Time Synchronization

Correlating VectorNav Measurements with External Systems

Application Note

Purpose

This application note provides an overview of the timing of the VectorNav inertial navigation systems and various approaches for synchronization with external sensing or control systems.

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Author	Jeremy Davis

VectorNav Technical Documentation

In addition to our product-specific technical data sheets, the following manuals are available to assist VectorNav customers in product design and development.

- **User Manuals** The user manual provides a high-level overview of product specific information for each of our inertial sensors. Further detailed information regarding hardware integration and application specific use can be found in the separate documentation listed below.
- **Hardware Integration Manuals** This manual provides hardware design instructions and recommendations on how to integrate our inertial sensors into your product.
- **Application Notes** This set of documents provides a more detailed overview of how to utilize many different features and capabilities offered by our products, designed to enhance performance and usability in a wide range of application-specific scenarios.

Document Symbols

The following symbols are used to highlight important information within the document:

i	The information symbol points to important information with the document.

!	The warning symbol points to crucial information or actions that should be followed to avoid reduced performance or damage to the navigation module.

Technical Support

Our website provides a large repository of technical information regarding our navigation sensors. A list of the available documents can be found at the following address:

http://www.vectornav.com/support

If you have technical problems or cannot find the information that you need in the provided documents, please contact our support team by email or phone. Our engineering team is committed to providing the required support necessary to ensure that you are successful with the design, integration, and operation of our embedded navigation sensors.

Email: support@vectornav.com Phone: +1.512.772.3615

1 Introduction

This application note provides the information necessary to synchronize a VectorNav inertial navigation systems (INS) to an external system, including system latencies, synchronization signal inputs and outputs, and timestamping capabilities. Section 2 provides an overview of the various timing events and processing steps. Section 3 provides an overview of the various timestamps and signal lines available for time synchronization purposes. Finally, Section 4 provides a review of the most common methods for time synchronization using VectorNav products.

2 System Timing

Figure 1 provides a diagram of the various events that occur on the INS and the processing steps that occur in between, which is referenced throughout this document to describe various latencies, timestamps, and synchronization signals. Table 2 provides the latencies involved with the various steps, broken down into three stages that directly impact time synchronization. The timing provided here results from testing performed using firmware versions listed under Table 1. Timing may vary from the values listed depending on firmware version and user settings.

Table 1: Hardware and firmware tested.

Series	Part Number	Hardware	Firmware
	VN-100	7	2.1.0.0
Industrial	VN-200	2	1.0.1.0
	VN-300	2	0.5.0.1
	VN-110	1	2.1.3.1
Tactical	VN-210	1	1.2.0.0
	VN-310	1	0.5.2.0

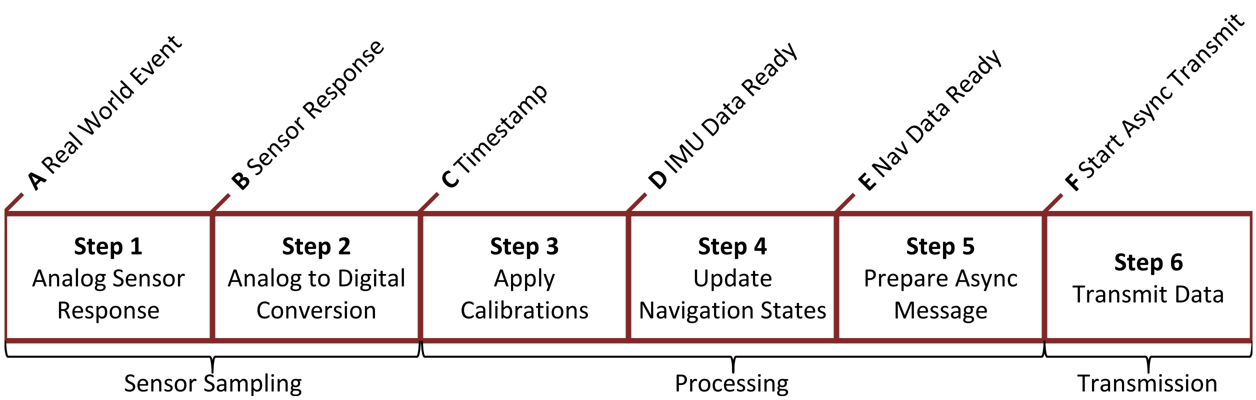

Figure 1: Timing diagram.

3 Timestamps & Synchronization Signals

The VectorNav inertial navigation systems (INS) provide two synchronization lines, SyncIn and SyncOut, and a variety of timestamps that can be used for time synchronization across devices. This section provides an overview of the functionality of each signal line; see the User Manual for specific configuration commands. The following discussion references the events diagrammed in Figure 1.

3.1 SyncIn

The SyncIn line is a 5V-tolerant input that can be configured for either rising or falling edge detection polarity. SyncIn events can also be specified to occur at some multiple of the input triggers, such that a high-frequency input signal

Table 2: Timing breakdown.

Step	Name	Duration	Notes
1-2	Sensor Sampling	1.75–2.75* ms	Includes analog sensor response and analog to digital conversion. Accelerometer sampling takes an additional 0.875 ms. The low-pass FIR filter specified by Register 85 effectively increases this delay by a fixed amount given by: $\delta = \frac{\text{WindowSize}-1}{2\times\text{ImuRate}}$ See User Manual for definition of ImuRate and WindowSize.
3-5	Processing	*Industrial* 1.1–1.7* ms *Tactical* 0.8–1.4 ms	Both factory and user calibrations are applied, navigation states are updated, and asynchronous messages are prepared. Typical spec for factory default configuration – depends on user setup (including configured messages, SPI, etc).
6	Transmission	Varies	Depends on baud rate and message length - see Tables 3-6 for a comparison of some common messages in both standard ASCII form and their binary equivalent at various baud rates.

**For VN-300, add an additional 0.5 ms*

Table 3: Yaw-Pitch-Roll (VNYPR) Transmission Times

Format	9600 baud	115200 baud	921600 baud
ASCII	39.6 ms	3.3 ms	0.41 ms
Binary	18.8 ms	1.6 ms	0.20 ms

Table 4: Yaw-Pitch-Roll, Magnetic, Acceleration, and Angular Rates (VNYMR) Transmission Times

Format	9600 baud	115200 baud	921600 baud
ASCII	127.1 ms	10.6 ms	1.3 ms
Binary	58.3 ms	4.9 ms	0.61 ms

Table 5: IMU Measurements (VNIMU) Transmission Times

Format	9600 baud	115200 baud	921600 baud
ASCII	114.6 ms	9.5 ms	1.2 ms
Binary	52.1 ms	4.3 ms	0.54 ms

Table 6: INS Solution - LLA (VNINS) Transmission Times

Format	9600 baud	115200 baud	921600 baud
ASCII	148.0 ms	12.3 ms	1.5 ms
Binary	93.8 ms	7.8 ms	0.98 ms

can be provided that is decimated down to the desired rate (eg. providing a 10 kHz signal that the INS responds to only every 100 triggers to yield a 100 Hz response). At every SyncIn event, a SyncIn timer is reset and a counter is incremented. Both the time since last SyncIn and the SyncIn count can be appended to any asynchronous output message. There are also two additional actions INS can be configured to take in response to a SyncIn event:

Event (C) Timestamp Initiate the processing of an IMU sample.

Event (F) Start Async Transmit Output the most recently available asynchronous message.

3.2 SyncOut

The SyncOut line is an output line that the user can configure for either positive or negative polarity and for pulse duration. As with the SyncIn line, the SyncOut line can be set to ouptut a trigger at some multiple of the internally defined SyncOut events (eg. outputting a 10 Hz signal based on the internal 800 Hz IMU sampling). A counter of the number of SyncOut triggers can be appended to asynchronous messages or read directly. There are three different events that can be defined for the SyncOut:

Event (C) Timestamp Start of processing an IMU sample.

Event (D) IMU Data Ready IMU measurements calibrated and available.

Event (E) Navigation Data Ready Navigation state processing complete and navigation measurements available.

Typically the two data-ready events are only of interest for initiating a SPI transaction to request the data and are not used when communicating over RS-232 or TTL serial ports.

On GPS-enabled products, the SyncOut line can also be configured to relay the PPS signal from the GPS, though the PPS signal is also available via dedicated PPS pin. There are three critical differences between these two PPS signal methods:

1. The dedicated PPS output is fixed to positive polarity and 1 Hz output whereas the SyncOut signal can have polarity flipped and output at a lower rate.
2. The SyncOut signal is delayed 10-20 microseconds whereas the dedicated PPS line has a time uncertainty of only 90 nanoseconds.
3. The dedicated PPS output provides a signal regardless of GPS fix whereas the SyncOut signal will only trigger if a 3D GPS fix is present.

3.3 Timestamps

There are several timestamps that can be appended to various output messages from the INS.

1. *TimeStartup* Time since system start-up.
2. *TimeSyncIn* Time since last SyncIn pulse.
3. *TimeGPS and TimeGPSPPS* On GPS-enabled products, both absolute GPS time and time since last GPS PPS are available.

4 Synchronization Approaches

This section describes the three most common approaches for synchronizing a VectorNav INS with an external system. Each has its own advantages and disadvantages and the choice typically depends on the capability of the external system to timestamp data and generate or receive synchronization signals. Please contact VectorNav for additional support if the proper synchronization approach for your particular application is unclear.

4.1 SyncIn Timestamps

When synchronizing multiple systems, it is often useful to have a single device providing a synchronization signal that all other devices use for timestamping. In this setup, that signal is sent into the SyncIn line and the TimeSyncIn timestamp is appended to any measurements output from the INS. Similar timestamping on the other sensing or control systems allows for interpolation to a common time basis. On GPS-enabled units, appending the GPS timestamp allows for easy synchronization to other GPS-enabled systems without the need for a separate synchronization signal on SyncIn.

4.2 SyncOut Trigger

In some cases, it is desirable to have the INS provide the synchronization signal, allowing an external system to be triggered by the INS (either for timestamping or to trigger a measurement). Typically this is done by configuring SyncOut to trigger on the start of processing an IMU sample, which corresponds to the timestamp event on the INS. Care must be taken to associate the correct output from the INS with the correct SyncOut trigger, something that can be aided by appending the SyncOut counter to the output message. On GPS-enabled products, this synchronization signal can be generated by the PPS, either on the SyncOut line or the dedicated PPS pin as discussed earlier.

4.3 SyncIn Trigger

Finally, it is possible to configure the INS to initiate sample processing by triggering the SyncIn line directly. While this can certainly be effective, great care must be taken in such a setup as the entire INS system will operate off the SyncIn triggers, so signals that are too fast, too slow, or unreliable can cause the unit to operate inconsistently and sometimes lock up altogether. The minimum SyncIn event rate is 200 Hz, with a maximum of the default ImuRate (see User Manual for default specification).