APN-002

External Oscillator and Time Transfer on OEM729 Receivers

Contents

Introduction

The NovAtel receivers are high performance GPS receivers utilizing 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. The NovAtel receivers are able to 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 aid 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 (ephmeris) 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 20 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, 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 transition of “Time Status” as it progresses from tracking no satellites to 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 1PPS to the GPS reference 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
[COM1]

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 synchronize closely to the GPS time. This would appear as "FINESTEERING". If the clock adjust is disabled, the receiver will reach "FINE" status but will not continuously synchronize 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 ±250 ms.

The 1PPS strobe output is a pulse generated by the hardware and is aligned to the receiver time and thus can also drift with respect to the GPS 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 reference time. The NovAtel specification for the 1PPS alignment to GPS reference time is 50 nanoseconds but with "FINESTEERING", the 1PPS is maintained within 20 ns of the GPS reference time.

The 1PPS offset to the GPS reference 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 input, where in the internal 100 MHz PLL locks on to an external frequency source. The EXTERNALCLOCK command allows the receiver to use the external frequency standard instead of the on-board VCTCXO. For example, the following command configures the receiver to use the external clock, which is a 10 MHz rubidium standard.

EXTERNALCLOCK Rubidium 10MHZ

Care must be taken that the clock input meets the receiver specifications. External clock can be used only with the CLOCKADJUST disabled. Hence, prior to issuing the external clock command, the CLOCKADJUST should be disabled.

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 the EXTERNALCLOCK command allows the receiver to use an external frequency standard and to synchronize with external time base (i.e. 1PPS In).

Time Transfer

GPS receivers indirectly perform time transfer by the way of tracking one (i.e. coarse time within 10 ms) or more satellites (fine time/fine steering). NovAtel receiver supports various time transfer modes.

These include:

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

In all the above cases, the primary and secondary GPS receivers are based on a common external frequency standard. The time transfer is essentially accomplished via the ADJUST1PPS command and TIMESYNC log. Note that the secondary receiver can be synchronized to external 1PPS once in continuous fashion.

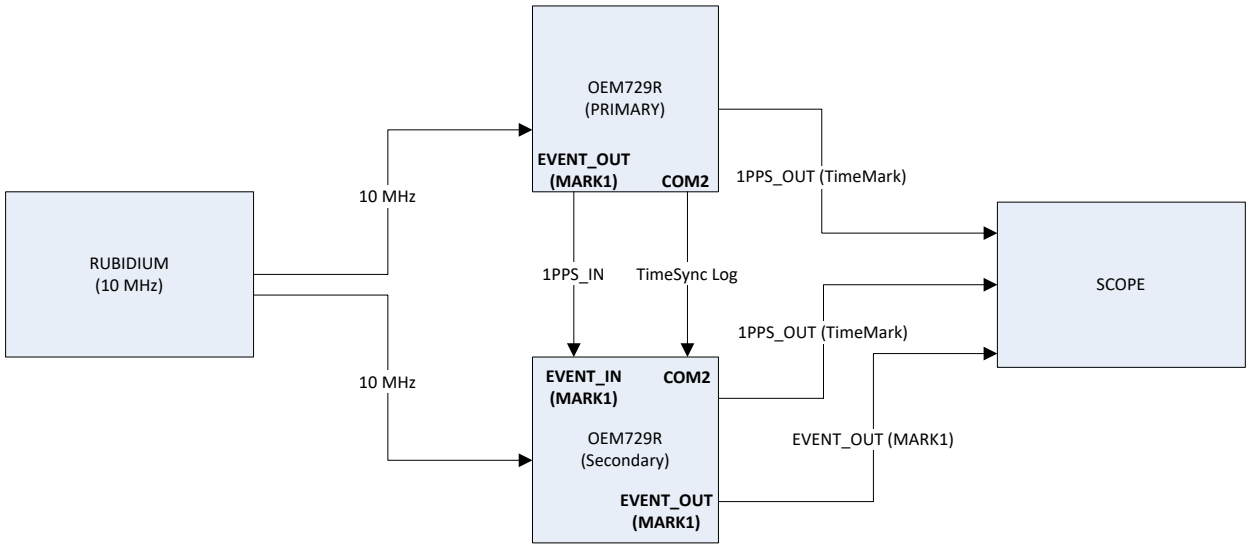
For example,

ADJUST1PPS MARK ONCE

ADJUST1PPS MARK CONTINUOUS

If configured continuous, the time is continuously monitored, and the receiver clock is corrected if an offset of more than 50 ns is detected. Similarly, the ADJUST1PPS can also set the receiver TOW, Week number and the time status to that of the primary receiver, if the TIMESYNC log is provided to the receiver and using ADJUST1PPS MARKWITHTIME on the secondary 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). The figure below shows the block diagram that summarizes the test setup used for synchronizing a primary and a secondary OEM729 receiver.



Block diagram showing the test setup for timing synchronization 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 MARKTIME ONNEW

ADJUST1PPS MARKWITHTIME CONTINUOUS

The preceding figure 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 FINE time, whereas the secondary was in COARSE time. TIMESYNC log was requested on COM2 of the primary and was provided to the COM2 of secondary receiver.

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

[COM1]<MARKTIME 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 follow:

[COM1]<MARKTIME 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

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 synchronizing 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
MARKTIME	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 synchronizing the time from the primary to secondary receiver. Should be logged by the primary and provided to the secondary (via COM)

Additional info can be found at:

https://docs.novatel.com/OEM7/Content/Operation/Transferring_Time_Receivers.htm