Application Note

External Oscillator and Time Transfer on OEM729 Receivers

HEXAGON AUTONOMOUS SOLUTIONS DIVISION

PROPRIETARY DATA

Contents

Introduction

NovAtel receivers are high performance GPS receivers utilising C/A code and carrier phase tracking. Our patented C/A code Narrow Correlator tracking technology achieves pseudo-range accuracy of near P-code performance while providing improved resistance against errors introduced by multipath signals. NovAtel receivers achieve this performance using a standard off-the-shelf TCXO master oscillator. Even further improvement on accuracy and frequency stability can be achieved with the use of atomic clocks (rubidium or cesium).

Receiver time, GPS time and 1PPS

NovAtel OEM receivers use the on-board Voltage Controlled Temperature Compensated Crystal Oscillator (VCTCXO) for the internal clock and timing signal. After startup and before tracking any satellites (i.e. decoding subframe), the receiver time status is set to UNKNOWN and reported time starts with GPS reference week 0 and time 0.0.

Once a GPS L1 C/A subframe (ephemeris) is decoded, the receiver will know the GPS reference time within ± 10 milliseconds. At this point, the receiver time status is set to “COARSE”. Once the position and time is known (from tracking 4 or more satellites), the receiver computes the GPS reference time and the associated receiver clock offset (i.e. from range bias) to within 5 ns. At this point, the receiver time status is set to “FINE”.

The local oscillator will drift with respect to the GPS reference time and thus diverge. The user can control the local clock steering using the CLOCKADJUST command.

If CLOCKADJUST is enabled (factory default), the receiver time is continually adjusted (steered) to be closer to the GPS reference time and the corresponding time status is set to “FINESTEERING”.

For example, the following logs show the “Time Status” in the log header progress from UNKNOWN time status while the receiver is tracking no satellites to FINESTEERING status when it tracks more than 4 satellites:

```
[COM1]<TIME COM1 0 91.0 UNKNOWN 0 36.000 024c0008 9924 13898
<     INVALID 0.000000000 0.000333564 0.00000000000 0 0 0 0 0 0 INVALID
[COM1]<TIME COM1 0 90.5 COARSESTEERING 1908 256003.000 02400008 9924 13898
<     ITERATING -0.003977254 4.160362378e-09 -16.99999999707 2016 8 2 23 6 25996
VALID
[COM1]<TIME COM1 0 89.5 FINESTEERING 1908 256004.000 02400008 9924 13898
<     ITERATING -0.003977259 3.405369411e-09 -16.99999999707 2016 8 2 23 6 26996
VALID
```

The receiver clock offset, and thus the offset of 1PPS to the GPS system time is provided as part of TIME log (Field#3 offset) in seconds. For example:

```
[COM1]<TIME COM1 0 90.5 FINESTEERING 1905 426887.000 02000020 9924 13898
<     VALID -3.183715587e-09 1.063155656e-09 -17.00000000000 2016 7 14 22 34
30000 VALID
```

CLOCKADJUST and external clock

With internal clock and CLOCKADJUST enabled, the receiver continuously computes the clock offset with respect to GPS time and corrects it to synchronise closely to the GPS time. This appears as “FINESTEERING” in the header time status. If the clock adjust is disabled, the receiver will reach “FINE” time status but will not continuously synchronise the receiver clock to that of the GPS time. However, it will adjust the time (jump) to within 1 µs, if the range bias (i.e. clock offset) exceeds ±250ms.

The 1PPS strobe output is a pulse generated by the hardware and is aligned to the receiver time and thus can drift with respect to the GPS system time. With CLOCKADJUST enabled, the receiver continuously adjusts the phase of the receiver clock and thus maintains the 1PPS as close as it can be to the GPS system time. The NovAtel specification for the 1PPS alignment to GPS system time is 50 nanoseconds, but with “FINESTEERING”, the 1PPS is maintained within 5 ns of the GPS system time.

The 1PPS offset to the GPS system time can be compensated externally using the “offset” value from the TIME log or internally adjusted using the CLOCKOFFSET command.

The OEM729 has an external oscillator (external clock) input, the internal 100 MHz PLL locks onto an external frequency source. The EXTERNALCLOCK command allows the receiver to use the external frequency source instead of the on-board VCTCXO. For example, the following command configures the receiver to use the external clock which int this example is a 10 MHz rubidium clock type.

```
EXTERNALCLOCK Rubidium 10MHZ
```

Care must be taken to ensure that the external clock input meets the receiver specifications. When an external clock is used and the user opts to disable clock adjustments, the "CLOCKADJUST DISABLE" command should be issued *prior to* issuing the external clock command.

```
CLOCKADJUST DISABLE
[COM1]<TIME COM1 0 89.5 FINE 1908 257673.000 02a00008 9924 13898
<     VALID 6.767703393e-08 9.315762033e-10 -16.99999999706 2016 8 2 23 34 16000
VALID
```

The CLOCKADJUST and EXTERNALCLOCK commands allow the receiver to use an external frequency source (frequency standard) and to synchronise with external time base.

Time transfer

OEM7 receivers perform time transfer from a primary to a secondary receiver by way of tracking one (transferring coarse time) or more satellites (transferring fine time) on the primary receiver. NovAtel receivers support various modes for time transfer. These include:

- Transferring coarse time (< 10 ms) from a primary receiver to a cold secondary receiver (no signal tracking).
- Transferring fine time (< 50 ns) from a primary receiver to a cold secondary receiver (no signal tracking).
- Transferring fine time (< 50 ns) from a primary receiver to a warm secondary receiver (signal tracking).

In all the above time transfer cases, the primary and secondary receivers are based on a common external frequency source in a typical use case.

The time transfer is accomplished using the ADJUST1PPS command and TIMESYNC log. Note that the secondary receiver can be synchronised to external 1PPS in a *once* or *continuous* fashion. For example:

```
ADJUST1PPS MARK ONCE
ADJUST1PPS MARK CONTINUOUS
```

If configured with the *continuous* period, the receiver time is continuously monitored, and the receiver clock is corrected if an offset of more than 50 ns is detected. Similarly, if the TIMESYNC log is provided to the receiver and using **ADJUST1PPS MARKWITHTIME** on the secondary receiver, the ADJUST1PPS can also set the receiver TOW, Week number and the time status to that of the primary receiver.

The following details the commands and the associated logs and outputs that can be used to verify the time transfer from a primary GPS receiver (with fine time) to a secondary GPS receiver (with coarse time). Figure 1 summarises the test setup used for synchronising a primary and secondary OEM729 receiver.

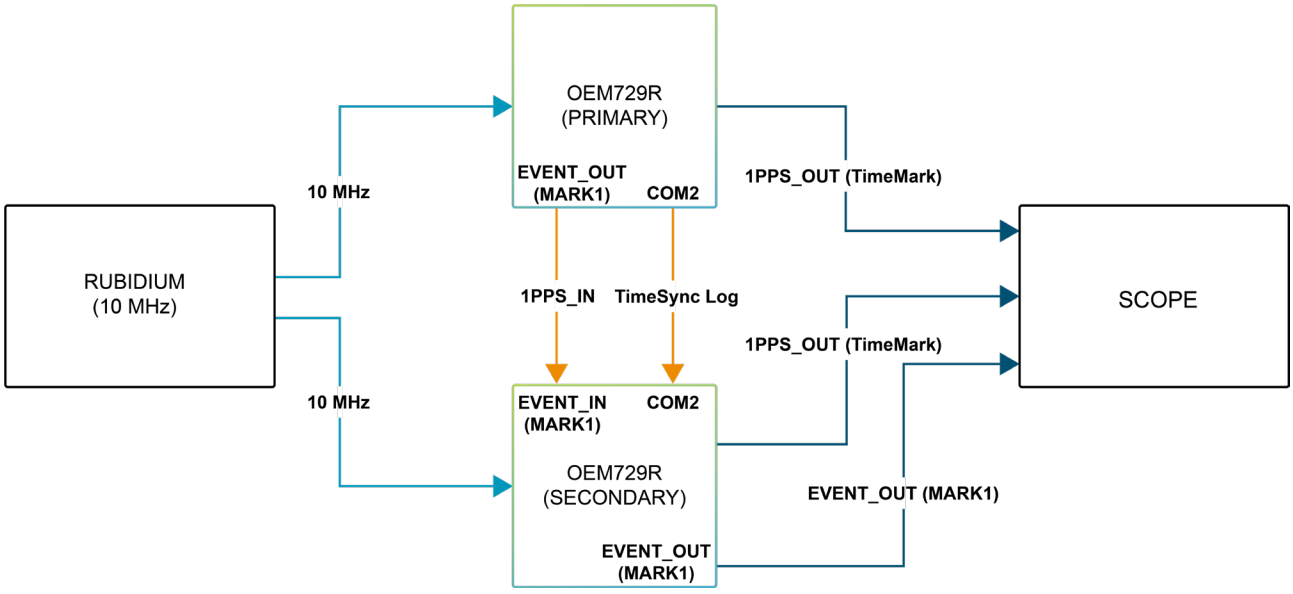

Figure 1: Block diagram showing the test setup for timing synchronisation between primary and secondary OEM729 GPS receiver

Both primary and secondary receivers were configured as follows:

```
CLOCKADJUST DISABLE
EXTERNALCLOCK RUBIDIUM 10MHZ
PPSCONTROL ENABLE POSITIVE 1.0 1000
EVENTOUTCONTROL MARK1 ENABLE POSITIVE 1000000 999000000
```
– only needed on the secondary receiver if the oscilloscope is being used for testing verification
```
INTERFACEMODE COM2 NOVATEL NOVATEL OFF
```

At the primary receiver:

```
LOG COM2 TIMESYNCA ONTIME 1
```

At the secondary receiver:

```
EVENTINCONTROL MARK1 EVENT POSITIVE 0 4
LOG MARK1TIMEA ONNEW
ADJUST1PPS MARKWITHTIME CONTINUOUS
```

Figure 1 shows the 1PPS Out and the External Event out for the secondary receiver that is in COARSE time, and the 1PPS Out (Time Mark) of the primary receiver.

Note that the 1PPS was obtained via external EVENT_OUT on the primary receiver, and was used as 1PPS Input for the secondary receiver via external EVENT_IN. The primary receiver was in FINE time, whereas the secondary was in COARSE time. The TIMESYNC log was requested on COM2 of the primary receiver and was provided to the COM2 of secondary receiver.

As the time status was COARSE (clock offset was not resolved), the 1PPS Out and the external EVENT_OUT for the secondary receiver were accurate to GPS time within 10 ms. After the ADJUST1PPS MARKWITHTIME was issued to the secondary receiver, its time status transitioned from COARSE to FINE, as shown below by the MARKTIME logs below.

```
[COM1]<MARK1TIMEA COM1 0 96.0 COARSE 1908 258458.002 02ec0008 292e 13898
<     1908 258458.002278320 0.000000000 0.000333564 -16.999999997 INVALID
```

After the secondary receiver accepted the ADJUST1PPS command, the time status changed as follows:

```
[COM1]<MARK1TIMEA COM1 0 95.5 FINE 1908 258459.000 02e80008 292e 13898
<     1908 258459.000000020 0.000000000 0.000333564 -16.999999997 INVALID
```

The 1PPS Out and the External Event out of the secondary receiver concurrently aligned with the 1PPS Input derived from the primary receiver and the 1PPS alignment is within a few nanoseconds. This is expected as the two receivers are locked on to the same external frequency standard with similar cable length. Note that both receivers can only be locked with a minimum resolution of 10 ns.

Commands and logs

Table 1: Relevant commands and logs

Command/Log	Description
PPSCONTROL	Command that allows configuring of the 1PPS OUT signal properties. The 1PPS will always be aligned to either GPS time or to an external 1PPS event in.
EVENTOUTCONTROL	Command that allows configuring the event-out triggers.
EVENTINCONTROL	Command that allows configuring the event-in triggers.
ADJUST1PPS	Command that allows adjusting of the 1PPS out, or for synchronising to external 1PPS or primary receiver time.
CLOCKADJUST	Command that enables (default) or disables whether the receiver clock is to be adjusted to be aligned with GPS reference time.
EXTERNALCLOCK	Command that is used to configure the receiver to use an external frequency standard.
CLOCKOFFSET	Command that is used to adjust/compensate the delay in the 1PPS Out.
MARK1TIME[1]	Log that provides the receiver time in GPS weeks and seconds when the MARK1 input edge was detected
TIME	Log that provides precise information related to receiver clock/1PPS OUT offset, associated drift (when clock adjust is disabled) to GPS time, UTC time and offset.
TIMESYNC	Log that is used for synchronising the time from the primary to secondary receiver. Should be logged by the primary and provided to the secondary (via COM).

Additional information can be found within the OEM7 Documentation Portal.

[1] The MARKTIME log (message ID 231) has been deprecated and replaced by MARK1TIME (message ID 1130).

Support

To help answer questions and/or diagnose any technical issues that may occur, the NovAtel Support website is a first resource.

Remaining questions or issues, including requests for test subscriptions or activation resends, can be directed to NovAtel Support.

Before contacting Support, it is helpful to collect data from the receiver to help investigate and diagnose any performance-related issues. A list of appropriate troubleshooting logs can be found on the OEM7 Documentation Portal (the LOG command with the recommended trigger and data rate is included with each log).

The data can also be collected using NovAtel Application Suite.

Documentation

For any questions on logs and commands, please visit the OEM7 Documentation Portal.