USING GPS RECEIVER 1PPS OUTPUT TO VERIFY TIME STAMP ACCURACY AND MEASURE PROPAGATION DELAY

Kevin Knudtson
Antonio Moreno

August 16, 2018
Agenda

• Introduction
• Purpose
• Test Cases
• Circuit Design
• Preliminary Test Results
• Chapter 10 Recorder Test Results
• Recommendations
• Questions?
Introduction

Measuring time stamp accuracy and signal propagation delay within telemetry/communication equipment can easily be done by overlaying a very precise 1 Pulse/Second (1PPS) time signal output from a GPS receiver into a standard PCM telemetry data stream. Overlaying this 1PPS signal into a telemetry PCM data stream provided an easy highly accurate method to measure time stamp accuracy and propagation delay on telemetry data processing and communication equipment.
Purpose

• Create a unique test signal to validate vendor’s claim of better than 1µs time stamp accuracy on their Chapter 10 recorder

• Build a Pulse Overlay Circuit to overlay a GPS receiver very accurate 1PPS output signal into a standard telemetry PCM data stream to measure time stamp accuracy and propagation delay on telemetry data processing and communication systems
Test Cases

1. Measure time stamp offset using the unique overlaid 1PPS signal data pattern
   - Chapter 10 recording, with/without 1PPS connected to recorder.
     » Vendor reports accuracy to be better than 10 µs without 1PPS and better than 1 µs with 1PPS
   - Processed telemetry data real-time and archive

2. Measure signal latency
   - OC-3 multiplexer/demultiplexer
   - Bit synchronizers
   - Analog video modems
Circuit Design
This presentation used a simple logic “OR” gate to overlay a 1PPS variable pulse width (VPW) signal into a telemetry PCM data stream. A one shot multivibrator circuit provides an adjustable pulse width for the 1PPS from ~10 µs -110 µs, while only adding a maximum 32 ns delay. The 1PPS VPW is overlaid on the PCM data stream by the OR gate.

Note: The GPS receiver 1PPS has a 20 µs pulse width with leading edge ±30 ns RMS & 100 ns peak offsets from true on the second.
Circuit Design
Measured latency of a 1 Mbps telemetry stream going through \( \sim 3296.412 \) meters of one way 62.5/125-\( \mu \)m multimode fiber transceiver lines (see next slide)

- \( \sim 34 \mu \text{s} \) latency round trip or \( \sim 17 \mu \text{s} \) one way
  - 11/03/14: One-way OTDR fiber link test read latency of 16.394 \( \mu \)s. Basic cable formula indicates latency to be 16.394643 \( \mu \)s.
    - \( \text{Pd} = 3296.412 \) meters \( \times 1.491 / (2.9979 \times 10^8) \) meters-second = 16.394643 \( \mu \)s (Pd = L*Ng/c).

- Pd: propagation delay in seconds
- L: length of fiber in meters
- Ng: fiber index of refraction
- c: speed of light in vacuum
Preliminary Test Results

![Graph showing test results]

- 1 MHz/2047 Return DATA
- 1 MHz/2047 Sent DATA
- 20 μs 1PPS

Parameters:
- Time: 34.00 μs
- Voltage: -360 mV
- Time: 0.000 s
- Voltage: -340 mV
- Δ Time: 34.00 μs
- Δ Voltage: 20.0 mV
Preliminary Test Results

Measured latency of 1Mbps data going through OC-3 mux/demux on transmission line of ~3411.9312 m. one way (see next slides for o-scope picture and test set up)
  • Average latency ~12.22 milliseconds (ms) (round trip)

Measured latency of 1 Mbps data going though range Bit Sync # 1 and Bit Sync # 2
  • BS # 1 average latency ~ 5 μs
  • BS # 2 average latency ~ 4 μs
Chapter 10 Recorder Test

Setup

* Test Setup: Without 1 PPS
With 1 PPS

DAU: Distribution Amplifier Unit
CH10 Recorder Test Results

Measured offset time stamp with merged 1PPS/PRN11 2.5 Mbps data being recorded onto CH10 Recorder WITHOUT 1 PPS connected recorder in packed mode

CH10 Time stamp offset ~6 to 8 µs.

<table>
<thead>
<tr>
<th>Bytes Offset Hex</th>
<th>Bits Offset</th>
<th>1st PCM Bit Time</th>
<th>1PPS Delta time (s)</th>
<th>1st 1PPS Bit Time</th>
<th>Time Off (us)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0A44</td>
<td>10</td>
<td>077:20:51:59.991612</td>
<td>0.0083816</td>
<td>077:20:51:59.9999936</td>
<td>6.40</td>
</tr>
<tr>
<td>0134</td>
<td>0</td>
<td>077:20:52:29.999038</td>
<td>0.0009536</td>
<td>077:20:52:29.9999916</td>
<td>8.40</td>
</tr>
<tr>
<td>12DF</td>
<td>0</td>
<td>077:20:52:58.984602</td>
<td>0.0153904</td>
<td>077:20:52:58.9999924</td>
<td>7.60</td>
</tr>
<tr>
<td>0C6F</td>
<td>3</td>
<td>077:20:53:57.989874</td>
<td>0.0101180</td>
<td>077:20:53:57.999992</td>
<td>8.00</td>
</tr>
<tr>
<td>0353</td>
<td>0</td>
<td>077:20:54:27.997302</td>
<td>0.0026912</td>
<td>077:20:54:27.9999932</td>
<td>6.80</td>
</tr>
<tr>
<td>1249</td>
<td>7</td>
<td>077:20:54:57.985078</td>
<td>0.0149132</td>
<td>077:20:54:57.9999912</td>
<td>8.80</td>
</tr>
<tr>
<td>020A</td>
<td>0</td>
<td>077:20:55:03.998354</td>
<td>0.0016384</td>
<td>077:20:55:03.9999924</td>
<td>7.60</td>
</tr>
<tr>
<td>0C60</td>
<td>5</td>
<td>077:20:56:28.989921</td>
<td>0.0100708</td>
<td>077:20:56:28.9999918</td>
<td>8.20</td>
</tr>
</tbody>
</table>

Average Time Offset 7.87
CH10 Recorder Without 1PPS Test Results PKS Mode

- Type Format: PKTM, 1
- Packing Format: PFS, PFS.

Legend:

- Channel 1: CH10 Recorder
- Channel 2: 1PPS Output
- Channel 3: Data merged with 20us 1PPS
- Channel 4: CH10 Recorder with 20us 1PPS
- Channel 5: CH10 Recorder without 1PPS Reference

- 10.0us
- 100MS/s
- 10k points

- Measurement:
  - Time: -7.50µs
  - Voltage: 100mV
  - Time: 22.0ns
  - Voltage: 6.90V
  - Time: Δ7.61µs
  - Voltage: Δ6.80V

- Date: 17 Mar 2016
- Time: 13:22:58
CH10 Recorder Test Results

Measured offset time stamp with merged 1PPS/PRN11 2.5 Mbps data being recorded onto CH10 Recorder WITH 1 PPS connected recorder in packed mode

CH10 Time stamp offset ~-0.6 to 1.0 µs.

<table>
<thead>
<tr>
<th>Bytes Offset Hex</th>
<th>Bits Offset</th>
<th>1st PCM Bit Time</th>
<th>1PPS Delta time (s)</th>
<th>1st 1PPS Bit Time</th>
<th>Time Off (us)</th>
</tr>
</thead>
<tbody>
<tr>
<td>08F3</td>
<td>6</td>
<td>077:20:42:57.992699</td>
<td>0.0073016</td>
<td>077:20:42:58.0000006</td>
<td>-0.60</td>
</tr>
<tr>
<td>0549</td>
<td>3</td>
<td>077:20:43:25.995701</td>
<td>0.0042988</td>
<td>077:20:43:25.9999998</td>
<td>0.20</td>
</tr>
<tr>
<td>1441</td>
<td>0</td>
<td>077:20:43:55.983476</td>
<td>0.0165232</td>
<td>077:20:43:55.9999992</td>
<td>0.80</td>
</tr>
<tr>
<td>00FB</td>
<td>0</td>
<td>077:20:44:11.999228</td>
<td>0.0007712</td>
<td>077:20:44:11.9999992</td>
<td>0.80</td>
</tr>
<tr>
<td>0B24</td>
<td>5</td>
<td>077:20:44:25.990904</td>
<td>0.0090964</td>
<td>077:20:44:26.0000004</td>
<td>-0.40</td>
</tr>
<tr>
<td>0D1D</td>
<td>4</td>
<td>077:20:44:55.989324</td>
<td>0.0106752</td>
<td>077:20:44:55.9999992</td>
<td>0.80</td>
</tr>
<tr>
<td>0400</td>
<td>7</td>
<td>077:20:45:25.996752</td>
<td>0.0032476</td>
<td>077:20:45:26.9999996</td>
<td>0.40</td>
</tr>
<tr>
<td>12F8</td>
<td>4</td>
<td>077:20:45:55.984528</td>
<td>0.015472</td>
<td>077:20:45:56.0000000</td>
<td>-0.00</td>
</tr>
<tr>
<td>14E6</td>
<td>1</td>
<td>077:20:46:25.982949</td>
<td>0.0170512</td>
<td>077:20:46:26.0000002</td>
<td>-0.20</td>
</tr>
<tr>
<td>0BC9</td>
<td>4</td>
<td>077:20:46:55.990375</td>
<td>0.009624</td>
<td>077:20:46:55.9999999</td>
<td>1.00</td>
</tr>
<tr>
<td>02B8</td>
<td>5</td>
<td>077:20:47:25.997803</td>
<td>0.0021972</td>
<td>077:20:47:26.0000002</td>
<td>-0.20</td>
</tr>
<tr>
<td>0759</td>
<td>4</td>
<td>077:20:47:54.994011</td>
<td>0.0059888</td>
<td>077:20:47:54.9999998</td>
<td>0.20</td>
</tr>
</tbody>
</table>
CH10 recorder With 1PPS Test
Results PKS Mode
Measured offset time stamp of 2.5 Mbps data being archived on Data Server

- Data Server archives ~180 µs -300 µs offset time stamp for 2.5 Mbps data.

<table>
<thead>
<tr>
<th>Offset Time Stamp</th>
<th>Slots #</th>
<th>Bit off</th>
<th>Updated second</th>
<th>Time offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>21:56:01.0002498</td>
<td>1850</td>
<td>8</td>
<td>1.0002498</td>
<td>-0.000250</td>
</tr>
<tr>
<td>21:56:02.0002206</td>
<td>481</td>
<td>2</td>
<td>2.0002206</td>
<td>-0.0002206</td>
</tr>
<tr>
<td>21:56:03.0002282</td>
<td>1159</td>
<td>1</td>
<td>3.0002282</td>
<td>-0.000228</td>
</tr>
<tr>
<td>21:56:04.0002492</td>
<td>1836</td>
<td>13</td>
<td>4.0002492</td>
<td>-0.0002492</td>
</tr>
<tr>
<td>21:56:05.0002218</td>
<td>467</td>
<td>10</td>
<td>5.0002218</td>
<td>-0.0002218</td>
</tr>
<tr>
<td>21:56:06.0002196</td>
<td>1145</td>
<td>6</td>
<td>6.0002196</td>
<td>-0.0002196</td>
</tr>
<tr>
<td>21:56:07.0002504</td>
<td>1823</td>
<td>2</td>
<td>7.0002504</td>
<td>-0.0002504</td>
</tr>
<tr>
<td>21:56:08.0002150</td>
<td>453</td>
<td>13</td>
<td>8.0002150</td>
<td>-0.000215</td>
</tr>
<tr>
<td>21:56:09.0002222</td>
<td>1131</td>
<td>3</td>
<td>9.0002222</td>
<td>-0.0002222</td>
</tr>
<tr>
<td>21:56:11.0002202</td>
<td>440</td>
<td>2</td>
<td>11.0002202</td>
<td>-0.0002202</td>
</tr>
</tbody>
</table>
The above image is a screen shot of the test 1PPS data pattern recorded with camera using IRIG-B time stamp. Camera time stamp is seen in left top corner of screen shot. Results show the viewable processed test 1PPS data pattern on the final Display Station System (DSS) delayed by ~28 ms. This offset varied between 20 ms to 80 ms.
This simple circuit validated vendor claims on time stamp accuracy and is an effective tool for accurately measuring signal propagation delay on telemetry and communication systems. This technique could be useful to other NASA centers or organizations using telemetry/communication systems.
Questions?