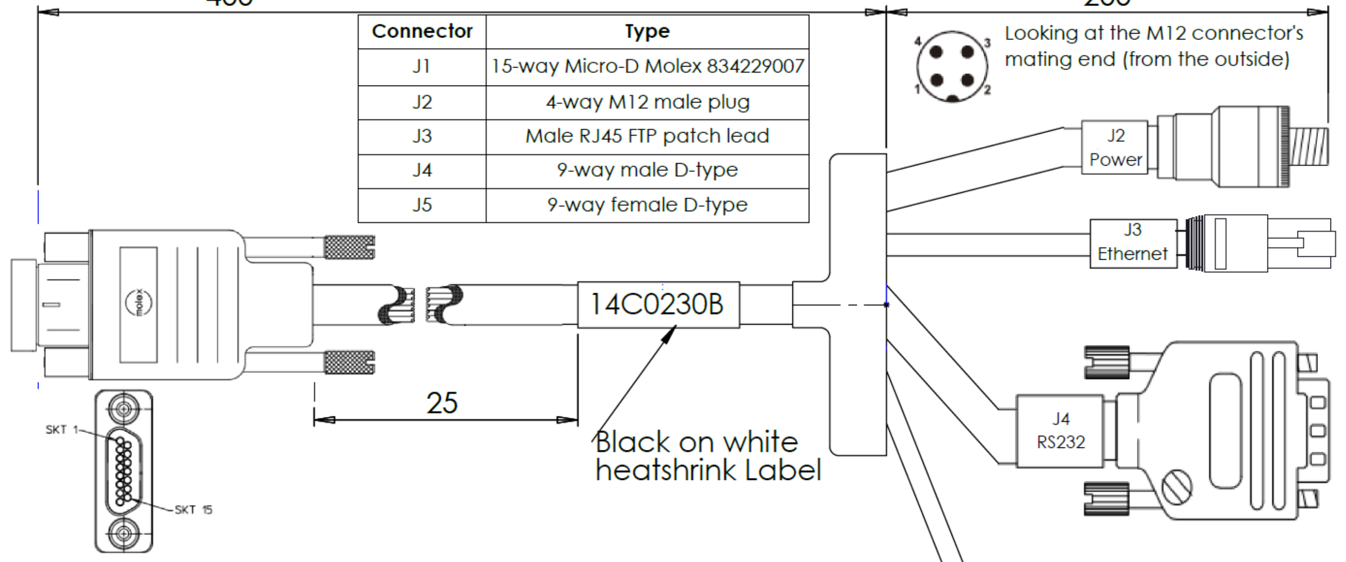
This cable is suitable for both the AV200 and xNAV650 products

In the xNAV650 J4 can be used as a serial port with this cable number: 14C0236.

Wire types not stated in the assembly notes are to be 7 strands of 34 AWG.

DATE: 06/08/24	OXTS
DRAWN BY: Matthew Hawes	Oxford Technical Solutions Ltd Park Farm Barns, Middleton Stoney Oxfordshire, OX25 4AL
CHECKED BY: Rhodry Forsberg	
APPROVED BY: Tom Bailey	
TITLE: AV200 Terminated User Cable	DRAWING No : 14C0241
DIMENSIONS: mm DRAWING NOT TO SCALE SHEET 1 OF 1	DRAWING REVISION: C

Connector	Type
J1	15-way Micro-D Molex 834229007
J2	4-way M12 male plug
J3	Male RJ45 FTP patch lead
J4	9-way male D-type
J5	9-way female D-type



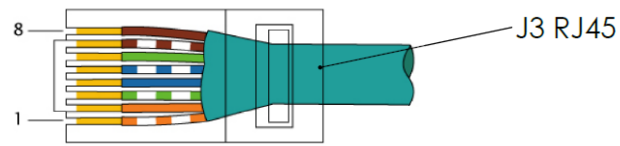
Pin	Function	Conn
1+2	Supply +	J1-1+2
3+4	Supply -	J1-14+15

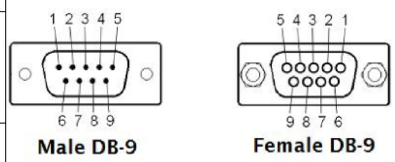
Pin	Function	Conn
1	ETX+	J1-8
2	ETX-	J1-7
3	ERX+	J1-6
6	ERX-	J1-5

Pin	Function	Conn
2	RS232 Rx	J1-3
3	RS232 Tx	J1-4
5	Signal Ground	J1-11

Pin	Function	Conn
1	PPS	J1-12
2+3	I/O 1	J1-10
4+5	I/O 2	J1-9
6-9	Signal Ground	J1-13

J1 Pin no.	Wire colour from J1	Signal Description	Terminate to	Assembly Notes
5	YEL	ERX-	J3-6, GRN	Pre-moulded shielded FTP Ethernet cable to be used for J3 and joined to wires from J1 in centre joint. Part should be selected with similar look to that of cable from J1.
6	GRN	ERX+	J3-3, W/GRN	
7	BLU	ETX-	J3-2, ORG	
8	VIO	ETX+	J3-1, W/ORG	
1	BLK	Supply +	J2-1+2, RED	2 core 7/32 shielded cable to be terminated to J1 wires at centre join. Must have red and black insulation on inner cores (red for supply +). Outer insulation to have similar look to cable from J1.
2	BRN			
14	W/ORG	Supply -	J2-3+4, BLK	
15	W/YEL			
3	RED	RS232 Rx	J4-2	Outer insulation to have similar look to cable from J1. No shielding required.
4	ORG	RS232 Tx	J4-3	
11	W/BLK	Signal Ground	J4-5	
12	W/BRN	PPS	J5-1	Outer insulation to have similar look to cable from J1. No shielding required.
13	W/RED	Signal Ground	J5-6 - 9	
9	GRY	I/O Signal 2	J5-4+5	
10	WHT	I/O Signal 1	J5-2+3	
Shield	Braid	Earth	Shields from J2&3's moulded cables to be joined to that of J1 at the centre join. Join should also be shielded.	





DATE: 14/12/22	OXTS Oxford Technical Solutions Ltd Park Farm Barns, Middleton Stoney Oxfordshire, OX25 4AL
DRAWN BY: Maciej Romanski	
CHECKED BY: Sean Bedford	
APPROVED BY: Sam Whelan	
TITLE: xNAV650 Mobile Mapping Cable	DRAWING No : 14C0230
DIMENSIONS: mm DRAWING NOT TO SCALE SHEET 1 OF 1	DRAWING REVISION: B

Revision history

Revision	Comments
250501	New manual created, combining latest versions of the AV200 Hardware Integration manual and the xNAV650 user manual. Cable references have been updated to reflect the current cables supplied with the AV200 and xNAV650, and references to cable modifications and wiring diagrams removed as they are no longer relevant.

Table 19:
Revision history

Blank for user notes

Connect with us today

Global Headquarters

Park Farm Business Centre,
Middleton Stoney, OX25 4AL,
United Kingdom
+44 (0) 1869 814 253

US

Office 304, Regus Business Center
41000 Woodward Avenue
Suite 350 East, Bloomfield Hills
Michigan 48304
+1 248 260 1981

China

Room 901-902, 9th Floor, Building C,
Guanghualu SOHO II, Building No.9,
Guanghualu Chaoyang District,
Beijing, 100020,
China

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linkedin.com/company/oxts/
x.com/oxts_official

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info@oxts.com
oxts.com

OXTS