VECTORNAV

VN-200 User Manual

Firmware v0.1.7.x

Table of Contents

1 Introduction

1.1 Product Description

The VN-200 is a miniature, surface-mount, high-performance Inertial Navigation System (INS). Incorporating the latest solid-state MEMS sensor technology, the VN-200 combines 3-axis accelerometers, 3-axis gyros, 3-axis magnetometer, a barometer, a 52-channel GPS receiver, and a 32-bit processor into a miniature surface-mount module. Along with providing calibrated inertial sensor measurements, the VN-200 also computes and outputs a real-time, high resolution 3D position, velocity and drift-free orientation solution that is continuous over the complete 360 degrees of motion.

1.2 Product Features

The VN-200 is available in two different configurations, as a surface-mount sensor (VN-200 SMD), or as an enclosed sensor (VN-200 Rugged). The VN-200 Rugged provides a robust, precision anodized aluminum clamshell enclosure, ensuring precise alignment and calibration while still retaining the smallest possible footprint.

1.3 Surface-Mount Package

For embedded applications, the VN-200 is available in a miniature surface-mount package.

Features

- Small Size: 22 x 24 x 3 mm
- Single Power Supply: 3.2 to 5.5 V
- Communication Interface: Serial TTL & SPI
- Low Power Requirement: < 330 mW @ 3.3V

1.4 Rugged Package

The VN-200 Rugged consists of the VN-200 sensor installed in a robust precision aluminum enclosure.

Features

- Precision aluminum enclosure
- Locking 10-pin connector
- Mounting tabs with alignment holes
- Compact Size: 34 x 36 x 9 mm
- Single Power Supply: 4.5 to 5.5 V
- Communication Interface: Serial RS-232 & TTL

1.5 Surface-Mount Development Kit

The VN-200 Development Kit provides the VN-200 surface-mount sensor installed onto a small PCB, providing easy access to all of the features and pins on the VN-200. Communication with the VN-200 is provided by either USB or RS-232 serial communication ports. A 20-pin header provides easy access to each of the critical pins. The VN-200 Development Kit also includes all of the necessary cabling, documentation, and support software.

Features

- Pre-installed VN-200 Sensor
- Onboard USB->Serial converter
- Onboard TTL->RS-232 converter
- 30-pin 0.1” header for access to VN-200 pins
- Power supply jack – 5V (Can be powered from USB)
- Board Size: 76 x 76 x 14 mm

1.6 VN-200 Rugged GPS/INS Development Kit

The VN-200 Rugged Development Kit includes the VN-200 Rugged sensor along with all of the necessary cabling required for operation. Two cables are provided in each Development Kit: one for RS-232 communication and a second custom cable with a built in USB converter. The Development Kit also includes all of the relevant documentation and support software.

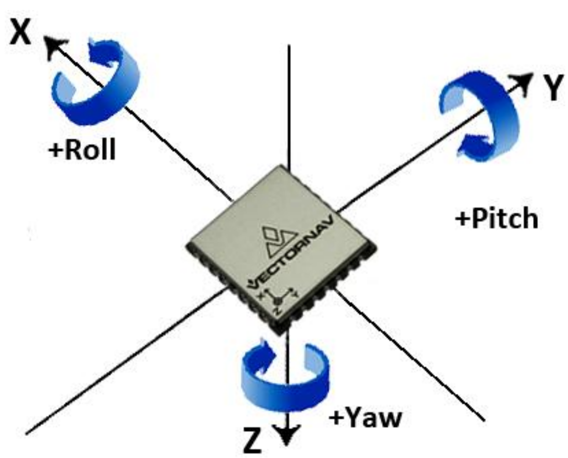
Features

- (1) VN-200 Rugged Sensor
- (1) 10-foot RS-232 cable
- (1) 6-foot USB connector cable

1.7 Sensor Coordinate System

The VN-200 uses a right-handed coordinate system: a positive yaw angle is defined as a positive right-handed rotation around the Z-axis; a positive pitch angle is defined as a positive right-handed rotation around the Y-axis; and a positive roll angle is defined as a positive right-handed rotation around the X-axis. The axes direction with respect to the VN-200 module is shown in Figure 1.

Figure 1 - VN-200 Coordinate System



2 Specifications

2.1 VN-200 Surface-Mount Sensor (SMD) Electrical

Figure 2 – Pin assignments (top down view)

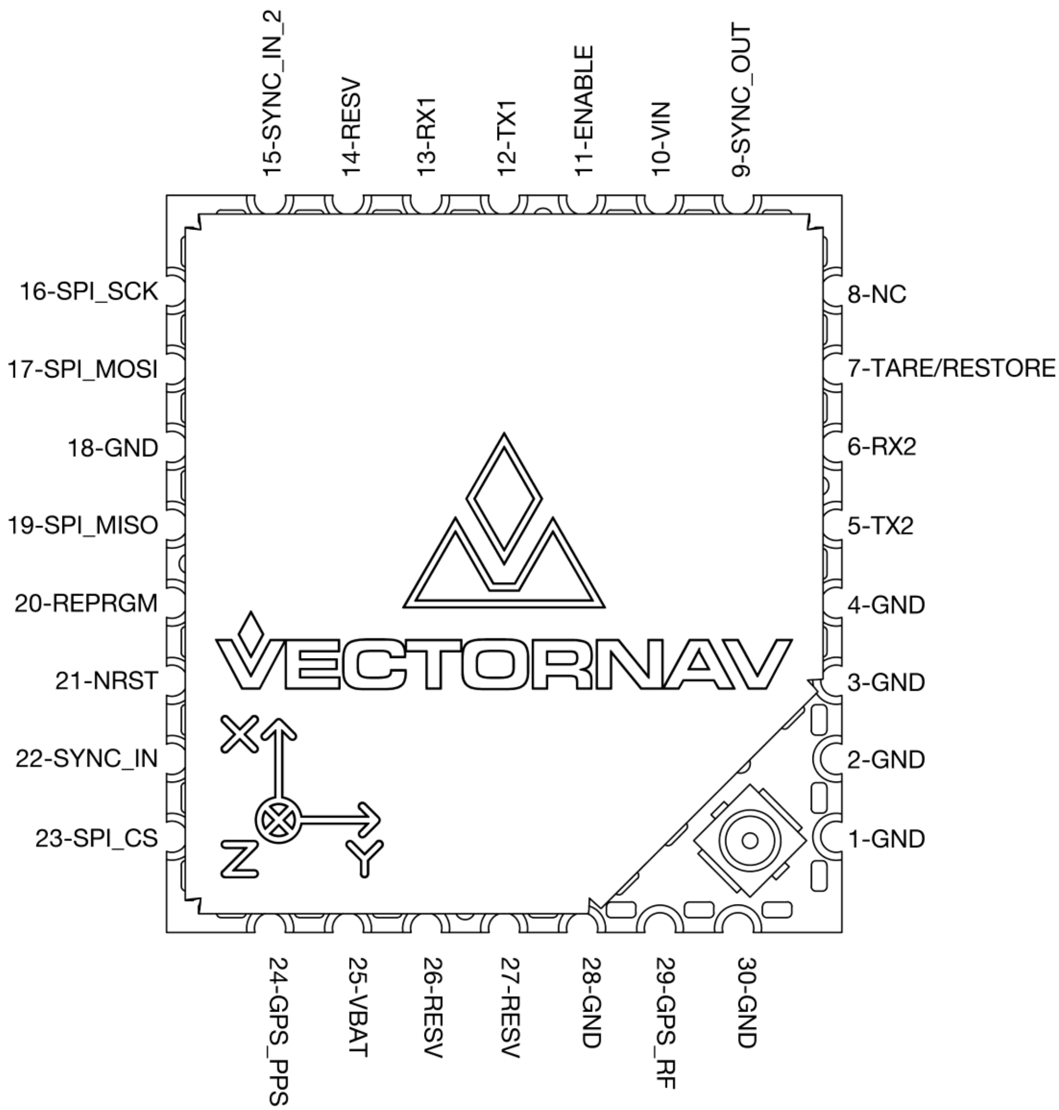


Table 1 – VN-200 SMD Pin Assignments

Pin #	Pin Name	Description
1	GND	Ground.
2	GND	Ground.
3	GND	Ground.
4	GND	Ground.
5	TX2	Serial UART #2 data output. (sensor)
6	RX2	Serial UART #2 data input. (sensor)
7	TARE/RESTORE	Normally used to zero (tare) the attitude. To tare, pulse high for at least 1 µs. During power on or device reset, holding this pin high will cause the module to restore its default factory settings. As a result, the pin cannot be used for tare until at least 5 ms after a power on or reset. Internally held low with 10k resistor.
8	NC	Not used.
9	SYNC_OUT	Time synchronization output signal. See Section 5.12 for more details.
10	VIN	3.2 - 5.5 V input.
11	ENABLE	Leave high for normal operation. Pull low to enter sleep mode. Internally pulled high with pull-up resistor.
12	TX1	Serial UART #1 data output. (sensor)
13	RX1	Serial UART #1 data input. (sensor)
14	RESV	Reserved for future use. Leave pin floating.
15	SYNC_IN_2	Reserved for future use. For backwards compatibility with older hardware revisions this pin can be configured in software to operate as the time synchronization input signal. For new designs it is recommended that SYNC_IN (pin 22) is used instead. See Section 5.12 for more details.
16	SPI_SCK	SPI clock.
17	SPI_MOSI	SPI input.
18	GND	Ground.
19	SPI_MISO	SPI output.
20	REPRGM	Used to reprogram the module. Must be left floating or set to low for normal operation. Pull high on startup to set the VN-200 in reprogram mode. Internally held low with 10k resistor.
21	NRST	Microcontroller reset line. Pull low for > 20 µs to reset MCU. Internally pulled high with 10k.
22	SYNC_IN	Time synchronization input signal. See Section 5.12 for more details.
23	SPI_CS	SPI slave select.
24	GPS_PPS	GPS time pulse. One pulse per second, synchronized at rising edge. Pulse width is 100 ms.
25	VBAT	Optional GPS RTC battery backup. 1.4 V – 3.6 V input.
26	RESV	Reserved for future use.
27	RESV	Reserved for future use.
28	GND	Ground.
29	GPS_RF	Optional GPS RF input for passive antenna. The surface-mount IPX (U.FL) connector should be used with an active GPS antenna.
30	GND	Ground.

2.1.1 VN-200 SMD Power Supply

The minimum operating supply voltage is 3.2 V and the absolute maximum is 5.5 V.

2.1.2 VN-200 SMD Serial (UART) Interface

The serial interface on the VN-200 operates with 3 V TTL logic.

Table 2 - Serial I/O Specifications

Specification	Min	Typical	Max
Input low level voltage	-0.5 V		0.8 V
Input high level voltage	2 V		5.5 V
Output low voltage	0 V		0.4 V
Output high voltage	2.4 V		3.0 V

2.1.3 VN-200 SMD Serial Peripheral Interface (SPI)

Table 3 - Serial I/O Specifications

Specification	Min	Typical	Max
Input low level voltage	-0.5 V		0.8 V
Input high level voltage	2 V		5.5 V
Output low voltage	0 V		0.4 V
Output high voltage	2.4 V		3.0 V
Clock Frequency		8 MHz	16 MHz
Close Rise/Fall Time			8 ns

2.1.4 VN-200 SMD Reset, SyncIn/Out, and Other General I/O Pins

Table 4 - NRST Specifications

Specification	Min	Typical	Max
Input low level voltage	-0.5 V		0.8 V
Input high level voltage	2 V		5.5 V
Weak pull-up equivalent resistor	30 kΩ	40 kΩ	50 kΩ
NRST pulse width	20 μs		

Table 5 - SyncIn Specifications

Specification	Min	Typical	Max
Input low level voltage	-0.5 V		0.8 V
Input high level voltage	2 V		5.5 V
Input Frequency	200 Hz	200 Hz	1 kHz
Pulse Width	500 μs		

Table 6 - SyncOut Specifications

Specification	Min	Typical	Max
Output low voltage	0 V		0.4 V
Output high voltage	2.4 V		3.0 V
Output high to low fall time			125 ns
Output low to high rise time			125 ns

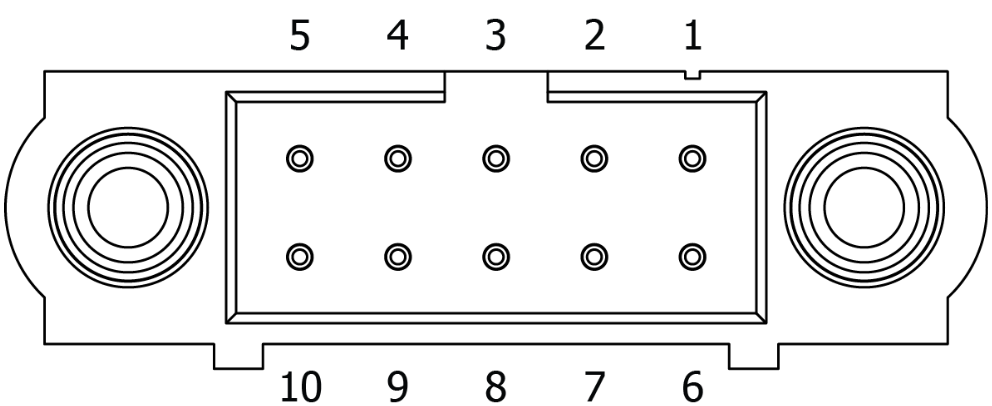
Output Frequency	1 Hz		200 Hz

2.2 VN-200 Rugged Electrical

Table 7 – VN-200 Rugged Pin Assignments

Pin #	Pin Name	Description
1	VCC	+5V (±0.5V)
2	TX1	RS-232 voltage levels data output from the sensor. (Serial UART #1)
3	RX1	RS-232 voltage levels data input to the sensor. (Serial UART #1)
4	SYNC_OUT	Output signal used for synchronization purposes. Software configurable to pulse when ADC, IMU, or attitude measurements are available.
5	GND	Ground
6	TARE/RESTORE	Input signal used to zero the attitude of the sensor. If high at reset, the device will restore to factory default state. Internally held low with 10k resistor.
7	SYNC_IN	Input signal for synchronization purposes. Software configurable to either synchronize the measurements or the output with an external device.
8	TX2_TTL	Serial UART #2 data output from the device at TTL voltage level (3V).
9	RX2_TTL	Serial UART #2 data into the device at TTL voltage level (3V).
10	RESV	This pin should be left unconnected.

Figure 3 - VN-200 Rugged External Connector



2.2.1 VN-200 Rugged Power Supply

The nominal power supply for the VN-200 Rugged is 5 V DC.

- The VN-200 Rugged internally has overvoltage protection set at a fixed voltage of 5.8 V. Upon an overvoltage event the protection circuitry will disable power to the VN-200 to reduce possibility of damage to the voltage regulator onboard the VN-200.

2.2.2 VN-200 Rugged Serial UART Interface

Table 8 - Serial I/O Specifications

Specification	Min	Typical	Max
Input low level voltage	-25 V		
Input high level voltage			25 V
Output low voltage	-5.0 V	-5.4 V	
Output high voltage	5.0 V	5.5 V	
Output resistance	300 Ω	10 MΩ	
Data rate			1 Mbps
Pulse slew		300 ns	

2.2.3 VN-200 Rugged Reset, SyncIn/Out, and Other General I/O Pins

Table 9 - NRST Specifications

Specification	Min	Typical	Max
Input low level voltage	-0.5 V		0.8 V
Input high level voltage	2 V		5.5 V
Weak pull-up equivalent resistor	30 kΩ	40 kΩ	50 kΩ
NRST pulse width	20 µs		

Table 10 - SyncIn Specifications

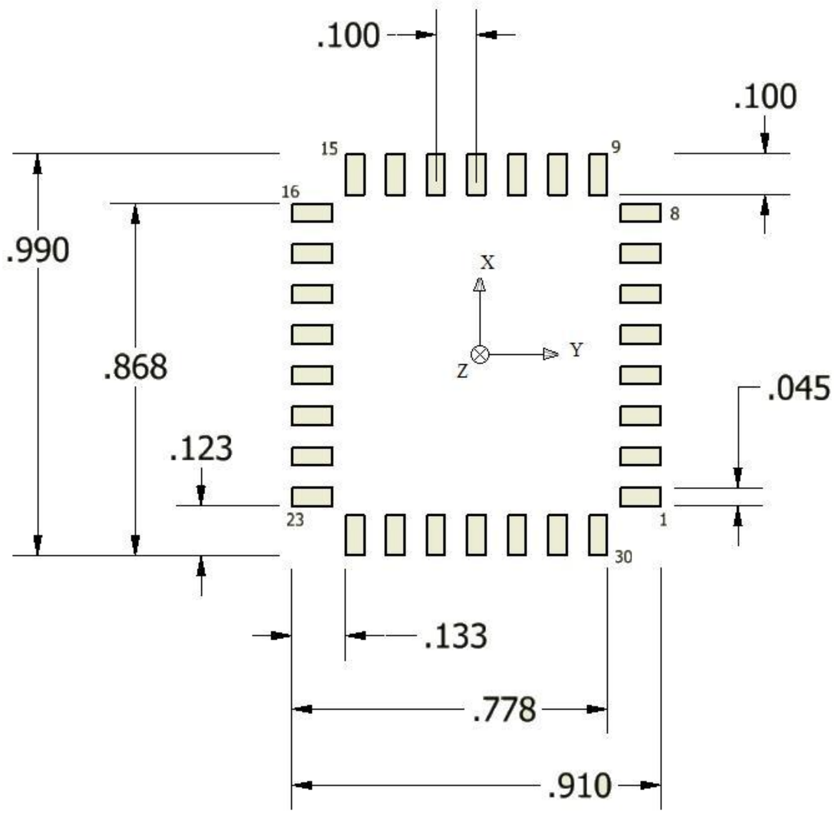
Specification	Min	Typical	Max
Input low level voltage	-0.5V		0.8V
Input high level voltage	2V		5.5V
Input Frequency	200 Hz	200 Hz	1 kHz
Pulse Width	500 µs		

Table 11 - SyncOut Specifications

Specification	Min	Typical	Max
Output low voltage	0 V		0.4 V
Output high voltage	2.4 V		3.0 V
Output high to low fall time			125 ns
Output low to high rise time			125 ns
Output Frequency	1 Hz		200 Hz

2.3 VN-200 Surface-Mount Sensor (SMD) Dimensions

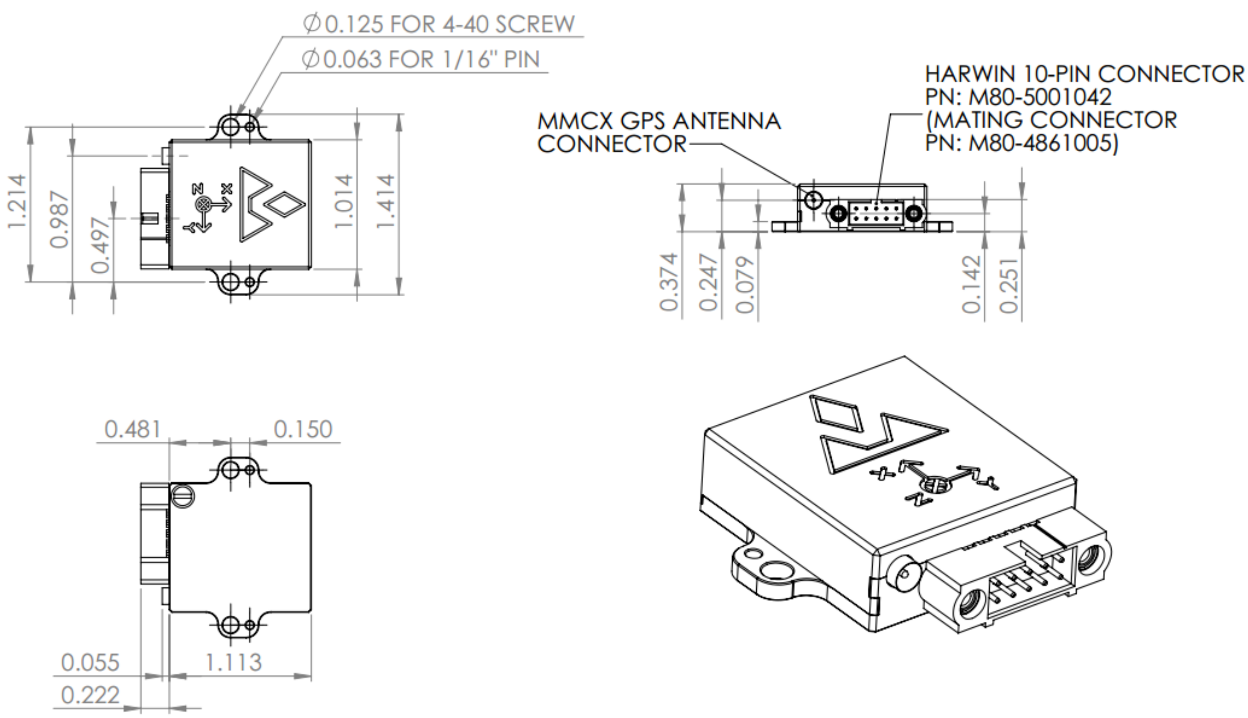
Figure 4 – VN-200 PCB Footprint*



* Measurements are in inches

2.4 VN-200 Rugged Dimensions

Figure 5 – VN-200 Rugged Dimensions



* Measurements are in inches

2.5 Absolute Maximum Ratings

Table 12 - Absolute Maximum Ratings

Specification	Min	Max
Input Voltage	-0.3 V	5.5 V
Operating Temperature	-40 C	85 C
Storage Temperature	-40 C	85 C

3 Basic Communication

The VN-200 module supports two communication interfaces: serial and SPI. On the serial interface, the module communicates over a universal asynchronous receiver/transmitter (UART) and uses ASCII text for its command and data format. On the SPI interface, the VN-200 module communicates as a slave device on a Serial Peripheral Interface (SPI) data bus and uses a binary command and data format. Both interfaces support the complete command set implemented by the module. A general overview of the command format for each interface is given in the next two Sections and formatting specific to each command and associated parameters is provided in the protocol and register Sections (Section 4 & 5).

3.1 Serial Interface

On the serial interface, the VN-200 uses ASCII text for its command format. All commands start with a dollar sign, followed by a five character command, a comma, command specific parameters, an asterisk, a checksum, and a newline character. An example command is shown below:

$VNRRG,11*73

3.2 Checksum / CRC

The serial interface provides the option for either an 8-bit checksum or a 16-bit cyclic redundancy check (CRC). In the event neither the checksum nor the CRC is needed, they can be turned off by the user.

3.2.1 8-bit Checksum

The 8-bit checksum is an XOR of all bytes between, but not including, the dollar sign ($) and asterisk (*). All comma delimiters are included in the checksum calculation. The resultant checksum is an 8-bit number and is represented in the command as two hexadecimal characters. The C function snippet below calculates the correct checksum:

```
unsigned char calculateChecksum(char* command, int length)
{
    unsigned char xor = 0;

    for(int i = 0; i < length; i++)
        xor ^= (unsigned char)command[i];

    return xor;
}
```

3.2.2 16-bit CRC

For cases where the 8-bit checksum does not provide enough error detection, a full 16-bit CRC is available. The VN-200 uses the CRC16-CCITT algorithm. The resultant CRC is a 16-bit number and is represented in the command as four hexadecimal characters. The C function snippet below calculates the correct CRC:

```
unsigned short calculateChecksum(char* command, int length)
{
  unsigned int i;
  unsigned short crc = 0;

  for(i=0; i<length; i++){
           crc  = (unsigned char)(crc >> 8) | (crc << 8);
    crc ^= command[i];
    crc ^= (u8)(crc & 0xff) >> 4;
    crc ^= (crc << 8) << 4;
    crc ^= ((crc & 0xff) << 4) << 1;
  }

  return crc;
}
```

3.3 SPI Interface

The SPI interface uses a lightweight binary message format. The start of a command is signaled by pulling the VN-200's slave select pin (pin 23) low. Both the slave select line and clock are active low. The first byte transmitted to the module should be the command ID and then a variable number of bytes will follow dependent on the type of command specified. A communication transaction can be cancelled at any time by releasing the slave select pin. Pulling the pin low again will start a new communication transaction. All binary data is sent to and from the slave with most significant bit (MSB) first in little-endian byte order with pad bytes inserted where required to ensure 16-bit values are aligned to two-byte boundaries and 32-bit values are aligned to 4-byte boundaries. For example, the serial baud rate register with a value of 9600 (0x2580) would be sent across the SPI as a 0x80, 0x25, 0x00, 0x00. Data is requested from and written to the device using multiple SPI transactions.

Figure 6 – SPI Timing Diagram

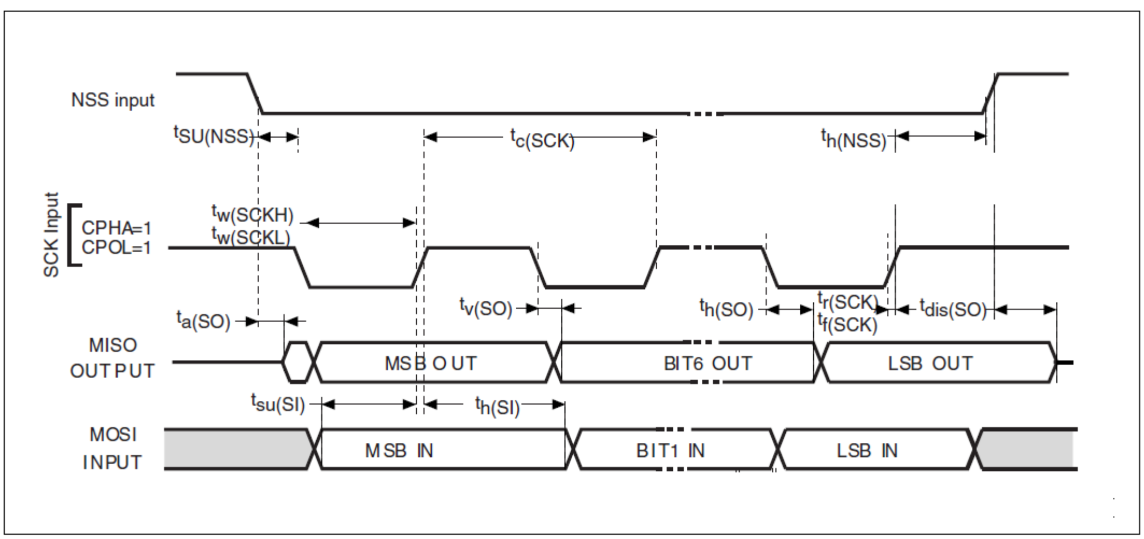
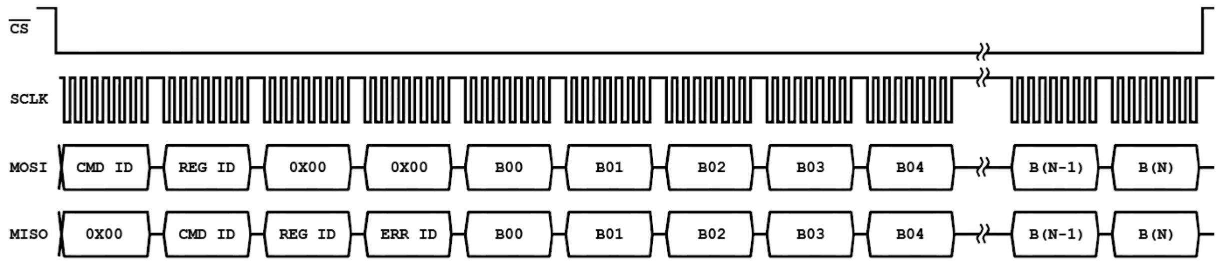


Figure 7 - SPI Data Diagram



A response for a given SPI command will be sent over the MISO line on the next SPI transaction. Thus the data received by the Master on the MISO line will always be the response to the previous transaction. For example, if Yaw, Pitch, Roll and Angular Rates are desired, then the necessary SPI transactions would proceed as shown below:

SPI Transaction 1		
Line	**Bytes**	**Description**
SCK	8 bytes	
MOSI	01 08 00 00 00 00 00 00 (shown as hex)	Read register 8 (Yaw, Pitch, Roll)
MISO	00 00 00 00 00 00 00 00 (shown as hex)	No response

SPI Transaction 2		
Line	**Bytes**	**Description**
SCK	16 bytes	
MOSI	01 13 00 00 00 00 00 00 00 00 00 00 00 00 00 00 (shown as hex)	Read register 13 (Angular Rates)
MISO	00 01 08 00 39 8A 02 43 FD 43 97 C1 CD 9D 67 42 (shown as hex)	Yaw, Pitch, Roll = -130.54, -18.91, +57.90

SPI Transaction 3		
Line	**Bytes**	**Description**
SCK	16 bytes	
MOSI	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 (shown as hex)	No command
MISO	00 01 13 00 00 F5 BF BA 00 80 12 38 B8 CC 8D 3B (shown as hex)	Rates = -0.001465, +0.000035, +0.004327

During the first transaction the master sends the command to read register 8. The available registers which can be read or written to are listed in Table 21 in Section 5. At the same time zeros are received by the master, assuming no previous SPI command was sent to the VN-200 since reboot. On the second transaction the master sends the command to read register 13. At the same time the response from the previously requested register 8 is received by the master on the MISO line. It consists of four 32-bit words. The first byte of the first word will always be zero. The second byte of the first word is the type of command that this transaction is in response to. In this case it is a 0x01, which means that on the previous transaction a read register command was issued. The third byte of the first word is the register that was requested on the previous transaction. In this case it shows to be 0x08, which is the yaw, pitch, roll register. The fourth byte of the first word is the error code for the previous transaction. Possible error codes are listed in Table 20 in Section 4.5. The remaining three 4-byte words are the yaw, pitch, and roll respectively given as single-precision floating-point numbers. The floating-point numbers are consistent with the IEEE 754 standard. On the third SPI transaction, 16 bytes are clocked on the SCK line, during which zeros are sent by the master as no further data is required from the sensor. These 16 bytes are clocked out the SPI for the sole purpose of reading the response from the previous read register 13 command. The response consists of four 32-bit words, starting with the zero byte, the requested command byte, register ID, error code, and three single-precision floating-point numbers. If only one register is required on a regular basis then this can be accomplished by sending the same command twice to the VN-200. The response received on the second transaction will contain the most up to date values for the desired register.

SPI Transaction 1		
Line	**Bytes**	**Description**
SCK	16 bytes	
MOSI	`01 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00 (shown as hex)`	Read register 8 (Yaw, Pitch, Roll)
MISO	`00 01 08 00 39 8A 02 43 FD 43 97 C1 CD 9D 67 42 (shown as hex)`	Yaw, Pitch, Roll = +130.54, -18.91, +57.90

SPI Transaction 2		
Line	**Bytes**	**Description**
SCK	16 bytes	
MOSI	`01 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00 (shown as hex)`	Read Register 8 (Yaw, Pitch, Roll)
MISO	`00 01 08 00 C5 9A 02 43 51 50 97 C1 32 9A 67 42 (shown as hex)`	Yaw, Pitch, Roll = +130.60, -18.91, +57.90

At first the device would be initialized by sending the eight bytes 01 08 00 00 00 00 00 00, requesting a read of the yaw, pitch, roll register. The response from the second transaction would be the response to the requested yaw, pitch, roll from the first transaction. The minimum time required between SPI transactions is 50 µs.

4 Communication Protocol

The following Sections describe the serial and SPI data protocol used by the VN-200.

4.1 Numeric Formats

Floating-point numbers displayed as ASCII text are presented in two formats: single/double precision floating-point and single/double precision fixed point. In order to conserve bandwidth each variable in the register has associated with it either a floating or fixed point representation. Any time this variable is accessed using a read/write register command or as Async output, the variable will always use its associated data format.

4.2 Single Precision Floating Points

Single-precision floating-point numbers are represented with seven significant digits and a two digit exponent. Both the sign of the number and exponent are provided. The decimal point will always follow the first significant digit. An 'E' will separate the significant digits from the exponential digits. Below are some samples of correct single-precision floating-point numbers:

Single Precision Floating Point Number Examples

```
+9.999999E+99     -7.344409E-05
-1.234567E+01     +4.893203E+00
```

4.3 Fixed-Point Numbers

The fixed-point representation consists of a specified number of digits to the left and right of a fixed decimal point. The registers that use fixed point representation and their associated formatting are listed below. It is important to note that all numeric calculations onboard the VN-200 are performed with 32-bit or 64-bit IEEE floating-point numbers. For the sake of simplifying the output stream, some of these numbers are displayed in ASCII as fixed point as described below.

Table 13 – Floating Point Representation

Variable Type	Fixed/Floating	Variable Size	Printf/Scanf	Example
Yaw, Pitch, Roll	Fixed	32-bit float	%+08.3f	+082.763
Quaternion	Fixed	32-bit float	%+09.6f	+0.053362
Magnetic	Fixed	32-bit float	%+07.4f	-0.3647
Acceleration	Fixed	32-bit float	%+07.3f	-09.091
Angular Rate	Fixed	32-bit float	%+09.6f	+00.001786
Latitude	Fixed	64-bit double	%+012.8f	+32.95614564

4.4 System Commands

This Section describes the list of commands available on the VN-200 module. All commands are available in both ASCII text (UART) and binary (SPI) command formats.

The table below lists the commands available along with some quick information about the commands. The Text ID is used to specify the command when using the text command format and the Binary ID is used to specify the command when using the binary command format. More details about the individual commands can be found in the referenced Section.

Table 14 – List of Available Commands

Command Name	Text ID	Binary ID	Section
Read Register	VNRRG	0x01	4.4.1
Write Register	VNWRG	0x02	4.4.2
Write Settings	VNWNV	0x03	4.4.3
Restore Factory Settings	VNRFS	0x04	0
Reset	VNRST	0x06	4.4.5

4.4.1 Read Register Command

This command allows the user to read any of the registers on the VN-200 module (see Section 5 for the list of available registers). The only required parameter is the ID of the register to be read. The first parameter of the response will contain the same register ID followed by a variable number of parameters. The number of parameters and their formatting is specific to the requested register. Refer to the appropriate register Section contained in Section 5 for details on this formatting. If an invalid register is requested, an error code will be returned. The error code format is described in Section 4.5.

Table 15 - Example Read Register Command

Example Command	Message
UART Command	`$VNRRG,5*46`
UART Response	`$VNRRG,5,9600*65`
SPI Command (8 bytes)	`01 05 00 00 80 25 00 00 (shown as hex)`
SPI Response (8 bytes)	`00 01 05 00 80 25 00 00 (shown as hex)`

4.4.2 Write Register Command

This command is used to write data values to a specified register on the VN-200 module (see Section 5 for the list of available registers). The ID of the register to be written to is the first parameter. This is followed by the data values specific to that register. Refer to the appropriate register Section in Section 5 for this formatting. If an invalid register is requested, an error code will be returned. The error code format is described in Section 4.5.

Table 16 - Example Write Register Command

Example Command	Message
UART Command	$VNWRG,5,9600*60
UART Response	$VNWRG,5,9600*60
SPI Command (8 bytes)	02 05 00 00 80 25 00 00 (shown as hex)
SPI Response (8 bytes)	00 02 05 00 80 25 00 00 (shown as hex)

4.4.3 Write Settings Command

This command will write the current register settings into non-volatile memory. Once the settings are stored in non-volatile (Flash) memory, the VN-200 module can be power cycled or reset, and the register will be reloaded from non-volatile memory. The module can always be reset to the factory settings by issuing the Restore Factory Settings command (Section 0) or by pulling pin 7 (Tare/Restore) high during reset.

Table 17 - Example Write Settings Command

Example Command	Message
UART Command	$VNWNV*57
UART Response	$VNWNV*57
SPI Command (8 bytes)	03 00 00 00 00 00 00 00 (shown as hex)
SPI Response (8 bytes)	00 03 00 00 00 00 00 00 (shown as hex)

Due to limitations in the flash write speed the write settings command takes ~ 500ms to complete. Any commands that are sent to the sensor during this time will be responded to after the operation is complete.

4.4.4 Restore Factory Settings Command

This command will restore the VN-200 module's factory default settings (see Section 6) and reset the module. There are no parameters for this command. The module will respond to this command before restoring the factory settings.

Table 18 - Example Restore Factory Settings Command

Example Command	Message
UART Command	$VNRFS*5F
UART Response	$VNRFS*5F
SPI Command (8 bytes)	04 00 00 00 00 00 00 00 (shown as hex)
SPI Response (8 bytes)	00 04 00 00 00 00 00 00 (shown as hex)

4.4.5 Reset Command

This command will reset the module. There are no parameters required for this command. The module will first respond to the command and will then perform a reset. Upon a reset all registers will be reloaded with the values saved in non-volatile memory. If no values are stored in non-volatile memory, the device will default to factory settings. Also upon reset the VN-200 will re-initialize its Kalman filter, thus the filter will take a few seconds to completely converge on the correct attitude and correct for gyro bias. This command is equivalent in functionality to the hardware reset performed by pulling pin 21 (NRST) low.

Table 19 - Example Reset Command

Example Command	Message
UART Command	$VNRST*4D
UART Response	$VNRST*4D
SPI Command (8 bytes)	06 00 00 00 00 00 00 00 (shown as hex)
SPI Response (8 bytes)	00 06 00 00 00 00 00 00 (shown as hex)

4.5 System Error Codes

In the event of an error, the VN-200 will output $VNERR, followed by an error code. The possible error codes are listed in the table below with a description of the error.

Table 20 – Error Codes

Error Name	Code	Description
Hard Fault	1	If this error occurs, then the firmware on the VN-200 has experienced a hard fault exception. To recover from this error the processor will force a restart, and a discontinuity will occur in the serial output. The processor will restart within 50 ms of a hard fault error.
Serial Buffer Overflow	2	The processor's serial input buffer has experienced an overflow. The processor has a 256 character input buffer.
Invalid Checksum	3	The checksum for the received command was invalid.
Invalid Command	4	The user has requested an invalid command.
Not Enough Parameters	5	The user did not supply the minimum number of required parameters for the requested command.
Too Many Parameters	6	The user supplied too many parameters for the requested command.
Invalid Parameter	7	The user supplied a parameter for the requested command which was invalid.
Invalid Register	8	An invalid register was specified.
Unauthorized Access	9	The user does not have permission to write to this register.
Watchdog Reset	10	A watchdog reset has occurred. In the event of a non-recoverable error the internal watchdog will reset the processor within 50 ms of the error.
Output Buffer Overflow	11	The output buffer has experienced an overflow. The processor has a 2048 character output buffer.
Insufficient Baud Rate	12	The baud rate is not high enough to support the requested asynchronous data output at the requested data rate.

5 System Registers

The VN-200 module contains a collection of registers used for configuring the module and accessing the data it produces. These registers may be read or written to using the Read Register and Write Register commands (Sections 4.4.1 and 4.4.2). When the module is rebooted or power-cycled, values written to the registers will revert back to their previous values unless a Write Settings command has been issued (Section 4.4.3) to save the registers to non-volatile memory.

Table 21 below provides a quick reference for all of the registers and their associated properties. The second column lists the Access ID, which is used to identify a specific register. The third column indicates the width of the register in bytes (relevant only in SPI mode) and the last column provides the Section number where a more detailed explanation of the register may be found.

Each register may be read or written to using either serial or SPI communication modes. The specific register Sections that follow describe the format used by each communication mode.

Table 21 –System Registers

Register Name	Access ID	Width (bytes)	Section
User Tag	0	20	5.1
Model Number	1	24	5.2
Hardware Revision	2	4	5.3
Serial Number	3	12	5.4
Firmware Version	4	4	5.5
Serial Baud Rate	5	4	5.6
Asynchronous Data Output Type	6	4	5.7
Asynchronous Data Output Frequency	7	4	5.8
Magnetic and Gravity Reference Vectors	21	6 x 4	5.9
Reference Frame Rotation	26	9 x 4	5.10
Communication Protocol Control	30	7	5.11
Synchronization Control	32	20	5.12
Calibrated Sensor Measurements	54	11 x 4	5.13
GPS Configuration	55	4	5.14
GPS Antenna Offset	57	3 x 4	0
GPS Solution	58	68	5.16
INS Solution	63	72	5.17

5.1 User Tag Register

User Tag						
Register ID :	0		**Firmware :**	v0.1 and up	**Access :**	Read / Write
Comment :	User assigned tag register. Any values can be assigned to this register. They will be stored to flash upon issuing a write settings command.					
Size (Bytes):	20					
Example Serial Read Register Response:	$VNRRG,00,SENSOR_A14*52					

Byte Offset	Name	Number Format	Unit	Description
0	Tag	C20	-	User defined tag register. Up to 20 bytes or characters.

5.2 Model Number Register

Model Number						
Register ID :	1		Firmware :	v0.1 and up	Access :	Read Only
Comment :	Model Number					
Size (Bytes):	24					
Example Serial Read Register Response:	$VNRRG,01,VN-200T-DEV*77					

Byte Offset	Name	Number Format	Unit	Description
0	Product Name	C24	-	Product name. 24 characters.

5.3 Hardware Revision Register

Hardware Revision Register				
Register ID :	2	**Firmware :** v0.1 and up		**Access :** Read Only
Comment :	Hardware revision.			
Size (Bytes):	4			
Example Serial Read Register Response:	$VNRRG,02,6*6B			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	Revision	U4	-	Hardware revision.

5.4 Serial Number Register

Serial Number						
Register ID :	3		**Firmware :**	v0.1 and up	**Access :**	Read Only
Comment :	Serial Number					
Size (Bytes):	12					
Example Serial Read Register Response:	$VNRRG,03,0100011981*5D					

Byte Offset	Name	Number Format	Unit	Description
0	SN[0]	U4	-	Serial Number (32-bit unsigned integer)

5.5 Firmware Version Register

Firmware Version Register				
Register ID :	4	**Firmware :** v0.1 and up		**Access :** Read Only
Comment :	Firmware version.			
Size (Bytes):	4			
Example Serial Read Register Response:	$VNRRG,04,0.1.7.0*73			

Byte Offset	Name	Number Format	Unit	Description
0	Major Version	U1	-	Major release version of firmware.
1	Minor Version	U1	-	Minor release version of firmware
2	Build	U1	-	Build number.
3	HotFix	U1	-	Hot fix number.

5.6 Serial Baud Rate Register

Serial Baud Rate				
Register ID :	5	**Firmware :** v0.1 and up		**Access :** Read / Write
Comment :	Serial baud rate.			
Size (Bytes):	4			
Example Serial Read Register Response:	$VNRRG,05,115200*5D			

Byte Offset	Name	Number Format	Unit	Description
0	Baud Rate	U4	-	Serial baud rate.
4	Serial Port	U1	-	Optional. The serial port to change the baud rate on. If this parameter is not provided then the baud rate will be changed for the active serial port. 1 – Serial Port 1 2 – Serial Port 2

This register specifies the baud rate of the serial data bus. The table below specifies the associated baud rate achieved when the register is set to one of the values listed in Table 22. The response for this command will be sent after the baud rate is changed.

Table 22 – Baud Rate Settings

Acceptable Baud Rates
9600
19200
38400
57600
115200
128000
230400
460800
921600

The serial port parameter in this register is optional. If it is not provided, the baud rate will be changed on the active serial port. The response to this register will include the serial port parameter if the optional parameter is provided. If the second parameter is not provided then the response will not include this parameter.

Upon receiving a baud rate change request, the VN-200 will send the response prior to changing the baud rate.

5.7 Async Data Output Type Register

Asynchronous Data Output Type				
Register ID :	6	**Firmware :** v0.1 and up		**Access :** Read / Write
Comment :	Asynchronous data output type.			
Size (Bytes):	4			
Example Serial Read Register Response:	$VNRRG,06,0*69			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	ADOR	U4	-	Output register.
4	Serial Port	U1	-	Optional. The serial port to change the asynchronous data type on. If this parameter is not provided then the ADOR will be changed for the active serial port. 1 – Serial Port 1 2 – Serial Port 2

This register controls the type of data that will be asynchronously outputted by the module. With this register, the user can specify which data register will be automatically outputted when it gets updated with a new reading. Table 23 below lists which registers can be set to asynchronously output, the value to specify which register to output, and the header of the asynchronous data packet. Asynchronous data output can be disabled by setting this register to zero. The asynchronous data output will be sent out automatically at a frequency specified by the Async Data Output Frequency Register (Section 5.8).

The serial port parameter in this register is optional. If it is not provided, the ADOR will be changed on the active serial port. The response to this register will include the serial port parameter if the optional parameter is provided. If the second parameter is not provided then the response will not include this parameter.

Table 23 – Asynchronous Solution Output Settings

Setting	Asynchronous Solution Output Type	Header	Formatting Section
0	Asynchronous output turned off	N/A	N/A
19	Calibrated Inertial Measurements	VNIMU	5.13
20	GPS Measurement	VNGPS	5.16
22	INS Solution	VNINS	5.17

5.8 Async Data Output Frequency Register

Asynchronous Data Output Frequency				
Register ID :	7	**Firmware :** v0.1 and up		**Access :** Read / Write
Comment :	Asynchronous data output frequency.			
Size (Bytes):	4			
Example Serial Read Register Response:	$VNRRG,07,40*5C			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	ADOF	U4	Hz	Output frequency.
4	Serial Port	U1	-	Optional. The serial port to change the asynchronous data type frequency on. If this parameter is not provided then the ADOF will be changed for the active serial port. 1 – Serial Port 1 2 – Serial Port 2

Table 24 - ADOR Data Rates

Acceptable Data Rates (Hz)
1
2
4
5
10
20
25
40
50
100
200

The serial port parameter in this register is optional. If it is not provided, the ADOF will be changed on the active serial port. The response to this register will include the serial port parameter if the optional parameter is provided. If the second parameter is not provided, the response will not include this parameter.

5.9 Magnetic and Gravity Reference Vectors

Magnetic and Gravity Reference Vectors				
Register ID :	21	**Firmware :** v0.1 and up		**Access :** Read / Write
Comment :	Magnetic and gravity reference vectors.			
Size (Bytes):	24			
Example Serial Read Register Response:	$VNRRG,21,1,0,1.8,0,0,-9.79375*53			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	MagRefX	F4	N/A	X-Axis Magnetic Reference
4	MagRefY	F4	N/A	Y-Axis Magnetic Reference
8	MagRefZ	F4	N/A	Z-Axis Magnetic Reference
12	AccRefX	F4	m/s^2	X-Axis Gravity Reference
16	AccRefY	F4	m/s^2	Y-Axis Gravity Reference
20	AccRefZ	F4	m/s^2	Z-Axis Gravity Reference

5.10 Reference Frame Rotation

Reference Frame Rotation				
Register ID :	26	Firmware : v0.1 and up		Access : Read / Write
Comment :	Allows the measurements of the VN-200 to be rotated into a different reference frame.			
Size (Bytes):	36			
Example Serial Read Register Response:	$VNRRG,26,1,0,0,0,1,0,0,0,1*6A			

Byte Offset	Name	Number Format	Unit	Description
0	C[0,0]	F4	-	
4	C[0,1]	F4	-	
8	C[0,2]	F4	-	
12	C[1,0]	F4	-	
16	C[1,1]	F4	-	
20	C[1,2]	F4	-	
24	C[2,0]	F4	-	
28	C[2,1]	F4	-	
32	C[2,2]	F4	-	

This register contains a transformation matrix that allows for the transformation of measured acceleration, magnetic, and angular rates from the body frame of the VN-200 to any other arbitrary frame of reference. The use of this register allows for the sensor to be placed in any arbitrary orientation with respect to the user's desired body coordinate frame. This register can also be used to correct for any orientation errors due to mounting the VN-200 on the user's circuit board.

$$\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_U = \begin{bmatrix} C00 & C01 & C02 \\ C10 & C11 & C12 \\ C20 & C21 & C22 \end{bmatrix} \cdot \begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_B$$

The variables $\{X, Y, Z\}_B$ are a measured parameter such as acceleration in the body reference frame with respect to the VN-200. The variables $\{X, Y, Z\}_U$ are a measured parameter, such as acceleration in the user's frame of reference. The reference frame rotation register needs to be loaded with the transformation matrix that will transform measurements from the body reference frame of the VN-200 to the desired user frame of reference. It is crucial that these two frames of reference be rigidly attached to each other. All nine numbers are represented by single-precision floating-points.

The reference frame rotation is performed on all vector measurements prior to entering the INS filter. As such, changing this register while the attitude filter is running may lead to unexpected behavior in the INS output. After setting the reference frame rotation register to its new value, send a write settings command and then reset the VN-200. This will allow the INS filter to startup with the newly set reference frame rotation.

5.11 Communication Protocol Control

Communication Protocol Control				
Register ID :	30	Firmware : v0.1 and up		Access : Read / Write
Comment :	Contains parameters that control settings relating to the communication protocol used to communicate with the VN-200.			
Size (Bytes):	7			
Example Serial Read Register Response:	$VNRRG,30,2,0,0,0,1,0,1*6E			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	SerialCount	U1	-	Provides the ability to append a counter to the end of the serial asynchronous messages.
1	SerialStatus	U1	-	Provides the ability to append the status to the end of the serial asynchronous messages.
2	SPICount	U1	-	Provides the ability to append a counter to the end of the SPI packets.
3	SPIStatus	U1	-	Provides the ability to append the status to the end of the SPI packets.
4	SerialChecksum	U1	-	Choose the type of checksum used for serial communications.
5	SPIChecksum	U1	-	Choose the type of checksum used for the SPI communications.
6	ErrorMode	U1	-	Choose the action taken when errors are generated.

5.11.1 SerialCount

The SerialCount field provides a means of appending a time or counter to the end of all asynchronous communication messages transmitted on the serial interface. The values for each of these counters come directly from the Synchronization Status Register.

With the SerialCount field set to OFF, a typical serial asynchronous message would appear as the following:

```
$VNYPR,+010.071,+000.278,-002.026*60
```

With the SerialCount field set to one of the non-zero values, the same asynchronous message would appear instead as:

```
$VNYPR,+010.071,+000.278,-002.026,T1162704*2F
```

When the SerialCount field is enabled, the counter will always be appended to the end of the message just prior to the checksum. The counter will be preceded by the T character to distinguish it from the status field.

Table 25 – SerialCount Field

Mode	Value	Description
NONE	0	OFF
SYNCIN_COUNT	1	SyncIn Counter
SYNCIN_TIME	2	SyncIn Time
SYNCOUT_COUNT	3	SyncOut Counter

5.11.2 SerialStatus

The SerialStatus field provides a means of tracking real-time status information pertaining to the overall state of the sensor measurements and onboard filtering algorithm. This information is very useful in situations where action must be taken when certain crucial events occur, such as the detection of gyro saturation or magnetic interference. As with the SerialCount, a typical serial asynchronous message would appear as the following:

```
$VNYPR,+010.071,+000.278,-002.026*60
```

With the SerialStatus field set to one of the non-zero values, the same asynchronous message would appear instead as:

```
$VNYPR,+010.071,+000.278,-002.026,S0000*1F
```

When the SerialStatus field is enabled the status will always be appended to the end of the message just prior to the checksum. If both the SerialCount and SerialStatus are enabled, the SerialStatus will be displayed first. The counter will be preceded by the 'S' character to distinguish it from the counter field. The status consists of 4 hexadecimal characters.

Table 26 – AsyncStatus

Value	Description
0	OFF
1	ON

5.11.3 SPICount

The SPICount field provides a means of appending a time or counter to the end of all SPI packets. The values for each of these counters come directly from the Synchronization Status Register.

Table 27 – SPICount Field

Mode	Value	Description
NONE	0	OFF
SYNCIN_COUNT	1	SyncIn Counter
SYNCIN_TIME	2	SyncIn Time
SYNCOUT_COUNT	3	SyncOut Counter

5.11.4 SPIStatus

The AsyncStatus field provides a means of tracking real-time status information pertaining to the overall state of the sensor measurements and onboard filtering algorithm. This information is very useful in situations where action must be taken when certain crucial events happen, such as the detection of gyro saturation or magnetic interference.

Table 28 – SPIStatus

Value	Description
0	OFF
1	ON

5.11.5 SerialChecksum

This field controls the type of checksum used for the serial communications. Normally, the VN-200 uses an 8-bit checksum identical to the type used for normal GPS NMEA packets. This form of checksum however offers only a limited means of error checking. As an alternative, a full 16-bit CRC (CRC16-CCITT with polynomial = 0x07) is also offered. The 2-byte CRC value is printed using 4 hexadecimal digits.

Table 29 – SerialChecksum

Value	Description
0	OFF
1	8-Bit Checksum
2	16-Bit CRC

5.11.6 SPIChecksum

This field controls the type of checksum used for the SPI communications. The checksum is appended to the end of the binary data packet. The 16-bit CRC is identical to the one described above for the SerialChecksum.

Table 30 – SPIChecksum

Value	Description
0	OFF
1	8-Bit Checksum
2	16-Bit CRC

5.11.7 ErrorMode

This field controls the type of action taken by the VN-200 when an error event occurs. If the send error mode is enabled then a message similar to the one shown below will be sent on the serial bus when an error event occurs.

```
$VNERR,03*72
```

Regardless of the state of the ErrorMode, the number of error events is always recorded and is made available in the SysErrors field of the Communication Protocol Status Register.

Table 31 – ErrorMode

Value	Description
0	Ignore Error
1	Send Error
2	Send Error and set ADOR register to OFF

5.12 Synchronization Control

Synchronization Control				
Register ID :	32 Firmware : v0.1 and up Access : Read / Write			
Comment :	Contains parameters which allow the timing of the VN-200 to be synchronized with external devices.			
Size (Bytes):	20			
Example Serial Read Register Response:	$VNRRG,32,6,0,0,0,6,1,0,100000000,0*6E			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	SyncInMode	U1	-	Input signal synchronization mode
1	SyncInEdge	U1	-	Input signal synchronization edge selection
2	SyncInSkipFactor	U2	-	Input signal trigger skip factor
4	RESERVED	U4	-	Reserved for future use. Defaults to 0.
8	SyncOutMode	U1	-	Output synchronization signal mode
9	SyncOutPolarity	U1	-	Output synchronization signal polarity
10	SyncOutSkipFactor	U2	-	Output synchronization signal skip factor
12	SyncOutPulseWidth	U4	ns	Output synchronization signal pulse width
16	RESERVED	U4	ns	Reserved for future use. Defaults to 0.

5.12.1 SyncInMode

The SyncInMode register controls the behavior of the SyncIn event. If the mode is set to COUNT, the internal clock will be used to control the ADC timing. If SyncInMode is set to ASYNC, the ADC loop will run on a SyncIn event. The relationship between the SyncIn event and a SyncIn trigger is defined by the SyncInEdge and SyncInSkipFactor parameters. It is very important to note that the VN-200 must always operate at an internal rate of 200 Hz. If the SyncIn event is used to control the ADC sampling, the SyncIn event must be kept always at 200 Hz. If set to ASYNC, the VN-200 will output asynchronous serial messages upon each trigger event.

Table 32 – SyncIn Mode

Mode	Pin	Value	Description
COUNT2	SYNC_IN_2	0	Count number of trigger events on SYNC_IN_2 (pin 15).
ADC2	SYNC_IN_2	1	Start ADC sampling on trigger of SYNC_IN_2 (pin 15).
ASYNC2	SYNC_IN_2	2	Output asynchronous message on trigger of SYNC_IN_2 (pin 15).
COUNT	SYNC_IN	3	Count number of trigger events on SYNC_IN (pin 22).
ADC	SYNC_IN	4	Start ADC sampling on trigger of SYNC_IN (pin 22).
ASYNC	SYNC_IN	5	Output asynchronous message on trigger of SYNC_IN (pin 22).
GPS_PPS	GPS_PPS	6	Count number of trigger events on GPS_PPS (pin 24).

The SyncIn pin is set by default to operate on pin 22. For reverse compatibility with existing VectorNav products it is possible to remap the SyncIn pin to operate on pin 15 instead. For future designs it is recommended that pin 22 is used for the SyncIn feature.

5.12.2 SyncInEdge

The SyncInEdge register controls the type of edge the signal is set to trigger on. The factory default state is to trigger on a rising edge.

Table 33 – SyncInEdge Mode

Value	Description
0	Trigger on rising edge
1	Trigger on falling edge

5.12.3 SyncInSkipFactor

The SyncInSkipFactor defines how many times trigger edges defined by SyncInEdge should occur prior to triggering a SyncIn event. The action performed on a SyncIn event is determined by the SyncIn mode. For example, if the SyncInSkipFactor was set to 4 and a 1 kHz signal was attached to the SyncIn pin, the SyncIn event would only occur at 200 Hz.

5.12.4 SyncOutMode

The SyncOutMode register controls the behavior of the SyncOut pin. If this is set to ADC, the SyncOut will start the pulse when the internal ADC loop starts. This mode is used to make a sensor the Master in a multi-sensor network array. If this is set to IMU mode, the pulse will start when IMU measurements become available. If this is set to INS mode, the pulse will start when INS measurements are made available. Changes to this register take effect immediately.

Table 34 – SyncOutMode

Mode	Value	Description
NONE	0	None
ADC	1	Trigger at start of ADC sampling
IMU	2	Trigger when IMU measurements are available
INS	3	Trigger when INS measurements are available
GPS	6	Trigger when GPS PPS pulse is present and GPS has a position fix.

5.12.5 SyncOutPolarity

The SyncOutPolarity register controls the polarity of the output pulse on the SyncOut pin. Changes to this register take effect immediately.

Table 35 – SyncOutPolarity

Value	Description
0	Negative Pulse
1	Positive Pulse

5.12.6 SyncOutSkipFactor

The SyncOutSkipFactor defines how many times the sync out event should be skipped before actually triggering the SyncOut pin.

5.12.7 SyncOutPulseWidth

The SyncOutPulseWidth field controls the desired width of the SyncOut pulse.

5.13 Calibrated Sensor Measurements

Calibrated Sensor Measurements				
Register ID :	54	**Firmware :** v0.1 and up		**Access :** Read Only
Comment :	Calibrated measurements from all onboard sensors.			
Size (Bytes):	44			
Example Serial Read Register Response:	$VNRRG,54,+01.5656,-00.2630,+01.5138,-00.888,+00.051,-09.814,+00.004525,+00.000271,+00.021949,+20.4,+00098.968*58			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	MagX	F4	gauss	Magnetic X-axis measurement.
4	MagY	F4	gauss	Magnetic Y-axis measurement.
8	MagZ	F4	gauss	Magnetic Z-axis measurement.
12	AccelX	F4	m/s^2	Acceleration X-axis measurement.
16	AccelY	F4	m/s^2	Acceleration Y-axis measurement.
20	AccelZ	F4	m/s^2	Acceleration Z-axis measurement.
24	GyroX	F4	rad/s	X-axis angular rate.
28	GyroY	F4	rad/s	Y-axis angular rate.
32	GyroZ	F4	rad/s	Z-axis angular rate.
36	Temp	F4	C	Temperature.
40	Pressure	F4	kPa	Pressure measurement.

5.14 GPS Configuration

GPS Configuration				
Register ID :	55	Firmware : v0.1 and up		Access : Read / Write
Comment :				
Size (Bytes):	4			
Example Serial Read Register Response:	$VNRRG,55,2,0,0,0*71			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	Mode	U1	-	GPS mode. 0 = Use onboard GPS. 1 = Use external GPS with hardware PPS support. 2 = Use external GPS with software PPS support.
1	NMEA_Serial1	U1	-	Selects which NMEA GPS packets are outputted on serial port #1. See table below for available NMEA messages.
2	NMEA_Serial2	U1	-	Selects which NMEA GPS packets are outputted on serial port #2. See table below for available NMEA messages.
3	NMEA_Rate	U1	-	GPS NMEA message skip factor. If set to 2 then the sensor will send out every other NMEA message. NMEA messages are internally collected at 5Hz. 0 – Off 1 – 5Hz 5 – 1Hz
4	GPS_Delay	U1	-	GPS delay for software based PPS support. This parameter is only used when Mode=2. Sets the number of INS filter steps the GPS data is delayed by. The INS filter runs at 200Hz (5ms). 0 = No delay 4 = 20ms delay

Table 36 - NMEA Messages

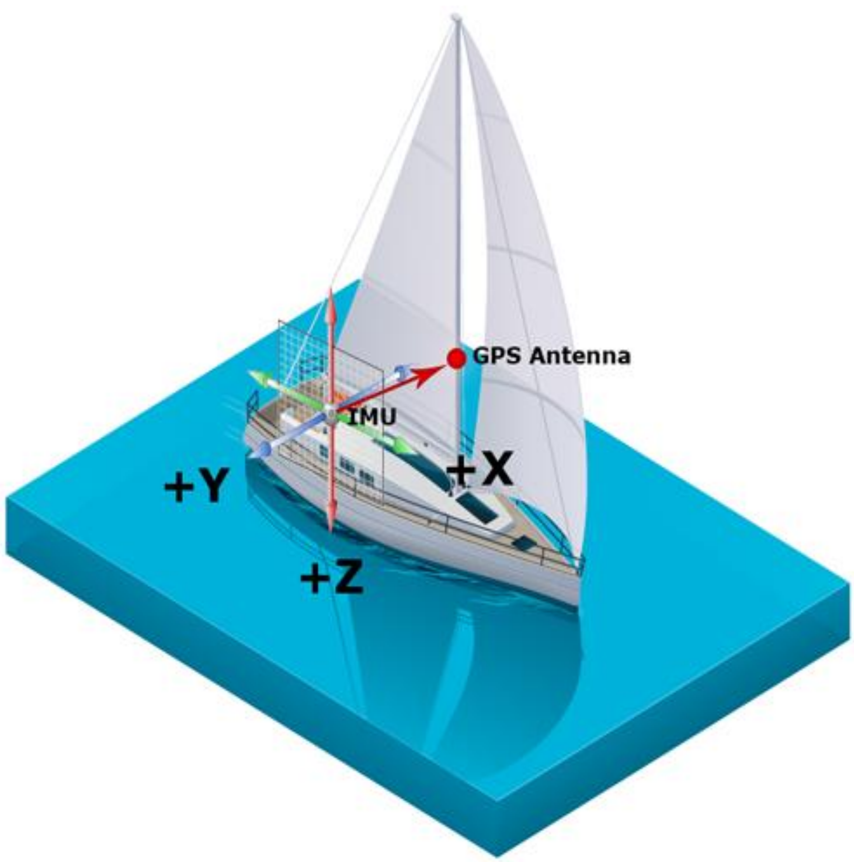
Name	Bit Offset	Description
GGA	0	Global positioning system fix data
GLL	1	Latitude and longitude
GRS	2	GNSS Range Residuals
GSA	3	GNSS DOP and Active Satellites
GST	4	GNSS Pseudo Range Error Statistics
GSV	5	GNSS Satellites in View
RMC	6	Recommended Minimum Data
VTG	7	Course over ground and Ground speed

5.15 GPS Antenna Offset

GPS Antenna Offset				
Register ID :	57	Firmware : v0.1 and up		Access : Read Only
Comment :	Configures the position offset of the GPS antenna from the VN-200 in the vehicle reference frame.			
Size (Bytes):	12			
Example Serial Read Register Response:	$VNRRG,57,0,0,0*6D			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	PosX	F4	m	Relative position of GPS antenna. (X-axis)
4	PosY	F4	m	Relative position of GPS antenna. (Y-axis)
8	PosZ	F4	m	Relative position of GPS antenna. (Z-axis)

The position of the GPS antenna relative to the sensor in the vehicle coordinate frame also referred to as the GPS antenna lever arm. In the example scenario shown in Figure 8 below, the GPS antenna offset is X= +2.5m, Y= +0.0m, Z= -2.0m.

Figure 8 - GPS Antenna Offset



5.16 GPS Solution

GPS Solution				
Register ID :	58	Firmware : v0.1 and up		Access : Read / Write
Comment :	Available at 5 Hz only.			
Size (Bytes):	72			
Example Serial Read Register Response:	$VNRRG,58,333733.000159,1694,3,05,+32.95622080,-096.71415970,+00169.457,-000.850,-000.580,-002.860,+005.573,+003.644,+009.760,+003.320,2.00E-08*0E			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	Time	F8	sec	GPS time of week in seconds.
8	Week	U2	week	GPS week.
10	GpsFix	U1	-	GPS fix type. See table below.
11	NumSats	U1	-	Number of GPS satellites used in solution.
16	Latitude	F8	deg	Latitude in degrees.
24	Longitude	F8	deg	Longitude in degrees.
32	Altitude	F8	m	Altitude above ellipsoid. (WGS84)
40	NedVelX	F4	m/s	Velocity measurement in north direction.
44	NedVelY	F4	m/s	Velocity measurement in east direction.
48	NedVelZ	F4	m/s	Velocity measurement in down direction.
52	NorthAcc	F4	m	North position accuracy estimate. (North)
56	EastAcc	F4	m	East position accuracy estimate. (East)
60	VertAcc	F4	m	Vertical position accuracy estimate. (Down)
64	SpeedAcc	F4	m/s	Speed accuracy estimate.
68	TimeAcc	F4	sec	Time accuracy estimate.

Table 37 - GPS Fix

Value	Description
0	No fix
1	Time only
2	2D
3	3D

5.17 INS Solution

INS Solution				
Register ID :	63	**Firmware :** v0.1 and up		**Access :** Read Only
Comment :				
Size (Bytes):	72			
Example Serial Read Register Response:	$VNRRG,63,333811.902862,1694,0004,+009.500,-004.754,-000.225,+32.95602815,-096.71424297,+00171.195,-000.840,-000.396,-000.109,07.8,01.6,0.23*5F			
Byte Offset	**Name**	**Number Format**	**Unit**	**Description**
0	Time	F8	sec	GPS time of week in seconds.
8	Week	U2	week	GPS week.
10	Status	X2	-	Status flags for INS filter. Hexadecimal format. See table below.
12	Heading	F4	deg	Heading angle relative to true north.
16	Pitch	F4	deg	Pitch angle relative to horizon.
20	Roll	F4	deg	Roll angle relative to horizon.
24	Latitude	F8	deg	INS solution position in geodetic latitude.
32	Longitude	F8	deg	INS solution position in geodetic longitude.
40	Altitude	F8	m	Height above ellipsoid. (WGS84)
48	NedVelX	F4	m/s	INS solution velocity in NED frame. (North)
52	NedVelY	F4	m/s	INS solution velocity in NED frame. (East)
56	NedVelZ	F4	m/s	INS solution velocity in NED frame. (Down)
60	AttUncertainty	F4	deg	Uncertainty in attitude estimate.
64	PosUncertainty	F4	m	Uncertainty in position estimate.
68	VelUncertainty	F4	m/s	Uncertainty in velocity estimate.

Table 38 - INS Status

Name	Bit Offset	Format	Description
Mode	0	2 bits	Indicates the current mode of the INS filter. 0 = Not tracking. Insufficient dynamic motion to estimate attitude. 1 = Sufficient dynamic motion, but solution not within performance specs. 2 = INS is tracking and operating within specifications.
GpsFix	2	1 bit	Indicates whether the GPS has a proper fix.
Error	3	4 bits	Sensor measurement error code. See table below. 0 = No errors detected.
Reserved	7	9 bits	Reserved for future use.

Table 39 - Error Bitfield

Name	Bit Offset	Format	Description
Time Error	0	1 bit	High if INS filter loop exceeds 5 ms.
IMU Error	1	1 bit	High if IMU communication error is detected.
Mag/Pres Error	2	1 bit	High if Magnetometer or Pressure sensor error is detected.
GPS Error	3	1 bit	High if GPS communication error is detected.

6 System Registers - Default Factory State

The following table details the VN-200's settings as it is delivered from the factory. These settings may be restored by issuing a Restore Factory Settings command (Section 0) or by using the Restore Factory Settings signal pins.

Table 40 – Factory Default Register Values

Settings Name	Default Factory Value
Serial Baud Rate	115200 (Both serial ports)
Async Data Output Frequency	40 Hz (Both serial ports)
Async Data Output Type	INS : INS Solution (Both serial ports)
Magnetic and Gravity Reference Vectors	+1.0e+0, +0.0e+0, +1.8e+0 +0.0e+0, +0.0e+0, -9.793746e+0
Reference Frame Rotation	1.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 1.0
Communication Protocol Control	0,0,0,0,1,0,1
Synchronization Control	3,0,0,0,6,1,0,100000000,0
GPS Antenna Offset	0,0,0