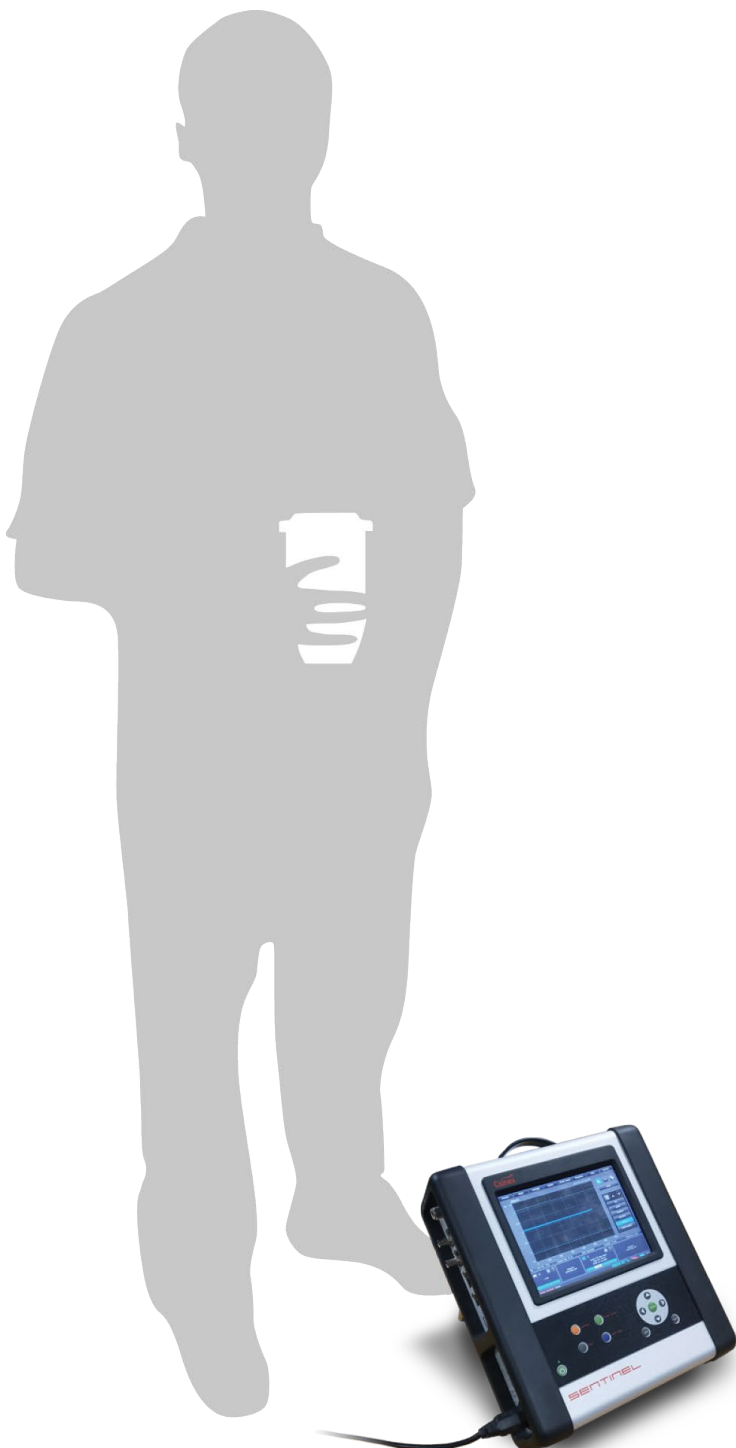


# Accurate 1PPS Measurements Using Sentinel

## Calnex Sentinel



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While frequency measurements using the Calnex Sentinel can be performed with a fairly straight forward test setup, time error measurements require consideration of the effects of delays introduced by differing cable lengths.

This document identifies the sources of measurement error and provides procedures to ensure that all measurement uncertainties introduced by the test environment are compensated for in the Sentinel settings, ensuring maximum accuracy in the test results.

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# 1 Introduction

The Calnex Sentinel provides the capability to measure both frequency and time error from a PTP Telecom Time Slave Clock (T-TSC) or a Telecom Boundary Clock (T-BC).

Time error measurements are performed by comparing the edges of the 1PPS output from the equipment under test to that of a reference 1PPS signal. The 1PPS reference can be a precision clock source or the 1PPS generated by Sentinel. The Sentinel 1PPS output is generated from an internal GNSS disciplined precision Rubidium oscillator.

While both frequency and time error measurement inaccuracies are affected by the accuracy of the reference used, time error is also affected by delays in the cables used to connect Sentinel to the equipment under test and also delays inherent in GNSS cabling and technology.

This document details how to quantify these inaccuracies and to compensate for them in the Sentinel measurement settings.

**NOTE:** Refers to firmware revision x.9.x.x

## 2 Field Test Setup

Figure 1 shows a typical setup for a 1PPS measurement in the field. A remote GNSS disciplined clock acts as a 1588v2 Grandmaster and sends PTP messages to allow the T-TSC / T-BC to recover the phase of the Grandmaster allowing a synchronised 1PPS output to be generated. The Sentinel reference can be provided from its internal Rubidium oscillator in holdover mode or disciplined to GNSS if an antenna is available.

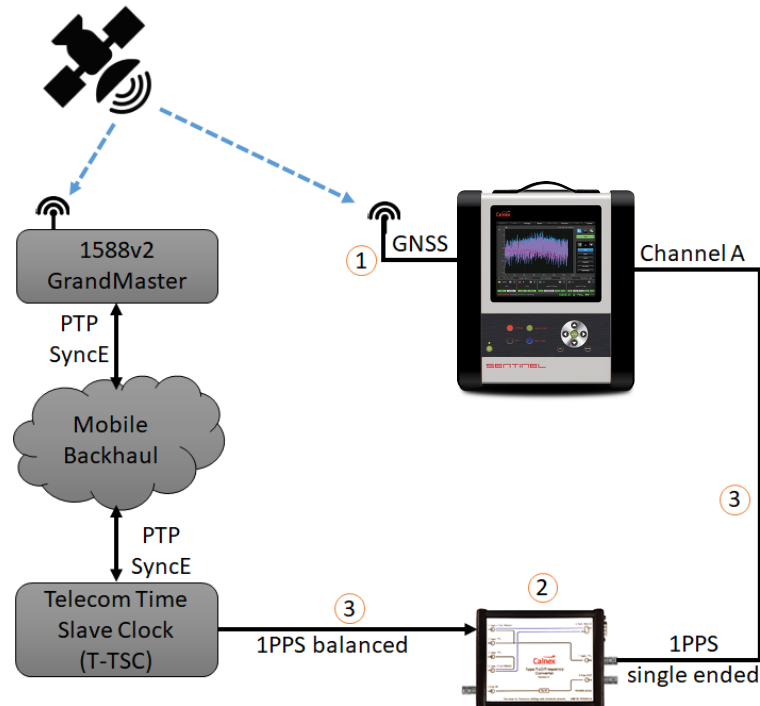


Figure 1 Typical 1PPS Test Setup

Time error delays can be introduced into the Sentinel measurement from the following sources:

1. GNSS cable delay
2. Balanced 1PPS to single ended conversion delay
3. 1PPS cable delay from the device under test

### 2.1 Cable Delays

Electrical cables will introduce a delay of 5ns per metre. Obviously using short cables will minimise this delay but this may not be possible when, for example, the GNSS antenna is on the roof of a building or the Sentinel cannot be located close to the T-TSC / T-BC under test.

### 2.2 Balanced to Single Ended Conversion Delay

The output of the 1PPS signal from the precision source or T-TSC can be either balanced or single ended of various amplitudes, for example, ITU-T G.703 defines the use of a RJ45 connector to carry 1PPS as a balanced RS422 output along with TOD time messages and this standard has been adopted on some T-TSCs.

Sentinel has a versatile measurement interface allowing selectable triggering on the positive or negative slopes of any input in the range of -5 to +5 Volts. As the measurement interface requires single ended inputs then the Calnex External 1PPS/ToD/Frequency Converter Accessory (Option 133) should be used to convert a balanced

1PPS RJ45 signal to a single ended BNC connection as shown in Figure 2. The T-TSC / T-BC 1PPS is connected to connector P1 and the converted output is connected from connector P7 to Sentinel. The Converter Accessory requires power either from a powered USB connection or from the external power supply provided.

This conversion is an active solution and the gate delay through the Converter Accessory will also add a fixed amount to the time error.

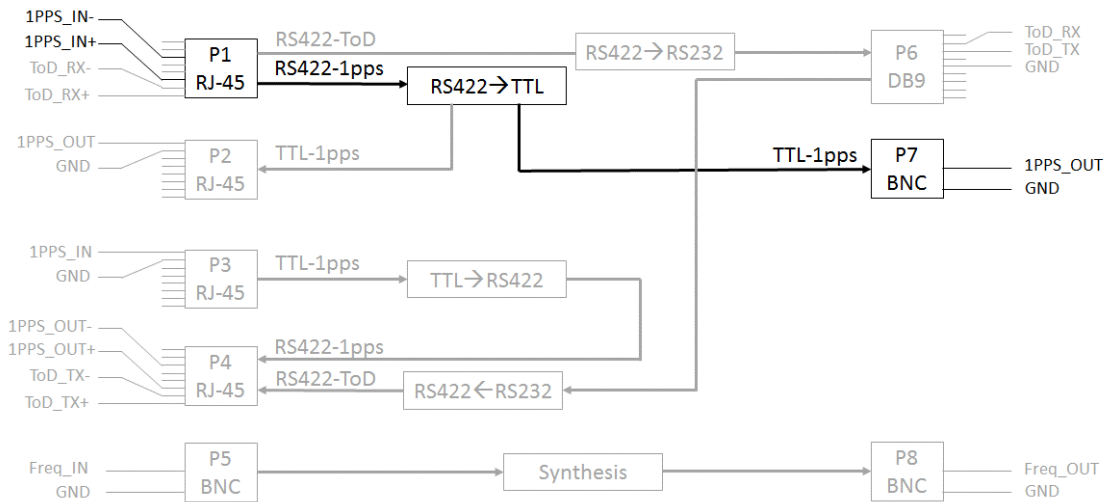


Figure 2. Converter Accessory Block Diagram

**NOTE:** Ensure that the Converter Accessory is Revision D or higher since functionality is different for previous revisions and will not work with Sentinel.

## 3 Sentinel Settings to remove Time Error Delays

### 3.1 GNSS Cable Delay

The antenna supplied with Sentinel has a 20m cable, which equates to a delay of 100ns.

Setting the Sentinel antenna delay **while GNSS is connected** could cause a step change in the 1PPS phase input to the internal Rubidium oscillator and will require the Sentinel to be re-disciplined for a period of 6 hours. To avoid this the following procedure should be followed.

#### STEP 1

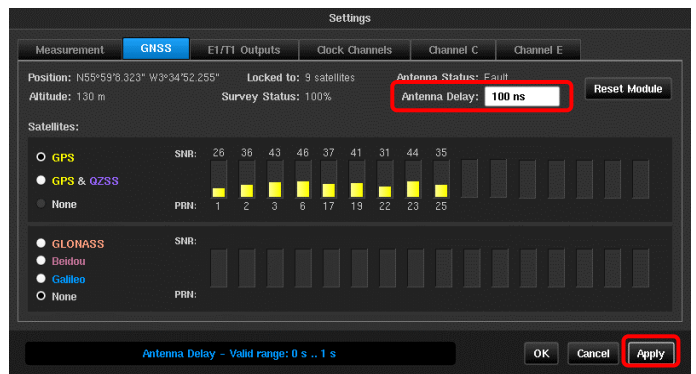
- In the **Settings > Measurement > Timebase** page set **Internal Reference Disciplining Mode** to **Never**
- Press **Apply**
- Connect the GNSS antenna to Sentinel.

**NOTE:** The Rubidium disciplining status will change to a green unlocked padlock.



#### STEP 2

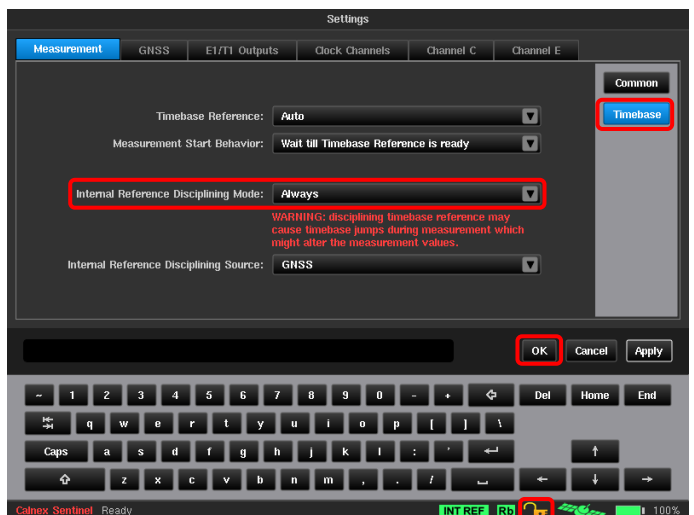
- Select the **GNSS** tab and enter the **Antenna Delay**
- Press **Apply**



#### STEP 3

- Wait 10 minutes.
- Go back to the **Settings > Measurement > Timebase** page and set **Internal Reference Disciplining Mode** to **Always** or **Not during measurement**
- Press **OK**

**NOTE:** The Rubidium disciplining icon will change to yellow.



#### STEP 4

- a. Wait 4 minutes.
- b. Measurements can begin when the GNSS icon is green and the Rubidium disciplining icon changes to a green locked padlock.



### 3.2 1PPS Cable Delay

Delay will be introduced by the cables that are used to connect the device under test to the Sentinel. Optionally an external 1PPS reference can be used rather than the Sentinel internal 1 PPS reference. In this case delay will be introduced to the reference input by the connecting cable. If the cables are the same length then the net delay will be zero. The cable delay values should be entered into the Sentinel settings as follows.

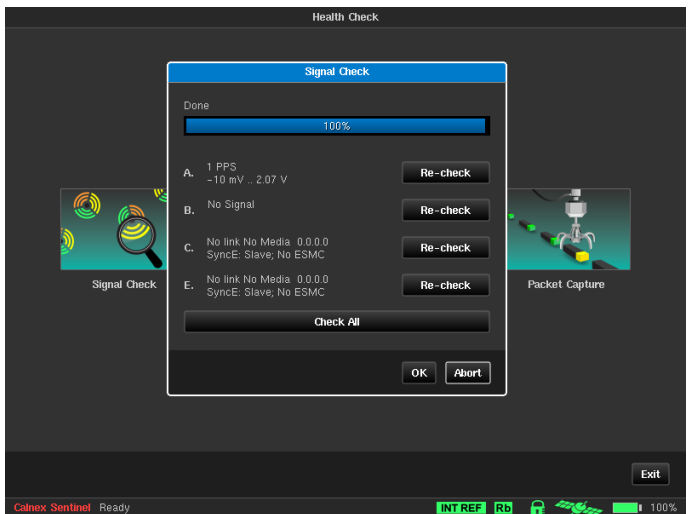
#### STEP 1

Press the **Health Check** tab on the main screen then the **Signal Check** button. This will automatically detect the 1PPS signals that are connected.

**NOTE:** If the signal check does not return a 1PPS signal type then check the following:

- a. Check all cables are connected correctly.
- b. Calnex recommends that 1PPS signals have the input filter enabled for the channel they are connected to. Check that the filter is ON in the **Settings > Measurement > Channels** page. (See **STEP 3**)

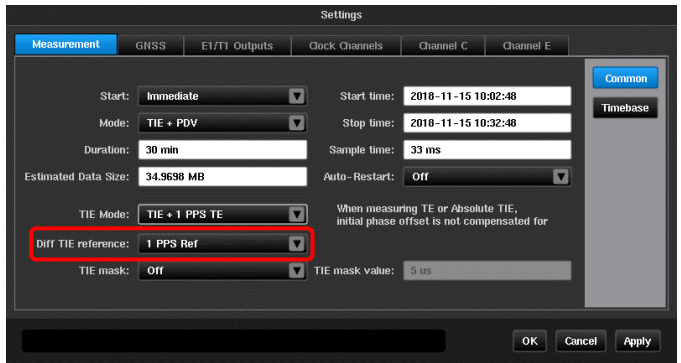
1PPS **Signal Type** can also be manually entered in the **Settings > Measurement > Channels** page.



## STEP 2

- Go to the **Settings > Measurement > Common** page.
- Ensure that **TIE Mode** on the is set to **TIE + 1PPS TE**
- Set the **Diff TIE Reference** to **1 PPS Ref** to select the internal 1 PPS as the measurement reference.

**NOTE:** If an external 1PPS is being used as a reference then the **DIFF TIE Reference** should be set to the channel that the reference is connected to.



## STEP 3

- Go to the **Settings > Clock Channels** page.
- Enter the cable delay associated with measured channel A in the **Cable comp.** field.
- Press **Apply**

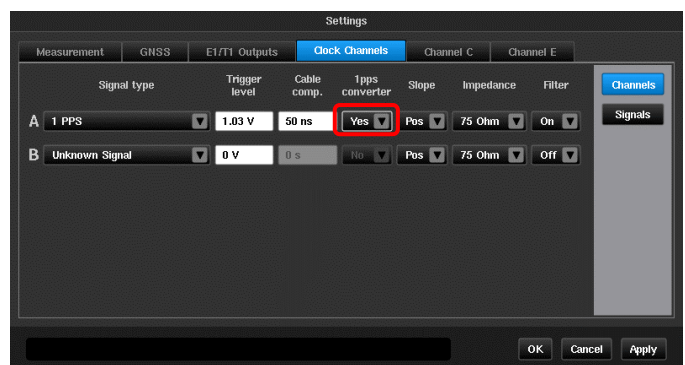
**NOTE:** If an external 1 PPS is being used as a reference then the cable delays associated with that connection should also be entered.



## 3.3 Converter Accessory Delay

Calnex has characterised the delay introduced by using the Converter Accessory to generate a single ended 1PPS output from the balanced 1PPS input. This delay has been coded into the Sentinel firmware and can be set as follows:

- Go to the **Settings > Measurement > Channels** page.
- Select **Yes** from the **1pps converter** drop down for the channel being converted.





## 4 Performing the 1PPS Time Error (TE) Measurement

The “Setting up a 1PPS Measurement” Getting Started Guide, available in the Calnex Solutions Technology Library at [www.calnexsol.com](http://www.calnexsol.com), details how to set up Sentinel to perform a 1PPS TE measurement.

Figure 3 shows the results of a 1PPS TE measurement without any delay compensation; Figure 4 shows the same measurement with a GNSS antenna delay of 100ns, a 1PPS cable compensation of 150ns and the Converter Accessory. The combined effect of applying all delays is a shift of 90 ns in the 1PPS TE result.

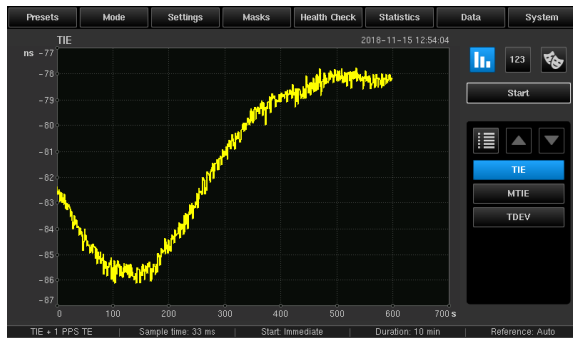


Figure 3. 1PPS TE without delay compensation

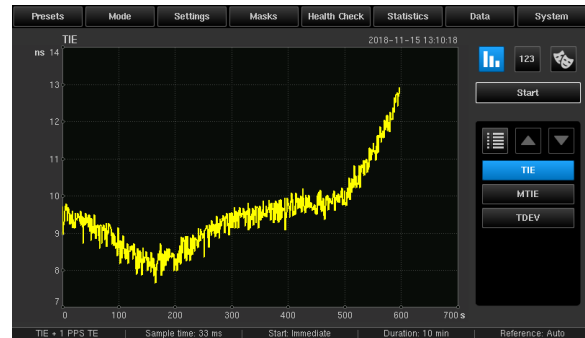


Figure 4. 1PPS TE with delay compensation

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