Introduction

This document describes the VectorNav embedded firmware library.

The firmware library consists of a collection of routines, data structures, and macros that provide the user with high level control over the functionality of the entire line of VectorNav embedded sensors. This library effectively serves two purposes. The first and foremost purpose is to create a set of device drivers for each of the VectorNav embedded sensors that help developers spend more time focusing on utilizing the rich features and capabilities of the sensors, and less time worrying about the low-level details of the communication protocols. The second purpose is to provide a rich embedded software library that will assists users in capturing the full capabilities provided by the line of VectorNav products. There are some applications that only require the measurements taken directly from the sensor. For these applications, the firmware library will help you get up and running with the data you need, without having to deal with the inter-workings of the device. When working with inertial and orientation sensors in particular, most users require some form of data post-processing in order to fulfill their project requirements. This post-processing may be in the form of mathematical coordinate transformations, or possibly selecting a different form of attitude representation. Performing many of these mathematical transformations in an embedded environment is not a trivial task to say the least. In order to help developers overcome this potential hurdle, VectorNav provides an extensive set of math routines integrated into the firmware library. This library consists of a wide variety of attitude and inertial guidance related functions that will assist developers in making use of the rich set of measurements provided by the VectorNav line of inertial sensors.

The driver source code is developed in 'Strict ANSI-C'. Providing the library in 'Strict ANSI-C' makes it independent from the software toolchain.

Note that since the firmware is generic and covers all device functionalities, the size and/or execution speed of the application code will not likely be optimized for your application. For many task, the library may be used as is. However for applications that have very strict requirements on code size or execution speed, the library should be used as a reference on how to interface with the sensors. In this case, the code may need to be tailored to meet your specific application requirements.

The firmware library user manual is structured as follows:

- Definitions, document conventions, and firmware library rules.
- Overview of the firmware library, and examples on how to make use of the library.
- Detailed description of the firmware library including all data structures and software functions for each of the VectorNav embedded sensors, and related peripheral library files.

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1 Document and library rules

1.1 Acronyms

Table 1 describes the acronyms used in the firmware and documentation.

Table 1. List of abbreviations

Acronym	Definition
ACC	Accelerometer
ADOF	Asynchronous Data Output Frequency
ADOR	Asynchronous Data Output Register
DCM	Directional Cosine Matrix
GYR	Gyro (angular rates)
HSI	Hard / Soft Iron
MAG	Magnetometer
MAT	Matrix
QUAT	Quaternion
REG	Register
SPI	Serial peripheral interface
SS	Slave select
VEC	Vector
VN	VectorNav
YPR	Yaw, pitch, roll

1.2 Naming conventions

The firmware library uses the following naming conventions:

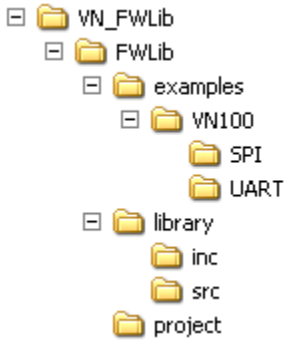
- All functions, constants, variables, and macros start with **VN_**.
- System and source/header file names are preceded by 'VN_', for example VN_lib.h.
- Registers for individual products are considered as constants. Their names are in upper case. The name of the registers is preceded by the product name followed by the register name. The register name is the same as in the product user manual. For example the ADOR register on the VN100 has the name VN100_ADOR.
- The name for all functions, constants, and variables that are specific to a given product are preceded by the product name. The first letter in each word is in upper case. For example VN100_SPI_WriteRegister.

2 Firmware Library

2.1 Package description

The firmware library is provided in one single zip file. After extracting this zip file you should have one folder VN_FWLib that contains the following subfolders:

Table 2. Firmware library folder structure



2.1.1 Examples folder

This Examples folder contains, for each product, examples for how to use each of the provided interfaces. Each example will contain the minimum number of files required to run a typical example listed below:

- Readme.txt – brief text file describing the example and how to make it work
- VN_user.h – header file allowing the user to configure which products should be included in the library.
- VN_user.c – source file containing the platform specific routines that need to be modified by the user for the example to work.
- main.c – main example code

All of the examples provided are independent of the software toolchain.

2.1.2 Library folder

The Library folder contains all the subdirectories and files that make up the core of the library:

- **inc** sub-folder contains the firmware library header files. They do not need to be modified by the user:
  - VN_type.h: common data types and enumeration used in all other files,
  - VN_lib.h: main header file that includes all other header files,
  - VN_math.h: math library header file,
  - VN100.h: header file for the VN-100 specific code.

- **src** sub-folder contains the firmware library source files. They do not need to be modified by the user:
  - VN_lib.c: main library source file. Includes routines that are shared between all VectorNav products,
  - VN_math.c: math library source file,
  - VN100.c: source file for the VN-100 specific code.

All library files are coded in Strict ANSI-C and are independent from the software toolchain.

2.1.3 Project folder

The Project folder contains a standard template project program that compiles all library files plus all the user-modifiable files that are necessary to create a new project:

- VN_user.h: header file for user-modifiable code and settings. Use this file to set which code will compile,
- VN_user.c: source file for the user-modifiable code. This file needs to be modified by the user to handle platform specific features,
- main.c: main program body.

2.2 Description of firmware library files

Table 2 lists and describes the different files used by the firmware library.

The firmware library layout design and file relationships are shown in Figure 2. Each product has both a source and header file.

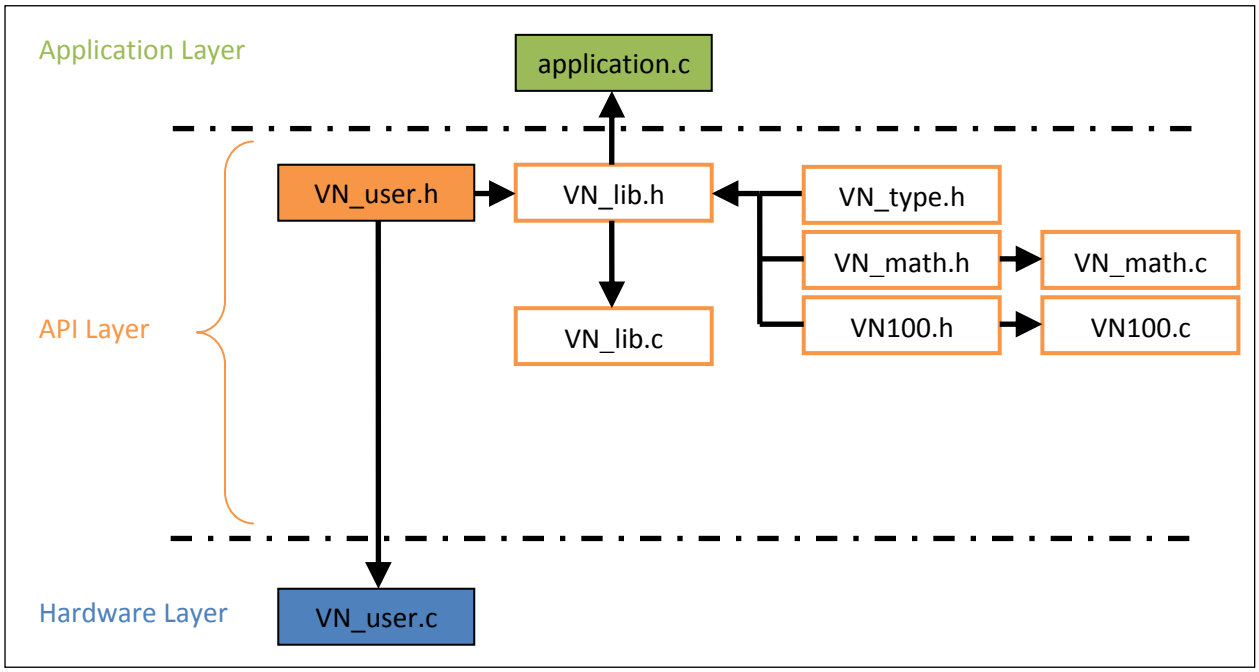
The header file VN_lib.h includes all the product header files. This is the only file that needs to be included in the user application to interface with the library.

VN_user.h and VN_user.c are the only files that need to be modified by the user. The VN_user.h file is used to determine which products will be included in the compiled version of the library.

Table 3. Firmware library files

Filename	Description
VN_lib.h	Header file including all other header files.
VN_lib.c	Source file that includes all code that is shared in between all of the VectorNav products.
VN_type.h	Header file that includes all data types that are shared by all other files in the library
VN_math.h	Header file for the VectorNav math library
VN_math.c	Source file for the VectorNav math library. This library is included to assist the user in performing attitude transformations and other matrix/vector mathematics.
VN_user.h	Header file for the user configuration file. This file is used to set which products in the library are included when compiled. For instance if you want to include the code necessary to interface with the VN100 then you need to uncomment the following line in this file: #define _VN100
VN_user.c	Source file for the user-modifiable code
VN100.h	Header file for the VN100. This file is compiled if the _VN100 is define in the VN_user.h file.
VN100.c	Source file for VN-100 specific functions. This file is compiled if the _VN100 is defined in the VN_user.h file. All functions specific to the VN-100 product are contained in this file.
main.c	Main example program body.

Figure 1. Firmware library file architecture



2.3 Library initialization and configuration

This section describes how to initialize and setup the VectorNav embedded library.

1. In the main application file, include the VN_lib.h, for example:

   #include “VN_lib.h”

2. In the VN_user.h header file uncomment the lines necessary to include the functions for the product(s) that you are interested in. For example, if you want to interface with the VN-100 then you will need to uncomment the following line:

   #define _VN100

3. If you are using the SPI interface then you will need to modify the following functions found in the VN_config.c file:

   a. VN_SPI_SetSS: Place your hardware specific code here that is required to set/reset the SPI slave slect lines for the given sensor.
   b. VN_SPI_SendReceive: Place your hardware specific code here that is required to send and receive 4 bytes over the SPI bus.
   c. VN_Delay: Place your hardware specific code here that is required to delay the processor by the given number of microseconds.

3 Device firmware overview

This section describes in detail the firmware library provided for each device. The related functions are fully described, along with an example of how to use them.

The functions are described in the following format:

Table 4. Function description format

Function Name	The name of the device function
Function prototype	Prototype declaration
Behavior description	Brief explanation of how the function is executed
Input parameter {x}	Description of the input parameters
Output parameter {x}	Description of the output parameters
Return value	Value returned by the function
Required preconditions	Requirements before calling the function
Called functions	Other library functions called

4 User Configuration Files

The VectorNav embedded firmware library is platform independent. In order for this library to be used on a specific hardware platform, the user will need to modify two files to enable hardware specific functionality. All of the necessary user configurable parameters and functions are located in the VN_user.h and VN_user.c source files.

4.1 Device Selection

The user needs to select which devices they want to control using the embedded firmware library. In the VN_user.h file you will find a set of constants, one for each device provided by VectorNav. The code for each device provided by the embedded library is conditionally compiled if the corresponding name of the device is defined as a constant in the VN_user.h header file.

For instance if you are working on a project using the VN-100 orientation sensor, then in the VN_user.h file you will want to make sure that the following line is NOT commented out.

```
/******************************** VN-100 *********************************/
#define _VN100
```

If the _VN100 constant is defined during compilation, then the code in the VN100.c file will be compiled in the user's program. If for instance you wanted to provide your own functions for the control of the VN-100 and you only wanted to use the math library provided by the firmware library then you could comment out the _VN100 line in order to keep the VN-100 drivers from being included in the final code.

```
/******************************** VN-100 *********************************/
/* #define _VN100 */
```

4.2 User Functions

There are three functions that need to be implemented by the user for the correct operation of the VectorNav embedded firmware library. These functions are found in the VN_user.c source file.

4.2.1 VN_SPI_SetSS

Table 5 describes the VN_SPI_SetSS function.

Table 5. _SPI_SetSS

Function Name	VN_SPI_SetSS
Function prototype	VN100_SPI_Packet* _SPI_SetSS (unsigned char sensorID, unsigned char regID, unsigned char regWidth);
Behavior description	This is a generic function that will set the SPI slave select line for the given sensor. This function needs to be added by the user with the logic specific to their hardware to perform the necessary actions to either raise or lower the slave select line for the given sensor. If a multiplexer is used then the logic/communications necessary to perform the actions should be placed here.
Input parameter 1	sensorID -> The sensor to set the slave select line for. This parameter allows the user to communicate with multiple orientation sensors.
Input parameter 2	state - -> The state to set the slave select to. Two possibilities are allowed, either VN_PIN_LOW or VN_PIN_HIGH.
Output parameter	None
Return value	None
Required preconditions	None
Called functions	Determined by user code.

Example:

```
/* Example code for an STM32F103 ARM7 MCU */
void VN_SPI_SetSS(unsigned char sensorID, VN_PinState state){

/* User code to set SPI SS lines goes here. */
      switch(sensorID){

            case 0:
                  if(state == VN_PIN_LOW){
                        /* Start SPI Transaction - Pull SPI CS line low */
                        GPIO_ResetBits(GPIOA, GPIO_Pin_0);
                  }else{
                        /* End SPI transaction - Pull SPI CS line high */
                        GPIO_SetBits(GPIOA, GPIO_Pin_0);
                  }
                  break;
      }
}
```

4.2.2 VN_SPI_SendReceive

Table 6 describes the VN_SPI_SendReceive function.

Table 6. VN_SPI_SendReceive

Function Name	VN_SPI_SendReceive
Function prototype	VN_SPI_SendReceive(unsigned long data);
Behavior description	Transmits the given 32-bit word on the SPI bus. The user needs to place their hardware specific logic here to send 4 bytes out the SPI bus. The slave select line is controlled by the function VN_SPI_SetSS given above, so the user only needs to deal with sending the data out the SPI bus with this function.
Input parameter 1	data -> The 32-bit data to send over the SPI bus
Output parameter	None
Return value	None
Required preconditions	None
Called functions	Determined by user code.

Example:

```
/* Example code for an STM32F103 ARM7 MCU */
unsigned long VN_SPI_SendReceive(unsigned long data){

/* User code to send out 4 bytes over SPI goes here */
  unsigned long i;
  unsigned long ret = 0;

  for(i=0;i<4;i++){
    /* Wait for SPI1 Tx buffer empty */
    while (SPI_I2S_GetFlagStatus(SPI1, SPI_I2S_FLAG_TXE) == RESET);

    /* Send SPI1 requests */
    SPI_I2S_SendData(SPI1, VN_BYTE(data, i));

    /* Wait for response from VN-100 */
    while (SPI_I2S_GetFlagStatus(SPI1, SPI_I2S_FLAG_RXNE) == RESET);

    /* Save received data in buffer */
    ret |= ((unsigned long)SPI_I2S_ReceiveData(SPI1) << (8*i));
  }
  return ret;
}
```

4.2.3 VN_Delay

Table 7 describes the VN_Delay function.

Table 7. VN_Delay

Function Name	VN_Delay
Function prototype	VN_SPI_Delay(unsigned long delay_uS);
Behavior description	Delay the processor for deltaT time in microseconds. The user needs to place the hardware specific code here necessary to delay the processor for the time span given by delay_uS measured in micro seconds. This function doesn't need to be ultra precise. The only requirement on this function is that the processor is delayed a time NO LESS THAN 90% of the time given by the variable delay_uS in microseconds. The minimum time span that is used by the VectorNav library code is 100uS so the function call shouldn't affect the timing accuracy much. If you decide to modify this library or wish to have more precision on this delay function then you can comment out this function and replace it with an optimized macro instead. Many compilers have their own delay routines or macros so make sure you check your compiler documentation before attempting to write your own.
Input parameter 1	delay_uS -> Time to delay the processor in microseconds
Output parameter	None
Return value	None
Required preconditions	None
Called functions	Determined by user code.

Example:

```
/* Example code for an STM32F103 ARM7 MCU */
void VN_Delay(unsigned long delay_uS){
  unsigned long i;
  for(i=delay_uS*10; i--; );
}
```

5 VN-100 Orientation Sensor

The data structures used in the VN-100 firmware library are described in Section 5.1, while Section 5.2 describes the firmware library functions.

5.1 Data Structures

The data structures used by the VN-100 firmware library are defined here. More information on the registers can be found in the VN-100 User Manual.

5.1.1 Registers

The registers present on the VN-100 are represented by as constants in the firmware as shown below:

```
/* VN-100 Registers */
#define     VN100_REG_MODEL         1
#define     VN100_REG_HWREV         2
#define     VN100_REG_SN            3
#define     VN100_REG_FWVER         4
#define     VN100_REG_SBAUD         5
#define     VN100_REG_ADOR          6
#define     VN100_REG_ADOF          7
#define     VN100_REG_YPR           8
#define     VN100_REG_QTN           9
#define     VN100_REG_QTM           10
#define     VN100_REG_QTA           11
#define     VN100_REG_QTR           12
#define     VN100_REG_QMA           13
#define     VN100_REG_QAR           14
#define     VN100_REG_QMR           15
#define     VN100_REG_DCM           16
#define     VN100_REG_MAG           17
#define     VN100_REG_ACC           18
#define     VN100_REG_GYR           19
#define     VN100_REG_MAR           20
#define     VN100_REG_REF           21
#define     VN100_REG_SIG           22
#define     VN100_REG_HSI           23
#define     VN100_REG_ATP           24
#define     VN100_REG_ACT           25
#define     VN100_REG_RFR           26
#define     VN100_REG_YMR           27
#define     VN100_REG_ACG           28
```

More information on each of these register can be found in Section 6 of the VN-100 User Manual.

5.1.2 Command IDs

The available commands for the VN-100 are presented by the following data structure:

```
/* Command IDs */
typedef enum VN100_CmdID
{
```

```
	VN100_CmdID_ReadRegister                = 0x01,
	VN100_CmdID_WriteRegister               = 0x02,
	VN100_CmdID_WriteSettings               = 0x03,
	VN100_CmdID_RestoreFactorySettings      = 0x04,
	VN100_CmdID_Tare                        = 0x05,
	VN100_CmdID_Reset                       = 0x06,
} VN100_CmdID;
```

The commands are described in more detail in Section 5.2 of the VN-100 User Manual.

5.1.3 Error IDs

The error codes for the VN-100 are represented by the following data structure:

```
/* System Error */
typedef enum VN100_Error
{
	VN100_Error_None                        = 0,
	VN100_Error_ErrorListOverflow           = 255,
	VN100_Error_HardFaultException          = 1,
	VN100_Error_InputBufferOverflow         = 2,
	VN100_Error_InvalidChecksum             = 3,
	VN100_Error_InvalidCommand              = 4,
	VN100_Error_NotEnoughParameters         = 5,
	VN100_Error_TooManyParameters           = 6,
	VN100_Error_InvalidParameter            = 7,
	VN100_Error_InvalidRegister             = 8,
	VN100_Error_UnauthorizedAccess          = 9,
	VN100_Error_WatchdogReset               = 10,
	VN100_Error_OutputBufferOverflow        = 11,
	VN100_Error_InsufficientBandwidth       = 12,
	VN100_Error_ErrorListOverflow           = 255
} VN100_Error;
```

The error codes are described in more detail in Section 5.3 of the VN-100 User Manual.

5.1.4 ADOR Type

The ADOR register values are represented by the following data structure:

```
/* Asynchronous Data Output Register */
typedef enum VN100_ADORType
{
	VN100_ADOR_OFF    = 0,
	VN100_ADOR_YPR    = 1,
	VN100_ADOR_QTN    = 2,
	VN100_ADOR_QTM    = 3,
	VN100_ADOR_QTA    = 4,
	VN100_ADOR_QTR    = 5,
	VN100_ADOR_QMA    = 6,
	VN100_ADOR_QAR    = 7,
	VN100_ADOR_QMR    = 8,
	VN100_ADOR_DCM    = 9,
	VN100_ADOR_MAG    = 10,
	VN100_ADOR_ACC    = 11,
	VN100_ADOR_GYR    = 12,
```

```
	VN100_ADOR_MAR	= 13,
	VN100_ADOR_YMR	= 14,
} VN100_ADORType;
```

The ADOR register is described in more detail in Section 6.6 of the VN-100 User Manual.

5.1.5 ADOF Type

The ADOF register values are represented by the following data structure:

```
/* Asynchronous Data Ouput Rate Register */
typedef enum VN100_ADOFType {
	VN100_ADOF_1HZ		= 1,
	VN100_ADOF_2HZ		= 2,
	VN100_ADOF_4HZ		= 4,
	VN100_ADOF_5HZ		= 5,
	VN100_ADOF_10HZ		= 10,
	VN100_ADOF_20HZ		= 20,
	VN100_ADOF_25HZ		= 25,
	VN100_ADOF_40HZ		= 40,
	VN100_ADOF_50HZ		= 50,
	VN100_ADOF_100HZ	= 100,
	VN100_ADOF_200HZ	= 200
} VN100_ADOFType;
```

The ADOF register is described in more detail in Section 6.7 of the VN-100 User Manual.

5.1.6 Baud Type

The baud rate register is represented by the following data structure:

```
/* Serial Baud Rate Register */
typedef enum VN100_BaudType {
	VN100_Baud_9600		= 9600,
	VN100_Baud_19200	= 19200,
	VN100_Baud_38400	= 38400,
	VN100_Baud_57600	= 57600,
	VN100_Baud_115200	= 115200,
	VN100_Baud_128000	= 128000,
	VN100_Baud_230400	= 230400,
	VN100_Baud_460800	= 460800,
	VN100_Baud_921600	= 921600
} VN100_BaudType;
```

The baud rate register is described in more detail in Section 6.5 of the VN-100 User Manual.

5.1.7 AccelGainType

The accelerometer gain register is represented by the following data structure:

```
/* Accelerometer Gain Type */
typedef enum VN100_AccGainType {
	VN100_AccGain_2G = 0,
	VN100_AccGain_6G = 1
} VN100_AccGainType;
```

The accelerometer gain register is described in more detail in Section 6.28 of the VN-100 User Manual.

5.1.8 SPI Response Packet

The SPI response packet is a data structure that is used to organize the SPI response data packets. Each time a command is sent to the VN-100 and a response is received, it is placed in a response packet structure. This allows for easy access to the various components of the response packet. The data structure used is given below:

```
/* 32-bit Parameter Type */
typedef union {
	unsigned long	UInt;
	float		Float;
} VN100_Param;

/* SPI Response Packet */
typedef struct {
	unsigned char	ZeroByte;
	unsigned char	CmdID;
	unsigned char	RegID;
	unsigned char	ErrID;
	VN100_Param	Data[VN100_SPI_BUFFER_SIZE];
} VN100_SPI_Packet;
```

The first four bytes of the packet are accessible via the CmdID, RegID, and ErrID members of the above structure. The actual data that is passed back to the user from the VN-100 will either take the form of a 32-bit unsigned integer or a 32-bit floating point number.

The following example code shows how the data in the SPI response packet is accessed as a 32-bit unsigned integer.

```
VN100_SPI_Packet  *ReturnPacket;
VN100_BaudType   baudRate  =  VN100_Baud_115200;

/* Set the baud rate to 115200 */
ReturnPacket  =  VN100_SPI_SetBaudRate(0, VN100_Baud_115200);

/* Check to see if the baud rate was set correctly */
if((VN100_BaudType)ReturnPacket->Data[0].UInt  ==  VN100_Baud_115200){
	/* The baud rate was set successfully */
}else{
	/* Check the error code */
}
```

The next example shows how you can access the data in the SPI response packet as a floating point value.

```
VN100_SPI_Packet  *ReturnPacket;
float  fp[4]  =  {1.0, 1.0, 0.99, 0.99};

/* Set the baud rate to 115200 */
ReturnPacket = VN100_SPI_SetFiltActTuning(0,&fp[0],&fp[1],&fp[2],&fp[3]);
```

```
/* Check to see if the second tuning parameter was set correctly */
if(fabs(ReturnPacket->Data[1].Float  - fp[1]) <= 0.0001f){
      /* The parameter was set successfully */
}else{
      /* Check the error code */
}
```

5.2 VN-100 library functions

Table 8 lists the various functions of the VN-100 firmware library.

Table 8. VN-100 library functions

Function Name	Description
VN100_SPI_ReadRegister	Read a register on the sensor using SPI
VN100_SPI_WriteRegister	Write to a register on the sensor using SPI
VN100_SPI_GetModel	Get the model number
VN100_SPI_GetHWRev	Get the hardware revision
VN100_SPI_GetSerial	Get the serial number
VN100_SPI_GetFWVer	Get the firmware version
VN100_SPI_GetBaudRate	Get the serial baud rate
VN100_SPI_SetBaudRate	Set the serial baud rate
VN100_SPI_GetADOR	Get the Async Data Output Register Type
VN100_SPI_SetADOR	Set the Async Data Output Register Type
VN100_SPI_GetADOF	Get the Async Data Output Frequency
VN100_SPI_SetADOF	Set the Async Data Output Frequency
VN100_SPI_GetYPR	Get the yaw, pitch, and roll
VN100_SPI_GetQuat	Get the quaternion attitude
VN100_SPI_GetQuatMag	Get the quaternion and magnetic
VN100_SPI_GetQuatAcc	Get the quaternion and acceleration
VN100_SPI_GetQuatRates	Get the quaternion, magnetic, and acceleration
VN100_SPI_GetQuatMagAccel	Get the quaternion, magnetic, and angular rates

VN100_SPI_GetQuatAccRates	Get the quaternion, acceleration, and angular rates
VN100_SPI_GetQuatMagAccRates	Get the quaternion, magnetic, acceleration, and angular rates
VN100_SPI_GetYPRMagAccRates	Get the yaw, pitch, roll, magnetic, acceleration, and angular rates
VN100_SPI_GetDCM	Get the directional cosine matrix
VN100_SPI_GetMag	Get the magnetic measurements
VN100_SPI_GetAcc	Get the acceleration measurements
VN100_SPI_GetRates	Get the angular rate measurements
VN100_SPI_GetMagAccRates	Get the magnetic, acceleration, and angular rates
VN100_SPI_GetMagAccRef	Get the magnetic and acceleration reference vectors
VN100_SPI_SetMagAccRef	Set the magnetic and acceleration reference vectors
VN100_SPI_GetFiltMeasVar	Get the filter measurement variance parameters
VN100_SPI_SetFiltMeasVar	Set the filter measurement variance parameters
VN100_SPI_GetHardSoftIronComp	Get the magnetic hard/soft iron compensation parameters
VN100_SPI_SetHardSoftIronComp	Set the magnetic hard/soft iron compensation parameters
VN100_SPI_GetFiltActTuning	Get the filter active tuning parameters
VN100_SPI_SetFiltActTuning	Set the filter active tuning parameters
VN100_SPI_GetAccComp	Get the accelerometer compensation parameters
VN100_SPI_SetAccComp	Set the accelerometer compensation parameters
VN100_SPI_GetRefFrameRot	Get the reference frame rotation
VN100_SPI_SetRefFrameRot	Set the reference frame rotation
VN100_SPI_GetAccGain	Get the accelerometer gain
VN100_SPI_SetAccGain	Set the accelerometer gain
VN100_SPI_RestoreFactorySettings	Restore sensor to factory default settings
VN100_SPI_Tare	Zero out the current attitude
VN100_SPI_Reset	Reset the VN-100 sensor

VN100_SPI_GetAccInertial	Get the measured inertial acceleration
VN100_SPI_GetMagInertial	Get the measured inertial magnetic

5.2.1 VN100_SPI_ReadRegister

Table 9 describes the VN100_SPI_ReadRegister function.

Table 9. VN100_SPI_ReadRegister

Function Name	VN100_SPI_ReadRegister
Function prototype	VN100_SPI_Packet* VN100_SPI_ReadRegister(unsigned char sensorID, unsigned char regID, unsigned char regWidth);
Behavior description	Read the register with the ID regID on a VN-100 sensor using the SPI interface.
Input parameter 1	sensorID: The sensor to get the requested data from
Input parameter 2	regID: The requested register ID number
Input parameter 3	regWidth: The width of the requested register in 32-bit words
Output parameter	None
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN_SPI_SetSS() VN_SPI_SendReceive() VN_Delay()

Example:

```
/* Read model number register */
VN100_SPI_Packet   *packet;
packet  =  VN100_SPI_ReadRegister(0, VN100_REG_MODEL, 3);
```

5.2.2 VN100_SPI_WriteRegister

Table 10 describes the VN100_SPI_WriteRegister function.

Table 10. VN100_SPI_WriteRegister

Function Name	VN100_SPI_WriteRegister
Function prototype	VN100_SPI_Packet* VN100_SPI_WriteRegister(unsigned char sensorID, unsigned char regID, unsigned char regWidth, unsigned long* ptrWriteValues);
Behavior description	Read the register with the ID regID on a VN-100 sensor using the SPI interface.
Input parameter 1	sensorID: The sensor to write the requested data to
Input parameter 2	regID: The register ID number
Input parameter 3	regWidth: The width of the register in 32-bit words
Output parameter	ptrWriteValues: The data to write to the requested register.
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN_SPI_SetSS() VN_SPI_SendReceive() VN_Delay()

Example:

```
/* Write to baud rate register */
VN100_SPI_Packet   *packet;
unsigned long  newBaud = 115200;
packet  =  VN100_SPI_WriteRegister(0, VN100_REG_SBAUD, 1, &newBaud);
```

5.2.3 VN100_SPI_GetModel

Table 11 describes the VN100_SPI_GetModel function.

Table 11. VN100_SPI_GetModel

Function Name	VN100_SPI_GetModel
Function prototype	VN100_SPI_GetModel(unsigned char sensorID, char* model);
Behavior description	Read the model number from the sensor.
Input parameter	sensorID: The sensor to get the model number from
Output parameter	model: Pointer to a character array where the requested model number is placed. This needs to be a character array that is 12 characters in size.
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the sensor model */
VN100_SPI_Packet   *packet;
char  model[12];
packet  =  VN100_SPI_GetModel(0, model);
```

5.2.4 VN100_SPI_GetHWRev

Table 12 describes the VN100_SPI_GetHWRev function.

Table 12. VN100_SPI_GetHWRev

Function Name	VN100_SPI_GetHWRev
Function prototype	VN100_SPI_GetHWRev(unsigned char sensorID, unsigned long* revision);
Behavior description	Get the hardware revision for the sensor
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	revision: The hardware revision requested
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the hardware revision */
VN100_SPI_Packet   *packet;
unsigned long  revision;
packet  =  VN100_SPI_GetHWRev(0, &revision);
```

5.2.5 VN100_SPI_GetSerial

Table 13 describes the VN100_SPI_GetSerial function.

Table 13. VN100_SPI_GetSerial

Function Name	VN100_SPI_GetSerial
Function prototype	VN100_SPI_GetSerial(unsigned char sensorID, unsigned long* serialNumber);
Behavior description	Get the serial number from the requested sensor
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	serialNumber: The serial number returned by the sensor
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the serial number */
VN100_SPI_Packet   *packet;
unsigned long  SN[3];
packet  =  VN100_SPI_GetSerial(0, SN);
```

5.2.6 VN100_SPI_GetFWVer

Table 14 describes the VN100_SPI_GetFWVer function.

Table 14. VN100_SPI_GetFWVer

Function Name	VN100_SPI_GetFWVer
Function prototype	VN100_SPI_GetFWVer (unsigned char sensorID, unsigned long* firmwareVersion);
Behavior description	Get the firmware version from the requested sensor
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	firmwareVersion: The firmware version returned
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the firmware version */
VN100_SPI_Packet   *packet;
unsigned long  version;
packet  =  VN100_SPI_ GetFWVer(0, &version);
```

5.2.7 VN100_SPI_GetBaudRate

Table 15 describes the VN100_SPI_GetBaudRate function.

Table 15. VN100_SPI_GetBaudRate

Function Name	VN100_SPI_GetBaudRate
Function prototype	VN100_SPI_GetBaudRate (unsigned char sensorID, VN100_BaudType* baudRate);
Behavior description	Get the serial baud rate from the requested sensor
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	baudRate: The baud rate returned by the sensor
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the baud rate */
VN100_SPI_Packet   *packet;
VN100_BaudType  baud;
packet  =  VN100_SPI_ GetBaudRate(0, &baud);
```

5.2.8 VN100_SPI_SetBaudRate

Table 16 describes the VN100_SPI_SetBaudRate function.

Table 16. VN100_SPI_SetBaudRate

Function Name	VN100_SPI_SetBaudRate
Function prototype	VN100_SPI_SetBaudRate(unsigned char sensorID, VN100_BaudType baudRate);
Behavior description	Set the serial baud rate for the requested sensor
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	baudRate : The baud rate to set on the sensor
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the serial baud rate to 115200 */
VN100_SPI_Packet   *packet;
packet  =  VN100_SPI_SetBaudRate(0, VN100_Baud_115200);
```

5.2.9 VN100_SPI_GetADOR

Table 17 describes the VN100_SPI_GetADOR function.

Table 17. VN100_SPI_GetADOR

Function Name	VN100_SPI_GetADOR
Function prototype	VN100_SPI_GetADOR (unsigned char sensorID, VN100_ADORType* ADOR);
Behavior description	Get the ADOR register value from the requested sensor
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	ADOR : The value returned for the ADOR register
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the ADOR */
VN100_SPI_Packet   *packet;
VN100_ADORType   ador;
packet  =  VN100_SPI_GetADOR(0, &ador);
```

5.2.10 VN100_SPI_SetADOR

Table 18 describes the VN100_SPI_SetADOR function.

Table 18. VN100_SPI_SetADOR

Function Name	VN100_SPI_SetADOR
Function prototype	VN100_SPI_SetADOR (unsigned char sensorID, VN100_ADORType ADOR);
Behavior description	Set the ADOR register value from the requested sensor
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	ADOR : The value to set the ADOR register to
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the ADOR to output angular rates*/
VN100_SPI_Packet   *packet;
packet  =  VN100_SPI_SetADOR(0, VN100_ADOR_GYR);
```

5.2.11 VN100_SPI_GetADOF

Table 19 describes the VN100_SPI_GetADOF function.

Table 19. VN100_SPI_GetADOF

Function Name	VN100_SPI_GetADOF
Function prototype	VN100_SPI_GetADOF (unsigned char sensorID, VN100_ADOFType* ADOF);
Behavior description	Get the async data output frequency
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	ADOR : The frequency returned for the ADOF register
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the ADOF */
VN100_SPI_Packet   *packet;
VN100_ADOFType   adof;
packet  =  VN100_SPI_GetADOF(0, &adof);
```

5.2.12 VN100_SPI_SetADOF

Table 20 describes the VN100_SPI_SetADOF function.

Table 20. VN100_SPI_SetADOF

Function Name	VN100_SPI_SetADOF
Function prototype	VN100_SPI_SetADOF (unsigned char sensorID, VN100_ADOFType ADOF);
Behavior description	Set the async data output frequency
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	ADOR : The desired frequency of the async data output
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the ADOF to 200 Hz */
VN100_SPI_Packet   *packet;
packet  =  VN100_SPI_SetADOF(0, VN100_ADOF_200HZ);
```

5.2.13 VN100_SPI_GetYPR

Table 21 Table 13describes the VN100_SPI_GetYPR function.

Table 21. VN100_SPI_GetYPR

Function Name	VN100_SPI_GetYPR
Function prototype	VN100_SPI_GetYPR(unsigned char sensorID, float* yaw, float* pitch, float* roll);
Behavior description	Get the measured yaw, pitch, roll orientation angles
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	yaw : The yaw angle measured in degrees
Output parameter 2	pitch : The pitch angle measured in degrees
Output parameter 3	roll : The roll angle measured in degrees
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the yaw, pitch, and roll*/
VN100_SPI_Packet   *packet;
float  yaw, pitch, roll;
packet  =  VN100_SPI_GetYPR(0, &yaw, &pitch, &roll);
```

5.2.14 VN100_SPI_GetQuat

Table 22 describes the VN100_SPI_GetQuat function.

Table 22. VN100_SPI_GetQuat

Function Name	VN100_SPI_GetQuat
Function prototype	VN100_SPI_GetQuat
Behavior description	Get the measured attitude quaternion. The quaternion is a 4x1 vector unit vector with the fourth term q[3] as the scalar term.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	q : The address of the location to write the returned measured quaternion (4x1).
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the quaternion */
VN100_SPI_Packet   *packet;
float  quat[4];
packet  =  VN100_SPI_GetQuat(0, quat);
```

5.2.15 VN100_SPI_GetQuatMag

Table 23 describes the VN100_SPI_GetQuatMag function.

Table 23. VN100_SPI_GetQuatMag

Function Name	VN100_SPI_GetQuatMag
Function prototype	VN100_SPI_GetQuatMag(unsigned char sensorID, float* q, float* mag);
Behavior description	Get the measured attitude quaternion and magnetic vector. The quaternion is a 4x1 unit vector with the fourth term q[3] as the scalar term. The magnetic is a 3x1 vector. The measured magnetic vector does not have any usable units. The magnetic vector is calibrated at the factory to have a magnitude of one on the XY plane.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	q : The address of the location to write the returned measured quaternion (4x1).
Output parameter 2	mag : The magnetic measured vector (3x1)
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the quaternion and magnetic */
VN100_SPI_Packet   *packet;
float  quat[4];
float  mag[3];
packet  =  VN100_SPI_GetQuatMag(0, quat, mag);
```

5.2.16 VN100_SPI_GetQuatAcc

Table 24 describes the VN100_SPI_GetQuatAcc function.

Table 24. VN100_SPI_GetQuatAcc

Function Name	VN100_SPI_GetQuatAcc
Function prototype	VN100_SPI_GetQuatAcc (unsigned char sensorID, float* q, float* acc);
Behavior description	The quaternion is a 4x1 unit vector with the fourth term q[3] as the scalar term.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	q : Measured quaternion (4x1)
Output parameter 2	acc : Measured acceleration (3x1) in m/s^2
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the quaternion and acceleration */
VN100_SPI_Packet   *packet;
float  quat[4];
float  acc[3];
packet  =  VN100_SPI_GetQuatAcc(0, quat, acc);
```

5.2.17 VN100_SPI_GetQuatRates

Table 25 describes the VN100_SPI_GetQuatRates function.

Table 25. VN100_SPI_GetQuatRates

Function Name	VN100_SPI_GetQuatRates(unsigned char sensorID, float* q, float* rates);
Function prototype	VN100_SPI_GetQuatRates
Behavior description	Get the measured attitude quaternion and angular rates
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	q : Measured quaternion (4x1)
Output parameter 2	rates : Measured angular rates (3x1) in rad/s
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the quaternion and angular rates*/
VN100_SPI_Packet   *packet;
float  quat[4];
float  rates[3];
packet  =  VN100_SPI_GetQuatRates(0, quat, rates);
```

5.2.18 VN100_SPI_GetQuatMagAcc

Table 26 describes the VN100_SPI_GetQuatMagAcc function.

Table 26. VN100_SPI_GetQuatMagAcc

Function Name	VN100_SPI_GetQuatMagAcc
Function prototype	VN100_SPI_GetQuatMagAcc(unsigned char sensorID, float* q, float* mag, float* acc);
Behavior description	Get the measured attitude quaternion, magnetic and acceleration
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	q : Measured quaternion (4x1)
Output parameter 2	mag : The magnetic measured vector (3x1)
Output parameter 3	acc : Measured acceleration (3x1) in m/s^2
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the quaternion, magnetic, and acceleration */
VN100_SPI_Packet   *packet;
float  quat[4];
float  mag[3];
float  acc[3];
packet  =  VN100_SPI_GetQuatMagAcc(0, quat, mag, acc);
```

5.2.19 VN100_SPI_GetQuatAccRates

Table 27 describes the VN100_SPI_GetQuatAccRates function.

Table 27. VN100_SPI_GetQuatAccRates

Function Name	VN100_SPI_GetQuatAccRates
Function prototype	VN100_SPI_GetQuatAccRates(unsigned char sensorID, float* q, float* acc, float* rates);
Behavior description	Get the measured attitude quaternion, acceleration, and angular rates
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	q : Measured quaternion (4x1)
Output parameter 2	acc : Measured acceleration (3x1) in m/s^2
Output parameter 3	rates : Measured angular rates (3x1) in rad/s
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the quaternion, acceleration, and angular rates */
VN100_SPI_Packet   *packet;
float  quat[4];
float  acc[3];
float  rates[3];

packet  =  VN100_SPI_GetQuatAccRates(0, quat, acc, rates);
```

5.2.20 VN100_SPI_GetQuatMagAccRates

Table 28 describes the VN100_SPI_GetQuatMagAccRates function.

Table 28. VN100_SPI_GetQuatMagAccRates

Function Name	VN100_SPI_GetQuatMagAccRates
Function prototype	VN100_SPI_GetQuatMagAccRates(unsigned char sensorID, float* q, float* mag, float* acc, float* rates);
Behavior description	Get the measured attitude quaternion, magnetic, acceleration, and angular rates
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	q : Measured quaternion (4x1)
Output parameter 2	mag : The magnetic measured vector (3x1)
Output parameter 3	acc : Measured acceleration (3x1) in m/s^2
Output parameter 4	rates : Measured angular rates (3x1) in rad/s
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the quaternion, magnetic, acceleration, and angular rates */
VN100_SPI_Packet   *packet;
float  quat[4];
float  mag[3];
float  acc[3];
float  rates[3];

packet  =  VN100_SPI_GetQuatMagAccRates(0, quat, mag, acc, rates);
```

5.2.21 VN100_SPI_GetYPRMagAccRates

Table 29 describes the VN100_SPI_GetYPRMagAccRates function.

Table 29. VN100_SPI_GetYPRMagAccRates

Function Name	VN100_SPI_GetYPRMagAccRates
Function prototype	VN100_SPI_GetYPRMagAccRates(unsigned char sensorID, float* YPR, float* mag, float* acc, float* rates);
Behavior description	Get the yaw, pitch, roll, magnetic, acceleration, and angular rates
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	YPR : Euler angles (Yaw, Pitch, Roll) in deg
Output parameter 2	mag : The magnetic measured vector (3x1)
Output parameter 3	acc : Measured acceleration (3x1) in m/s^2
Output parameter 4	rates : Measured angular rates (3x1) in rad/s
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the yaw, pitch, roll, magnetic, acceleration, and angular rates*/
VN100_SPI_Packet   *packet;
float  ypr[3];
float  mag[3];
float  acc[3];
float  rates[3];
packet  =  VN100_SPI_GetYPRMagAccRates(0, ypr, mag, acc, rates);
```

5.2.22 VN100_SPI_GetDCM

Table 30 describes the VN100_SPI_GetDCM function.

Table 30. VN100_SPI_GetDCM

Function Name	VN100_SPI_GetDCM
Function prototype	VN100_SPI_GetDCM(unsigned char sensorID, float* DCM);
Behavior description	Get the measured attitude as a directional cosine matrix
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	DCM : Directional Cosine Matrix (9x1). The order of the terms in the matrix is {first row, second row, third row}
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the directional cosine matrix */
VN100_SPI_Packet  *packet;
float dcm_data[9] = {0};
float *dcm_ptr = {&dcm_data[0], &dcm_data[3], &dcm_data[6]};
float **dcm = dcm_ptr;
packet = VN100_SPI_GetDCM(0, dcm);
```

5.2.23 VN100_SPI_GetMag

Table 31 describes the VN100_SPI_GetMag function.

Table 31. VN100_SPI_GetMag

Function Name	VN100_SPI_GetMag
Function prototype	VN100_SPI_GetMag(unsigned char sensorID, float* mag);
Behavior description	Get the measured magnetic field. The measured magnetic field does not have any usable units. The magnetic vector is calibrated at the factory to have a magnitude of one on the XY plane.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	mag : The magnetic measured vector (3x1)
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the magnetic measurements */
VN100_SPI_Packet *packet;
float mag[3];
packet = VN100_SPI_GetMag(0, mag);
```

5.2.24 VN100_SPI_GetAcc

Table 32 describes the VN100_SPI_GetAcc function.

Table 32. VN100_SPI_GetAcc

Function Name	VN100_SPI_GetAcc
Function prototype	VN100_SPI_GetAcc(unsigned char sensorID, float* Acc);
Behavior description	Get the measured acceleration. The measured acceleration has the units of m/s^2 and its range is dependent upon the gain set by the VN100_SPI_SetAccGain() function.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	Acc : The measured acceleration (3x1) in m/s^2
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the acceleration measurements */
VN100_SPI_Packet *packet;
float acc[3];
packet = VN100_SPI_GetAcc(0, acc);
```

5.2.25 VN100_SPI_GetRates

Table 33 describes the VN100_SPI_GetRates function.

Table 33. VN100_SPI_GetRates

Function Name	VN100_SPI_GetRates
Function prototype	VN100_SPI_GetRates
Behavior description	Get the measured angular rates. The measured angular rates have the units of rad/s. This is the filtered angular rate and is compensated by the onboard Kalman filter to account for gyro bias drift.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	rates : The measured angular rates (3x1) in rad/s
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the angular rate measurements */
VN100_SPI_Packet *packet;
float rates[3];
packet = VN100_SPI_GetRates(0, rates);
```

5.2.26 VN100_SPI_GetMagAccRates

Table 34 describes the VN100_SPI_GetMagAccRates function.

Table 34. VN100_SPI_GetMagAccRates

Function Name	VN100_SPI_GetMagAccRates
Function prototype	VN100_SPI_GetMagAccRates(unsigned char sensorID, float* mag, float* acc, float* rates);
Behavior description	Get the measured magnetic, acceleration, and angular rates. The measurements are taken in the body reference frame.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	mag : Measured magnetic field (3x1) [Non-dimensional]
Output parameter 2	Acc : Measured acceleration (3x1) [m/s^2]
Output parameter 3	rates : Measured angular rates (3x1) [rad/s]
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the magnetic, acceleration, and angular rate measurements */
VN100_SPI_Packet *packet;
float mag[3];
float acc[3];
float rates[3];
packet = VN100_SPI_GetMagAccRates(0, mag, acc, rates);
```

5.2.27 VN100_SPI_GetMagAccRef

Table 35 describes the VN100_SPI_GetMagAccRef function.

Table 35. VN100_SPI_GetMagAccRef

Function Name	VN100_SPI_GetMagAccRef
Function prototype	VN100_SPI_GetMagAccRef(unsigned char sensorID, float* refMag, float* refAcc);
Behavior description	Get the magnetic and acceleration reference vectors. The reference vectors are the vectors measured by the magnetometer and accelerometer respectively in the inertial reference frame. The inertial reference frame is NED (North, East, Down).
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	refMag : The reference vector for the magnetic field
Output parameter 2	refAcc : The reference vector for the Accerometer (gravity)
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the magnetic and acceleration reference vectors */
VN100_SPI_Packet *packet;
float magRef[3];
float accRef[3];
packet = VN100_SPI_GetMagAccRef(0, magRef, accRef);
```

5.2.28 VN100_SPI_SetMagAccRef

Table 36 describes the VN100_SPI_SetMagAccRef function.

Table 36. VN100_SPI_SetMagAccRef

Function Name	VN100_SPI_SetMagAccRef
Function prototype	VN100_SPI_SetMagAccRef(unsigned char sensorID, float* refMag, float* refAcc)
Behavior description	Set the magnetic and acceleration reference vectors. The reference vectors are the vectors measured by the magnetometer and accelerometer respectively in the inertial reference frame. The inertial reference frame is NED (North, East, Down).
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	refMag : The reference vector for the magnetic field
Output parameter 2	refAcc : The reference vector for the Accelerometer (gravity)
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the magnetic and acceleration reference vectors */
VN100_SPI_Packet *packet;
float magRef[3] = {1.0, 0.0, 1.73};
float accRef[3] = {0.0, 0.0, 1.0};
packet = VN100_SPI_GetMagAccRef(0, magRef, accRef);
```

5.2.29 VN100_SPI_GetFiltMeasVar

Table 37 describes the VN100_SPI_GetFiltMeasVar function.

Table 37. VN100_SPI_GetFiltMeasVar

Function Name	VN100_SPI_GetFiltMeasVar
Function prototype	VN100_SPI_GetFiltMeasVar(unsigned char sensorID, float* measVar);
Behavior description	Get the Kalman filter measurement variance parameters. This is discussed in the User Manual in Section 6.22. The measurement variance parameters controls how much weight the Kalman filter will place on each measurement. See application note A001 for more details on how to set these values for your specific application.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	measVar : The variance on the measured inputs to the filter. This is a (10x1) vector.
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the filter measurement variance parameters */
VN100_SPI_Packet *packet;
float measVar[10];
packet = VN100_SPI_GetFiltMeasVar(0, measVar);
```

5.2.30 VN100_SPI_SetFiltMeasVar

Table 38 describes the VN100_SPI_SetFiltMeasVar function.

Table 38. VN100_SPI_SetFiltMeasVar

Function Name	VN100_SPI_SetFiltMeasVar
Function prototype	VN100_SPI_SetFiltMeasVar(unsigned char sensorID, float* measVar);
Behavior description	Set the Kalman filter measurement variance parameters. This is discussed in the User Manual in Section 6.22. The measurement variance parameters controls how much weight the Kalman filter will place on each measurement. See application note A001 for more details on how to set these values for your specific application.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	measVar : The variance on the measured inputs to the filter. This is a (10x1) vector
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the filter measurement variance parameters */
VN100_SPI_Packet *packet;
float measVar[10] = {1e-9,1e-9,1e-9,1e-9,1e-6,1e-6,1e-6,1e-6,1e-6,1e-6};
packet = VN100_SPI_SetFiltMeasVar(0, measVar);
```

5.2.31 VN100_SPI_GetHardSoftIronComp

Table 39 describes the VN100_SPI_GetHardSoftIronComp function.

Table 39. VN100_SPI_GetHardSoftIronComp

Function Name	VN100_SPI_GetHardSoftIronComp
Function prototype	VN100_SPI_GetHardSoftIronComp(unsigned char sensorID, float* HSI);
Behavior description	Get the magnetic hard/soft iron compensation parameters. These values allow the magnetometer to compensate for distortions in the local magnetic field due to ferromagnetic materials in the vicinity of the sensor. More information on the parameters can be found in the User Manual in Section 6.23.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	HSI : magnetic hard/soft iron paramteters (12x1)
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the magnetic hard/soft iron compensation parameters */
VN100_SPI_Packet *packet;
float HSI[12];
packet = VN100_SPI_GetHardSoftIronComp(0, HSI);
```

5.2.32 VN100_SPI_SetHardSoftIronComp

Table 40 describes the VN100_SPI_SetHardSoftIronComp function.

Table 40. VN100_SPI_SetHardSoftIronComp

Function Name	VN100_SPI_SetHardSoftIronComp
Function prototype	VN100_SPI_SetHardSoftIronComp(unsigned char sensorID, float* HSI);
Behavior description	Set the magnetic hard/soft iron compensation parameters. These values allow the magnetometer to compensate for distortions in the local magnetic field due to ferromagnetic materials in the vicinity of the sensor. More information on the parameters can be found in the User Manual in Section 6.23.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	HSI : magnetic hard/soft iron parameters (12x1)
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the magnetic hard/soft iron compensation parameters */
VN100_SPI_Packet *packet;
float HSI[12] = {1,0,0,0,1,0,0,0,1,0,0,0};
packet = VN100_SPI_SetHardSoftIronComp(0, HSI);
```

5.2.33 VN100_SPI_GetFiltActTuning

Table 41 describes the VN100_SPI_GetFiltActTuning function.

Table 41. VN100_SPI_GetFiltActTuning

Function Name	VN100_SPI_GetFiltActTuning
Function prototype	VN100_SPI_GetFiltActTuning(unsigned char sensorID, float gainM, float gainA, float memM, float memA);
Behavior description	Get the filter active tuning parameters. The active tuning parameters control how the filter handles dynamic disturbances in both magnetic and acceleration. These values are not needed for normal operation. More on these parameters can be found in the User Manual in Section 6.24.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter 1	gainM : Magnetic Disturbance Gain
Output parameter 2	gainA : Acceleration Disturbance Gain
Output parameter 3	memM : Magnetic Disturbance Memory
Output parameter 4	memA : Acceleration Disturbance Gain
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the filter active tuning parameters */
VN100_SPI_Packet *packet;
float atp1, atp2, atp3, atp4;
packet = VN100_SPI_GetFiltActTuning(0, &atp1, &atp2, &atp3, &atp4);
```

5.2.34 VN100_SPI_SetFiltActTuning

Table 42 describes the VN100_SPI_SetFiltActTuning function.

Table 42. VN100_SPI_SetFiltActTuning

Function Name	VN100_SPI_SetFiltActTuning
Function prototype	VN100_SPI_SetFiltActTuning(unsigned char sensorID, float gainM, float gainA, float memM, float memA);
Behavior description	Set the filter active tuning parameters. The active tuning parameters control how the filter handles dynamic disturbances in both magnetic and acceleration. These values are not needed for normal operation. More on these parameters can be found in the User Manual in Section 6.24.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	gainM : Magnetic Disturbance Gain
	gainA : Acceleration Disturbance Gain
	memM : Magnetic Disturbance Memory
	memA : Acceleration Disturbance Gain
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the filter active tuning parameters */
VN100_SPI_Packet *packet;
float atp[4] = {1.0, 1.0, 0.99, 0.99};
packet = VN100_SPI_SetFiltActTuning(0, &atp[0], &atp[1], &atp[2], &atp[3]);
```

5.2.35 VN100_SPI_GetAccComp

Table 43 describes the VN100_SPI_GetAccComp function.

Table 43. VN100_SPI_GetAccComp

Function Name	VN100_SPI_GetAccComp
Function prototype	VN100_SPI_GetAccComp(unsigned char sensorID, float* AccComp);
Behavior description	Get the accelerometer compensation parameters. The purpose of these parameters is explained in Section 6.25 of the User Manual. These parameters are not required for normal operation.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	AccComp : Acceleration compensation register values
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the accelerometer compensation parameters */
VN100_SPI_Packet *packet;
float act[12];
packet = VN100_SPI_GetAccComp(0, act);
```

5.2.36 VN100_SPI_SetAccComp

Table 44 describes the VN100_SPI_SetAccComp function.

Table 44. VN100_SPI_SetAccComp

Function Name	VN100_SPI_SetAccComp
Function prototype	VN100_SPI_SetAccComp(unsigned char sensorID, float* AccComp);
Behavior description	Set the accelerometer compensation parameters. The purpose of these parameters is explained in Section 6.25 of the User Manual. These parameters are not required for normal operation.
Input parameter	sensorID: The sensor to get the requested data from
Input parameter	AccComp : Acceleration compensation register values
Output parameter	None
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the accelerometer compensation parameters */
VN100_SPI_Packet *packet;
float act[12] = {1,0,0,0,1,0,0,0,1,0,0,0};
packet = VN100_SPI_SetAccComp(0, act);
```

5.2.37 VN100_SPI_GetRefFrameRot

Table 45 describes the VN100_SPI_GetRefFrameRot function.

Table 45. VN100_SPI_GetRefFrameRot

Function Name	VN100_SPI_GetRefFrameRot
Function prototype	VN100_SPI_GetRefFrameRot(unsigned char sensorID, float* refFrameRot);
Behavior description	Get the reference frame rotation matrix. This matrix allows the user to transform all measured vectors from the body reference frame of the VN-100, to any other rigidly attached coordinate frame. The effect of this transformation is that the computed attitude solution and measured measurement vectors will now be measured in the chosen coordinate system of the user and not the VN-100 coordinate system. This is further explained in Section 6.26 of the User Manual.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	refFrameRot : Reference frame rotation matrix (9x1)
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the reference frame rotation parameters */
VN100_SPI_Packet *packet;
float rfr[9];
packet = VN100_SPI_GetRefFrameRot(0, rfr);
```

5.2.38 VN100_SPI_SetRefFrameRot

Table 46 describes the VN100_SPI_SetRefFrameRot function.

Table 46. VN100_SPI_SetRefFrameRot

Function Name	VN100_SPI_SetRefFrameRot
Function prototype	VN100_SPI_SetRefFrameRot(unsigned char sensorID, float* refFrameRot);
Behavior description	Set the reference frame rotation matrix. This matrix allows the user to transform all measured vectors from the body reference frame of the VN-100, to any other rigidly attached coordinate frame. The effect of this transformation is that the computed attitude solution and measured measurement vectors will now be measured in the chosen coordinate system of the user and not the VN-100 coordinate system. This is further explained in Section 6.26 of the User Manual.
Input parameter 1	sensorID: The sensor to get the requested data from
Input parameter 2	refFrameRot : Reference frame rotation matrix (9x1)
Output parameter	None
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the reference frame rotation parameters */
VN100_SPI_Packet *packet;
float rfr[9] = {1,0,0,0,1,0,0,0,1};
packet = VN100_SPI_SetRefFrameRot(0, rfr);
```

5.2.39 VN100_SPI_GetAccGain

Table 47 describes the VN100_SPI_GetAccGain function.

Table 47. VN100_SPI_GetAccGain

Function Name	VN100_SPI_GetAccGain
Function prototype	VN100_SPI_GetAccGain(unsigned char sensorID, VN100_AccGainType gain);
Behavior description	Get the current accelerometer gain setting. The accelerometer on the VN-100 can be set to either a +/- 2g or +/- 6g gain setting.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	gain : The current accelerometer gain setting
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the accelerometer gain */
VN100_SPI_Packet *packet;
VN100_AccGainType gain;
packet = VN100_SPI_GetAccGain(0, &gain);
```

5.2.40 VN100_SPI_SetAccGain

Table 48 describes the VN100_SPI_SetAccGain function.

Table 48. VN100_SPI_SetAccGain

Function Name	VN100_SPI_SetAccGain
Function prototype	VN100_SPI_SetAccGain(unsigned char sensorID, VN100_AccGainType gain);
Behavior description	Set the current accelerometer gain setting. The accelerometer on the VN-100 can be set to either a +/- 2g or +/- 6g gain setting.
Input parameter 1	sensorID: The sensor to get the requested data from
Input parameter 2	gain : The current accelerometer gain setting
Output parameter	None
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_WriteRegister ()

Example:

```
/* Set the accelerometer gain */
VN100_SPI_Packet *packet;
packet = VN100_SPI_SetAccGain(0, VN100_AccGain_6G);
```

5.2.41 VN100_SPI_RestoreFactorySettings

Table 49 describes the VN100_SPI_RestoreFactorySettings function.

Table 49. VN100_SPI_RestoreFactorySettings

Function Name	VN100_SPI_RestoreFactorySettings
Function prototype	VN100_SPI_RestoreFactorySettings(unsigned char sensorID);
Behavior description	Restore the selected sensor to factory default state. The values for factory default state for each register can be found in Section 7 of the User Manual.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	None
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Restore sensor to factory default settings */
VN100_SPI_Packet *packet;
packet = VN100_SPI_RestoreFactorySettings(0);
```

5.2.42 VN100_SPI_Tare

Table 50 describes the VN100_SPI_Tare function.

Table 50. VN100_SPI_Tare

Function Name	VN100_SPI_Tare
Function prototype	VN100_SPI_Tare(unsigned char sensorID);
Behavior description	Send a tare command to the selected VN-100. The tare command will zero out the current sensor orientation. The attitude of the sensor will be measured form this point onwards with respect to the attitude present when the tare command was issued. It is important with v4 of the firmware to keep the device still for at least 3 seconds after performing a tare command. The tare command will also set the reference vectors in the inertial frame to the vectors currently measured in the body frame.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	None
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Zero out current attitude */
VN100_SPI_Packet *packet;
packet = VN100_SPI_Tare(0);
```

5.2.43 VN100_SPI_Reset

Table 51 describes the VN100_SPI_Reset function.

Table 51. VN100_SPI_Reset

Function Name	VN100_SPI_Reset
Function prototype	VN100_SPI_Reset(unsigned char sensorID);
Behavior description	Command the given sensor to perform a device hardware reset. This is equivalent to pulling the NRST pin low on the VN-100. Any changes to any of the registers on the VN-100 that were made since last issuing a Write Settings commands will be lost.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	None
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Reset the sensor */
VN100_SPI_Packet *packet;
packet = VN100_SPI_Reset(0);
```

5.2.44 VN100_SPI_GetAccInertial

Table 52 describes the VN100_SPI_GetAccInertial function.

Table 52. VN100_SPI_GetAccInertial

Function Name	VN100_SPI_GetAccInertial
Function prototype	VN100_SPI_GetAccInertial(unsigned char sensorID, float *AccI);
Behavior description	Request the inertial acceleration from the VN-100. This function will internally request both the measured acceleration and attitude from the sensor, then compute the inertial acceleration. If you want to integrate your acceleration to find velocity or position, then this is the acceleration that you want to measure. It is measured in a fixed NED (North, East, Down) coordinate frame.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	AccI : The inertial acceleration measured by the device.
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the inertial acceleration measurement */
VN100_SPI_Packet *packet;
float accI[3];
packet = VN100_SPI_AccInertial(0, accI);
```

5.2.45 VN100_SPI_GetMagInertial

Table 53 describes the VN100_SPI_GetMagInertial function.

Table 53. VN100_SPI_GetMagInertial

Function Name	VN100_SPI_GetMagInertial
Function prototype	VN100_SPI_GetMagInertial(unsigned char sensorID, float *MagI);
Behavior description	Request the inertial magnetic measurement from the VN-100. This function will internally request both the measured magnetic and attitude from the sensor, then compute the inertial magnetic measurement. It is measured in a fixed NED (North, East, Down) coordinate frame.
Input parameter	sensorID: The sensor to get the requested data from
Output parameter	MagI : The inertial magnetic measurement measured by the device.
Return value	Pointer to SPI packet returned by the sensor
Required preconditions	None
Called functions	VN100_SPI_ReadRegister()

Example:

```
/* Get the inertial magnetic measurement */
VN100_SPI_Packet *packet;
float magI[3];
packet = VN100_SPI_MagInertial(0, magI);
```

6 Math Library

The data structures used in the math library are described in Section 6.1, while Section 6.2 describes the firmware library functions.

6.1 Data Structures

6.2 Math library functions

Table 54 lists the various functions of the math firmware library.

Table 54. Math library functions

Function Name	Description
VN_DotP	Compute the dot product of vector A with vector B.
VN_CrossP	Compute the cross product of vector A with vector B.
VN_VecAdd	Compute the addition of vector A with vector B.
VN_VecSub	Compute the subtraction of vector A with vector B.
VN_VecMultT	Compute the multiplication of a vector with the transpose of another vector.
VN_Diagonal	Create a zero matrix with the diagonal elements equal to the magnitude of a scalar.
VN_MatAdd	Compute the addition of matrix A and B.
VN_MatSub	Compute the subtraction of matrix A and B.
VN_MatMult	Compute the multiplication of matrix A and B.
VN_MatMultMMT	Compute the multiplication of matrix A with the transpose of matrix B.
VN_MatMultMTM	Compute the multiplication of the transpose of matrix A with matrix B.
VN_MatScalarMult	Compute the multiplication of a scalar times a matrix.
VN_MatVecMult	Compute the multiplication of matrix A with vector B.
VN_MatTVecMult	Multiply the transpose of the matrix A by the vector B.
VN_MatCopy	Copy the values from one matrix to another.

VN_MatInv	Compute the matrix inverse of A.
VN_SkewMatrix	Compute the matrix cross product of vector V. This operation converts a vector into a matrix that when multiplied by another vector would give the result of a cross product operation between the two vectors.
VN_Transpose	Calculate the transpose of matrix A.
VN_Norm	Compute the length of the given vector with size m x 1.
VN_Normalize	Compute the unit normal vector with the direction given by vector V1.
VN_Quat2DCM	Convert a quaternion into to a directional cosine matrix.
VN_YPR2DCM	Convert the given yaw, pitch, and roll into a directional cosine matrix.
VN_MatZeros	Sets all elements of matrix A equal to zero.
VN_Quat2Euler121	Convert a quaternion attitude representation to an Euler angle 1,2,1 set.
VN_Quat2Euler123	Convert a quaternion attitude representation to an Euler angle 1,2,3 set.
VN_Quat2Euler131	Convert a quaternion attitude representation to an Euler angle 1,3,1 set.
VN_Quat2Euler132	Convert a quaternion attitude representation to an Euler angle 1,3,2 set.
VN_Quat2Euler212	Convert a quaternion attitude representation to an Euler angle 2,1,2 set.
VN_Quat2Euler213	Convert a quaternion attitude representation to an Euler angle 2,1,3 set.
VN_Quat2Euler231	Convert a quaternion attitude representation to an Euler angle 2,3,1 set.
VN_Quat2Euler232	Convert a quaternion attitude representation to an Euler angle 2,3,2 set.
VN_Quat2Euler312	Convert a quaternion attitude representation to an Euler angle 3,1,2 set.
VN_Quat2Euler313	Convert a quaternion attitude representation to an Euler angle 3,1,3 set.

VN_Quat2Euler321	Convert a quaternion attitude representation to an Euler angle 3,2,1 set.
VN_Quat2Euler323	Convert a quaternion attitude representation to an Euler angle 3,2,3 set.
VN_Quat2Gibbs	Convert a quaternion attitude representation to the Gibbs angle representation.
VN_Quat2MRP	Convert a quaternion attitude representation to an Modified Rodrigues Parameters representation.
VN_Quat2PRV	Convert a quaternion attitude representation to the principal rotation vector.
VN_AddQuat	VN_AddQuat provides the quaternion which corresponds to performing two successive rotations from q1 and q2.
VN_SubQuat	VN_SubQuat provides the quaternion which corresponds to the relative rotation from q2 to q1.
VN_QuatKinematicDiffEq	Computes the time rate of change of the quaternion parameters as a function of the angular rates.
VN_YPRKinematicDiffEq	Computes the time rate of change of the 321 Euler angles (yaw, pitch, roll) as a function of the angular rates.
VN_Body2Inertial	Converts a vector measured in the body frame into the inertial reference frame.
VN_Inertial2Body	Convert a vector measured in the inertial frame into the body reference frame.

6.2.1 VN_DotP

Table 55 describes the VN_DotP function.

Table 55. VN_DotP

Function Name	VN_DotP
Function prototype	float VN_DotP(float *A, float *B);
Behavior description	Compute the cross product of vector A with vector B.
Matlab equation	C = dot(A, B)
Input parameter 1	A : 3x1 vector
Input parameter 2	B : 3x1 vector
Output parameter	None
Return value	Result of dot product between two vectors.
Required preconditions	None
Called functions	None

Example:

```
/* Compute the dot product of A and B */
float A[3];
float B[3];
float C;

C = VN_DotP(A, B);
```

6.2.2 VN_CrossP

Table 56 describes the VN_CrossP function.

Table 56. VN_CrossP

Function Name	VN_CrossP
Function prototype	void VN_CrossP(float *A, float *B, float *C);
Behavior description	Compute the cross product of vector A with vector B.
Matlab equation	C = cross(A, B)
Input parameter 1	A : 3x1 vector
Input parameter 2	B : 3x1 vector
Input parameter 3	C : 3x1 vector
Output parameter	None
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Compute the cross product of A and B */
float A[3];
float B[3];
float C[3];

VN_CrossP(A, B, C);
```

6.2.3 VN_VecAdd

Table 57 describes the VN_VecAdd function.

Table 57. VN_VecAdd

Function Name	VN_VecAdd
Function prototype	void VN_VecAdd(float *A, float *B, unsigned long rows, float *C);
Behavior description	Compute the addition of vector A with vector B.
Matlab equation	C = A + B
Input parameter 1	A : vector with length given by rows
Input parameter 2	B : vector with length given by rows
Input parameter 3	rows : length of vector A, B, and C
Output parameter	C : result of vector addition
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Add vector A and B */
float A[3];
float B[3];
float C[3];

VN_VecAdd(A, B, 3, C);
```

6.2.4 VN_VecSub

Table 58 describes the VN_VecSub function.

Table 58. VN_VecSub

Function Name	VN_VecSub
Function prototype	void VN_VecSub(float *A, float *B, unsigned long rows, float *C)
Behavior description	Compute the subtraction of vector A with vector B.
Matlab equation	C = A - B
Input parameter 1	A : vector with length given by rows
Input parameter 2	B : vector with length given by rows
Input parameter 3	rows : length of vector A, B, and C
Output parameter	C : result of vector subtraction
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Subtract vector A and B */
float A[3];
float B[3];
float C[3];

VN_VecSub(A, B, 3, C);
```

6.2.5 VN_VecMultT

Table 59 describes the VN_VecMultT function.

Table 59. VN_VecMultT

Function Name	VN_VecMultT
Function prototype	void VN_VecMultT(float *A, float *BT, unsigned long rows, float **C)
Behavior description	Compute the multiplication of a vector with the transpose of another vector. The result will be a square matrix with the size of nxn where n=rows.
Matlab equation	C = A * transpose(B)
Input parameter 1	A : vector with length given by rows
Input parameter 2	BT : vector with length given by rows
Input parameter 3	rows : length of vector A and B
Output parameter	C : result of multiplication of A with the transpose of B
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Multiply vector A with transpose of vector B */
float A[3];
float B[3];
VN_CreateMatrix(C, 3, 3, {0});

VN_VecMultT(A, B, 3, C);
```

6.2.6 VN_Diagonal

Table 60 describes the VN_Diagonal function.

Table 60. VN_Diagonal

Function Name	VN_Diagonal
Function prototype	void VN_Diagonal(float scalar, unsigned long Arows, unsigned long Acols, float *A)
Behavior description	Create a diagonal matrix with the diagonal terms equal to scalar and the non-diagonal elements equal to zero.
Matlab equation	A = scalar * eye(Arows, Acols)
Input parameter 1	scalar : desired magnitude of diagonal terms
Input parameter 2	Arows : number of rows for the resulting matrix A
Input parameter 3	Acols : number of columns for the resulting matrix A
Output parameter	A : resulting diagonal matrix
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Create 5x5 identity matrix */
VN_CreateMatrix(A, 5, 5, {0});

VN_Diagonal(1.0f, 5, 5, A);
```

6.2.7 VN_MatAdd

Table 61 describes the VN_MatAdd function.

Table 61. VN_MatAdd

Function Name	VN_MatAdd
Function prototype	void VN_MatAdd(float **A, float **B, unsigned long Arows, unsigned long Acols, float **C)
Behavior description	Compute the addition of matrix A and B.
Matlab equation	C = A + B
Input parameter 1	A : Matrix A with size of Arows x Acols.
Input parameter 2	B : Matrix B with size of Arows x Acols.
Input parameter 3	Arows : Number of rows in matrix A and B.
Input parameter 4	Acols : Number of cols in matrix A and B.
Output parameter	C : Result of matrix addition with size of Arows x Acols.
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Add matrix A and B to get C */
VN_CreateMatrix(A, 3, 3, {0});
VN_CreateMatrix(B, 3, 3, {0});
VN_CreateMatrix(C, 3, 3, {0});

VN_MatAdd(A, B, 3, 3, C);
```

6.2.8 VN_MatSub

Table 62 describes the VN_MatSub function.

Table 62. VN_MatSub

Function Name	VN_MatSub
Function prototype	void VN_MatSub(float **A, float **B, unsigned long Arows, unsigned long Acols, float **C)
Behavior description	Compute the subtraction of matrix A and B.
Matlab equation	C = A - B
Input parameter 1	A : Matrix A with size of Arows x Acols.
Input parameter 2	B : Matrix B with size of Arows x Acols.
Input parameter 3	Arows : Number of rows in matrix A and B.
Input parameter 4	Acols : Number of cols in matrix A and B.
Output parameter	C : Result of matrix subtraction with size of Arows x Acols.
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Subtract matrix A and B to get C */
VN_CreateMatrix(A, 3, 3, {0});
VN_CreateMatrix(B, 3, 3, {0});
VN_CreateMatrix(C, 3, 3, {0});

VN_MatSub(A, B, 3, 3, C);
```

6.2.9 VN_MatMult

Table 63 describes the VN_MatMult function.

Table 63. VN_MatMult

Function Name	VN_MatMult
Function prototype	void VN_MatMult(float **A, float **B, unsigned long Arows, unsigned long Acols, unsigned long Bcols, float **C)
Behavior description	Compute the multiplication of matrix A and B.
Matlab equation	C = A * B
Input parameter 1	A : Matrix A with size of Arows x Acols
Input parameter 2	B : Matrix B with size of Acols x Bcols
Input parameter 3	Arows : Number of rows in matrix A
Input parameter 4	Acols : Number of columns in matrix A
Input parameter 5	Bcols : Number of columns in matrix B
Output parameter	C : Result of the matrix multiplication with size Arows x Bcols
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Multiply matrix A and B to get C */
VN_CreateMatrix(A, 3, 3, {0});
VN_CreateMatrix(B, 3, 3, {0});
VN_CreateMatrix(C, 3, 3, {0});
VN_MatMult(A, B, 3, 3, 3, C);
```

6.2.10 VN_MatMultMMT

Table 64 describes the VN_MatMultMMT function.

Table 64. VN_MatMultMMT

Function Name	VN_MatMultMMT
Function prototype	void VN_MatMultMMT(float **A, float **BT, unsigned long Arows, unsigned long Acols, unsigned long Brows, float **C)
Behavior description	Compute the multiplication of matrix A with the transpose of matrix B.
Matlab equation	C = A * transpose(B)
Input parameter 1	A : Matrix A with size of Arows x Acols
Input parameter 2	B : Matrix B with size of Acols x Bcols
Input parameter 3	Arows : Number of rows in matrix A
Input parameter 4	Acols : Number of columns in matrix A
Input parameter 5	Brows : Number of rows in matrix B
Output parameter	C : Result of the matrix multplication with size Arows x Brows
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Multiply matrix A and transpose of B to get C */
VN_CreateMatrix(A, 5, 3, {0});
VN_CreateMatrix(B, 7, 3, {0});
VN_CreateMatrix(C, 5, 7, {0});
VN_MatMultMMT(A, B, 5, 3, 7, C);
```

6.2.11 VN_MatMultMTM

Table 65 describes the VN_MatMultMTM function.

Table 65. VN_MatMultMTM

Function Name	VN_MatMultMTM
Function prototype	void VN_MatMultMTM(float **A, float **BT, unsigned long Arows, unsigned long Acols, unsigned long Bcols, float **C)
Behavior description	Compute the multiplication of matrix A with the transpose of matrix B.
Matlab equation	C = A * transpose(B)
Input parameter 1	A : Matrix A with size of Arows x Acols
Input parameter 2	B : Matrix B with size of Arows x Bcols
Input parameter 3	Arows : Number of rows in matrix A
Input parameter 4	Acols : Number of columns in matrix A
Input parameter 5	Bcols : Number of columns in matrix B
Output parameter	C : Result of the matrix multiplication with size Acols x Bcols
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Multiply the transpose of matrix A and B to get C */
VN_CreateMatrix(A, 3, 5, {0});
VN_CreateMatrix(B, 3, 7, {0});
VN_CreateMatrix(C, 5, 7, {0});
VN_MatMultMTM(A, B, 3, 5, 7, C);
```

6.2.12 VN_MatScalarMult

Table 66 describes the VN_MatScalarMult function.

Table 66. VN_MatScalarMult

Function Name	VN_MatScalarMult
Function prototype	void VN_MatScalarMult(double **A, double scalar, unsigned long Arows, unsigned long Acols, double **C)
Behavior description	Compute the multiplication of a scalar times a matrix.
Matlab equation	C = scalar * A
Input parameter 1	scalar : The scalar term
Input parameter 2	A : The matrix with the size Arows x Acols
Input parameter 3	Arows : The number of rows in the matrix A
Input parameter 4	Acols : The number of columns in the matrix B
Output parameter	C : The result of the operation scalar * A
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Multiply all the terms in matrix A by 10 */
VN_CreateMatrix(A, 3, 5, {0});
VN_CreateMatrix(B, 3, 5, {0});
VN_MatMultMTM(A, 10.0f, 3, 5, B);
```

6.2.13 VN_MatVecMult

Table 67 describes the VN_MatVecMult function.

Table 67. VN_MatVecMult

Function Name	VN_MatVecMult
Function prototype	void VN_MatVecMult(float **A, float *B, unsigned long Arows, unsigned long Acols, float *C)
Behavior description	Compute the multiplication of matrix A with vector B.
Matlab equation	C = A * B
Input parameter 1	A : Matrix with size Arows x Acols
Input parameter 2	B : Column vector with size Acols x 1
Input parameter 3	Arows : Number of rows in matrix A
Input parameter 4	Acols : Number of columns in matrix A
Output parameter	C : Matrix result with size Arows x Acols
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Multiply matrix A by vector B */
VN_CreateMatrix(A, 3, 3, {0});
float B[3];
float C[3];

VN_MatVecMult(A, B, 3, 3, C);
```

6.2.14 VN_MatTVecMult

Table 68 describes the VN_MatTVecMult function.

Table 68. VN_MatTVecMult

Function Name	VN_MatTVecMult
Function prototype	void VN_MatTVecMult(float **A, float *B, unsigned long Arows, unsigned long Acols, float *C)
Behavior description	Multiply the transpose of the matrix A by the vector B.
Matlab equation	C = transpose(A) * B
Input parameter 1	A : Matrix with size Arows x Acols
Input parameter 2	B : Column vector with size Arows x 1
Input parameter 3	Arows : Number of rows in matrix A
Input parameter 4	Acols : Number of columns in matrix A
Output parameter	C : Matrix result with size Acols x Arows
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Multiply transpose of matrix A by vector B */
VN_CreateMatrix(A, 3, 3, {0});
float B[3];
float C[3];

VN_MatTVecMult(A, B, 3, 3, C);
```

6.2.15 VN_MatCopy

Table 69 describes the VN_MatCopy function.

Table 69. VN_MatCopy

Function Name	VN_MatCopy
Function prototype	void VN_MatCopy(float **A, unsigned long nrows, unsigned long ncols, float **B)
Behavior description	Copy the values from one matrix to another.
Matlab equation	B = A
Input parameter 1	A : Matrix with size nrows x ncols
Input parameter 2	nrows : number of rows in matrix A
Input parameter 3	ncols : number of columns in matrix A
Output parameter	B : Resulting matrix with size nrows x ncols
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Copy matrix A into matrix B */
VN_CreateMatrix(A, 3, 3, {1,0,0,0,1,0,0,0,1}); /* Identity matrix */
VN_CreateMatrix(B, 3, 3, {0});

VN_MatCopy(A, 3, 3, B); /* B will now be equal to A */
```

6.2.16 VN_MatInv

Table 70 describes the VN_MatInv function.

Table 70. VN_MatInv

Function Name	VN_MatInv
Function prototype	void VN_MatInv(float **A, s32 n, float **B)
Behavior description	Compute the matrix inverse of A.
Matlab equation	B = inv(A)
Input parameter 1	A : Matrix with size n x n
Input parameter 2	n : Number of rows or columns in matrix A
Output parameter	B : Matrix result with size n x n
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Calculate inverse of A */
VN_CreateMatrix(A, 3, 3, {1,0,0,0,1,0,0,0,1}); /* Identity matrix */
VN_CreateMatrix(B, 3, 3, {0});

VN_MatInv(A, 3, B); /* B will now be equal to inverse of A */
```

6.2.17 VN_SkewMatrix

Table 71 describes the VN_SkewMatrix function.

Table 71. VN_SkewMatrix

Function Name	VN_SkewMatrix
Function prototype	void VN_SkewMatrix(float *V, float **A)
Behavior description	Compute the matrix cross product of vector V. This operation converts a vector into a matrix that when multiplied by another vector would give the result of a cross product operation between the two vectors.
Matlab equation	A = skew(V) where A*b = cross(V,b) if b is a vector same size as V.
Input parameter 1	V : Vector of size 3x1 to perform operation on.
Output parameter	A : Resulting matrix with size 3x3.
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Calculate skew matrix of A */
float A[3] = {1, 0, 0};
float B[3] = {0, 1, 0};
VN_CreateMatrix(C, 3, 3, {0});
float D[3];

VN_SkewMatrix(A, C); /* C will now equal skew matrix of A */

D = VN_MatVecMult(C, B, 3, 3, D); /* D = VN_crossP(A, B) = {0, 0, -1} */
```

6.2.18 VN_Transpose

Table 72 describes the VN_Transpose function.

Table 72. VN_Transpose

Function Name	VN_Transpose
Function prototype	void VN_Transpose(float **A, unsigned long Arows, unsigned long Acols, float **B)
Behavior description	Calculate the transpose of matrix A.
Matlab equation	B = transpose(A)
Input parameter 1	A : Matrix with size Arows x Acols
Input parameter 2	Arows : Number of rows in matrix A
Input parameter 3	Acols : Number of columns in matrix A
Output parameter	B : Resulting matrix with size Acols x Arows
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Calculate transpose of A */
VN_CreateMatrix(A, 3, 3, {1,2,3,4,5,6,7,8,9});
VN_CreateMatrix(B, 3, 3, {0});

VN_Transpose(A, 3, 3, B); /* B = {1,4,7,2,5,8,3,6,9} */
```

6.2.19 VN_Norm

Table 73 describes the VN_Norm function.

Table 73. VN_Norm

Function Name	VN_Norm
Function prototype	float VN_Norm(float *A, unsigned long m)
Behavior description	Compute the length of the given vector with size m x 1.
Matlab equation	norm(A)
Input parameter 1	A : Vector to compute the length of with size m x 1
Input parameter 2	m : Number of terms in the vector A.
Output parameter	None
Return value	The computed length of the vector.
Required preconditions	None
Called functions	None

Example:

```
/* Calculate length of vector A */
float A[3] = {1, 2, 3};
float len;

len = VN_Norm(A, 3); /* len = sqrt(1*1 + 2*2 + 3*3) */
```

6.2.20 VN_Normalize

Table 74 describes the VN_Normalize function.

Table 74. VN_Normalize

Function Name	VN_Normalize
Function prototype	void VN_Normalize(float *V1, unsigned long m, float *V2)
Behavior description	Compute the unit normal vector with the direction given by vector V1.
Matlab equation	V2 = V1 ./ norm(V1)
Input parameter 1	V1 : Vector with size m x 1
Input parameter 2	m : Number of terms in the vector V1
Output parameter	V2 : Unit vector with the size of m x 1
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Normalize vector A */
float A[3] = {3, 0, 0};
float B[3];

VN_Normalize(A, 3, B); /* B = {1, 0, 0} */
```

6.2.21 VN_Quat2DCM

Table 75 describes the VN_Quat2DCM function.

Table 75. VN_Quat2DCM

Function Name	VN_Quat2DCM
Function prototype	void VN_quat2DCM(float *q, float **A)
Behavior description	Convert a quaternion into to a directional cosine matrix.
Matlab equation	A = quat2dcm(q)
Input parameter 1	q : Quaternion attitude
Output parameter	A : Directional cosine matrix (3x3)
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a directional cosine matrix */
float q[4];
VN_CreateMatrix(DCM, 3, 3, {0});

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2DCM(q, DCM); /* Compute the DCM */
```

6.2.22 VN_YPR2DCM

Table 76 describes the VN_YPR2DCM function.

Table 76. VN_YPR2DCM

Function Name	VN_YPR2DCM
Function prototype	void VN_YPR2DCM(float *YPR, float **A)
Behavior description	Convert the given yaw, pitch, and roll into a directional cosine matrix.
Matlab equation	A = ANGLE2DCM(YPR[0], YPR[1], YPR[2], 'ZYX')
Input parameter 1	YPR : Yaw, pitch, roll as a 3x1 vector
Output parameter	A : Directional cosine matrix
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the yaw, pitch, roll into a directional cosine matrix */
float ypr[3];
VN_CreateMatrix(DCM, 3, 3, {0});

VN100_SPI_GetYPR(0, &ypr[0], &ypr[1], &ypr[2]); /* Get YPR from device */

VN100_YPR2DCM(q, DCM); /* Compute the DCM */
```

6.2.23 VN_MatZeros

Table 77 describes the VN_MatZeros function.

Table 77. VN_MatZeros

Function Name	VN_MatZeros
Function prototype	void VN_MatZeros(float **A, unsigned long Arows, unsigned long Acols)
Behavior description	Sets all elements of matrix A equal to zero.
Matlab equation	A = zeros(Arows, Acols)
Input parameter 1	A : Matrix with size of Arows x Acols
Input parameter 2	Arows : Number of rows in matrix A
Input parameter 3	Acols : Number of columns in matrix A
Output parameter	Matrix A with all elements set to zero
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Zero out matrix A */
VN_CreateMatrix(A, 3, 3, {1, 0, 0, 0, 1, 0, 0, 0, 0}); /* Identity matrix */

VN_MatZeros(A, 3, 3); /* Zero out matrix A */
```

6.2.24 VN_Quat2Euler121

Table 78 describes the VN_Quat2Euler121 function.

Table 78. VN_Quat2Euler121

Function Name	VN_Quat2Euler121
Function prototype	void VN_Quat2Euler121(float *q, float *Euler121)
Behavior description	Convert a quaternion attitude representation to an Euler angle 1,2,1 set.
Matlab equation	Euler121 = quat2angle(q, 'XYX')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 121 angles */
float q[4];
float Euler121[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler121(q, Euler121); /* Compute the Euler 121 angles */
```

6.2.25 VN_Quat2Euler123

Table 79 describes the VN_Quat2Euler123 function.

Table 79. VN_Quat2Euler123

Function Name	VN_Quat2Euler123
Function prototype	void VN_Quat2Euler123(float *q, float *Euler123)
Behavior description	Convert a quaternion attitude representation to an Euler angle 1,2,3 set.
Matlab equation	Euler123 = quat2angle(q, 'XYZ')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 123 angles */
float q[4];
float Euler123[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler123(q, Euler123); /* Compute the Euler 123 angles */
```

6.2.26 VN_Quat2Euler131

Table 80 describes the VN_Quat2Euler131 function.

Table 80. VN_Quat2Euler131

Function Name	VN_Quat2Euler131
Function prototype	void VN_Quat2Euler131(float *q, float *Euler131)
Behavior description	Convert a quaternion attitude representation to an Euler angle 1,3,1 set.
Matlab equation	Euler131 = quat2angle(q, 'XZX')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 131 angles */
float q[4];
float Euler131[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler131(q, Euler131); /* Compute the Euler 131 angles */
```

6.2.27 VN_Quat2Euler132

Table 81 describes the VN_Quat2Euler132 function.

Table 81. VN_Quat2Euler132

Function Name	VN_Quat2Euler132
Function prototype	void VN_Quat2Euler132(float *q, float *Euler132)
Behavior description	Convert a quaternion attitude representation to an Euler angle 1,3,2 set.
Matlab equation	Euler132 = quat2angle(q, 'XZY')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 132 angles */
float q[4];
float Euler132[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler132(q, Euler132); /* Compute the Euler 132 angles */
```

6.2.28 VN_Quat2Euler212

Table 82 describes the VN_Quat2Euler212 function.

Table 82. VN_Quat2Euler212

Function Name	VN_Quat2Euler212
Function prototype	void VN_Quat2Euler212(float *q, float *Euler212)
Behavior description	Convert a quaternion attitude representation to an Euler angle 2,1,2 set.
Matlab equation	Euler212 = quat2angle(q, 'YXY')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 212 angles */
float q[4];
float Euler212[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler212(q, Euler212); /* Compute the Euler 212 angles */
```

6.2.29 VN_Quat2Euler213

Table 83 describes the VN_Quat2Euler213 function.

Table 83. VN_Quat2Euler213

Function Name	VN_Quat2Euler213
Function prototype	void VN_Quat2Euler213(float *q, float *Euler213)
Behavior description	Convert a quaternion attitude representation to an Euler angle 2,1,3 set.
Matlab equation	Euler213 = quat2angle(q, 'YXZ')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 213 angles */
float q[4];
float Euler213[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler213(q, Euler213); /* Compute the Euler 213 angles */
```

6.2.30 VN_Quat2Euler231

Table 84 describes the VN_Quat2Euler231 function.

Table 84. VN_Quat2Euler231

Function Name	VN_Quat2Euler231
Function prototype	void VN_Quat2Euler231(float *q, float *Euler231)
Behavior description	Convert a quaternion attitude representation to an Euler angle 2,3,1 set.
Matlab equation	Euler231 = quat2angle(q, 'YZX')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 231 angles */
float q[4];
float Euler231[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler231(q, Euler231); /* Compute the Euler 231 angles */
```

6.2.31 VN_Quat2Euler232

Table 85 describes the VN_Quat2Euler232 function.

Table 85. VN_Quat2Euler232

Function Name	VN_Quat2Euler232
Function prototype	void VN_Quat2Euler232(float *q, float *Euler232)
Behavior description	Convert a quaternion attitude representation to an Euler angle 2,3,2 set.
Matlab equation	Euler232 = quat2angle(q, 'YZY')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 232 angles */
float q[4];
float Euler232[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler232(q, Euler232); /* Compute the Euler 232 angles */
```

6.2.32 VN_Quat2Euler312

Table 86 describes the VN_Quat2Euler312 function.

Table 86. VN_Quat2Euler312

Function Name	VN_Quat2Euler312
Function prototype	void VN_Quat2Euler312(float *q, float *Euler312)
Behavior description	Convert a quaternion attitude representation to an Euler angle 3,1,2 set.
Matlab equation	Euler312 = quat2angle(q, 'ZXY')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 312 angles */
float q[4];
float Euler312[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler312(q, Euler312); /* Compute the Euler 312 angles */
```

6.2.33 VN_Quat2Euler313

Table 87 describes the VN_Quat2Euler313 function.

Table 87. VN_Quat2Euler313

Function Name	VN_Quat2Euler313
Function prototype	void VN_Quat2Euler313(float *q, float *Euler313)
Behavior description	Convert a quaternion attitude representation to an Euler angle 3,1,3 set.
Matlab equation	Euler313 = quat2angle(q, 'ZXZ')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 313 angles */
float q[4];
float Euler313[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler313(q, Euler313); /* Compute the Euler 313 angles */
```

6.2.34 VN_Quat2Euler321

Table 88 describes the VN_Quat2Euler321 function.

Table 88. VN_Quat2Euler321

Function Name	VN_Quat2Euler321
Function prototype	void VN_Quat2Euler321(float *q, float *Euler321)
Behavior description	Convert a quaternion attitude representation to an Euler angle 3,2,1 set.
Matlab equation	Euler321 = quat2angle(q, 'ZYX')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 321 angles */
float q[4];
float Euler321[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler321(q, Euler321); /* Compute the Euler 321 angles */
```

6.2.35 VN_Quat2Euler323

Table 89 describes the VN_Quat2Euler323 function.

Table 89. VN_Quat2Euler323

Function Name	VN_Quat2Euler323
Function prototype	void VN_Quat2Euler323(float *q, float *Euler323)
Behavior description	Convert a quaternion attitude representation to an Euler angle 3,2,3 set.
Matlab equation	Euler323 = quat2angle(q, 'ZYZ')
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Euler angles
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Euler 323 angles */
float q[4];
float Euler323[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Euler323(q, Euler323); /* Compute the Euler 323 angles */
```

6.2.36 VN_Quat2Gibbs

Table 90 describes the VN_Quat2Gibbs function.

Table 90. VN_Quat2Gibbs

Function Name	VN_Quat2Gibbs
Function prototype	void VN_Quat2Gibbs(float *q, float *Gibb)
Behavior description	Convert a quaternion attitude representation to the Gibbs angle representation.
Matlab equation	N/A
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	Gibb : Gibbs vector
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Gibbs vector */
float q[4];
float Gibbs[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2Gibbs(q, Gibbs); /* Compute the Gibbs vector */
```

6.2.37 VN_Quat2MRP

Table 91 describes the VN_Quat2MRP function.

Table 91. VN_Quat2MRP

Function Name	VN_Quat2MRP
Function prototype	void VN_Quat2MRP(float *q, float *MRP)
Behavior description	Convert a quaternion attitude representation to an Modified Rodrigues Parameters representation.
Matlab equation	N/A
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	MRP : Modified Rodrigues Parameters
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a Modified Rodrigues Parameters */
float q[4];
float MRP[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2MRP(q, MRP); /* Compute the Modified Rodrigues Parameters */
```

6.2.38 VN_Quat2PRV

Table 92 describes the VN_Quat2PRV function.

Table 92. VN_Quat2PRV

Function Name	VN_Quat2PRV
Function prototype	void VN_Quat2PRV(float *q, float *PRV)
Behavior description	Convert a quaternion attitude representation to the principal rotation vector.
Matlab equation	N/A
Input parameter 1	q : Quaternion 4x1 vector
Output parameter	PRV : Principal rotation vector
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Convert the quaternion into a principal rotation vector */
float q[4];
float PRV[3];

VN100_SPI_GetQuat(0, q);  /* Get quaternion from device */

VN100_Quat2PRV(q, PRV); /* Compute the principal rotation vector */
```

6.2.39 VN_AddQuat

Table 93 describes the VN_AddQuat function.

Table 93. VN_AddQuat

Function Name	VN_AddQuat
Function prototype	void VN_AddQuat(float *q1, float *q2, float *q3)
Behavior description	VN_AddQuat provides the quaternion which corresponds to performing two successive rotations from q1 and q2.
Matlab equation	N/A
Input parameter 1	q1 : First quaternion
Input parameter 2	q2 : Second quaternion
Output parameter	q3 : Combined sucessive rotation of q1 and q2
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Create a combined rotation of quaternion 1 and 2 */
float q1[4];
float q2[4];
float q3[4];

VN100_AddQuat(q1, q2, q3);
```

6.2.40 VN_SubQuat

Table 94 describes the VN_SubQuat function.

Table 94. VN_SubQuat

Function Name	VN_SubQuat
Function prototype	void VN_SubQuat(float *q1, float *q2, float *q3)
Behavior description	VN_SubQuat provides the quaternion which corresponds to the relative rotation from q2 to q1.
Matlab equation	N/A
Input parameter 1	q1 : First quaternion
Input parameter 2	q2 : Second quaternion
Output parameter	q3 : Relative rotation from q2 to q1
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Create a relative rotation from q2 to q1 */
float q1[4];
float q2[4];
float q3[4];

VN100_SubQuat(q1, q2, q3);
```

6.2.41 VN_QuatKinematicDiffEq

Table 95 describes the VN_QuatKinematicDiffEq function.

Table 95. VN_QuatKinematicDiffEq

Function Name	VN_QuatKinematicDiffEq
Function prototype	void VN_QuatKinematicDiffEq(float *q, float *rates, float *q_dot)
Behavior description	Computes the time rate of change of the quaternion parameters as a function of the angular rates. You can use this function if you need to determine how the quaternion parameters are instantaneously changing as a function of time.
Matlab equation	N/A
Input parameter 1	q : Current attitude quaternion
Input parameter 2	rates : angular rates [rad/s]
Output parameter	q_dot : derivative of q
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Compute the instantaneous time derivative of the quaternion parameters */
float q[4];
float angular_rates[3];
float q_dot[4];

VN100_SPI_GetQuatRates(0, q, angular_rates); /* Get quat and angular rates */

VN_QuatKinematicDiffEq(q,angular_rates,q_dot); /* Derivative of quaternion */
```

6.2.42 VN_YPRKinematicDiffEq

Table 96 describes the VN_YPRKinematicDiffEq function.

Table 96. VN_YPRKinematicDiffEq

Function Name	VN_YPRKinematicDiffEq
Function prototype	void VN_YPRKinematicDiffEq(float *YPR, float *rates, float *YPR_dot)
Behavior description	Computes the time rate of change of the 321 Euler angles (yaw, pitch, roll) as a function of the angular rates. You can use this function if you need to determine how the Euler angles are instantaneously changing as a function of time.
Matlab equation	N/A
Input parameter 1	YPR : Yaw, Pitch, Roll angles [rad]
Input parameter 2	rates : angular rates [rad/s]
Output parameter	YPR_dot : rate of change of yaw, pitch, roll [rad/s]
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Compute the instantaneous time derivative of the Euler angles */
float q[4];
float ypr[3];
float angular_rates[3];
float ypr_dot[3];

VN100_SPI_GetQuatRates(0, q, angular_rates); /* Get quat and angular rates */

VN_Quat2Euler321(q, ypr); /* Convert quaternion into yaw, pitch, and roll */

VN_QuatKinematicDiffEq(q,angular_rates,ypr_dot); /* Get ypr_dot */

/* ypr_dot = {yaw_dot, pitch_dot, roll_dot} where dot is derivative */
```

6.2.43 VN_Body2Inertial

Table 97 describes the VN_Body2Inertial function.

Table 97. VN_Body2Inertial

Function Name	VN_Body2Inertial
Function prototype	void VN_Body2Inertial(float *v1, float *q, float *v2)
Behavior description	Converts a vector measured in the body frame into the inertial reference frame.
Matlab equation	N/A
Input parameter 1	V1 : vector measured in the body reference frame.
Input parameter 2	q : quaternion attitude of body with respect to the inertial reference frame. Input in the quaternion here that you receive from the attitude sensor.
Output parameter	V2 : vector measured in the inertial reference frame.
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Compute the inertial acceleration */
float accel_body[3];
float accel_inertial[3];
float q[4];  /* quaternion */

VN100_SPI_GetQuatAcc(0, q, accel_body); /* Get body acceleration */

VN_Body2Inertial(accel_body, q, accel_inertial); /* Convert to inertial
measured acceleration */

accel_inertial[2] += VN_G; /* Remove gravity in inertial frame */

/* Now accel_inertial is the actual acceleration measured in the body frame.
It can be integrated once to find inertial velocity, and twice to find
inertial acceleration. */
```

6.2.44 VN_Inertial2Body

Table 98 describes the VN_Inertial2Body function.

Table 98. VN_Inertial2Body

Function Name	VN_Inertial2Body
Function prototype	void VN_Inertial2Body(float *v1, float *q, float *v2)
Behavior description	Convert a vector measured in the inertial frame into the body reference frame.
Matlab equation	N/A
Input parameter 1	V1 : vector measured in the inertial reference frame.
Input parameter 2	q : quaternion attitude of body with respect to the inertial reference frame. Input in the quaternion here that you receive from the attitude sensor.
Output parameter	V2 : vector measured in the body reference frame.
Return value	None
Required preconditions	None
Called functions	None

Example:

```
/* Compute the body acceleration without gravity */
float accel_body[3];     /* Accel in body frame */
float gravityB[3];       /* Gravity in body frame */
float q[4];              /* Quaternion */

float gravityI[3] = {0,0,-VN_G}; /* Gravity acceleration in inertial frame */

VN100_SPI_GetQuatAcc(0, q, accel_body); /* Get quat and measured accel in
body reference frame */

VN_Inertial2Body(gravity, q, gravityB); /* Convert gravity into body frame */

VN_vecSub(accel_body, gravityB, 3, accel_body); /* Remove gravity in body
frame */

/* Now accel_body is the actual acceleration measured in the body reference
frame.  The acceleration measured by the accelerometers is the actual
acceleration plus the "measured" acceleration due to gravity. */
```

7 Revision history

Table 99. Revision history

Date	Revision	Changes
Oct-06-2009	1	Initial release.