NIF Cross timing overview

NIF User Forum

September 18, 2017

Brad Golick
Cross Timing RI
Overview

- Integrated Timing System (ITS) overview
  - Hardware, software & archive

- Fidu
  - Hardware

- Diagnostic timing commissioning process
What is Integrated Timing System (ITS)

- ITS is a combination of hardware and software products which provides triggers for the entire NIF facility.

- ITS is a distributive system which originates in the NIF MOR and provides triggers to local zones in key locations in the facility such as MOR, Laser bays, Switchyards, OSB and Diagnostic mezzanines.

- Depending on shot type and instrument various software products provide input for trigger setup, including CMT/SST, AppMan, LoCos, LPOM & multiple ICCS products.
ITS Top Level View

The Facility Timing Transmitter sends the trigger message to the delay generators located in each timing zone. When a message is sent with a trigger key, the delay generated will start the process of issuing a trigger based on data from the FTT message.
ITS Zone Layout

Each zone is capable of supporting multiple delay generators (V880). A V880 has 8 individually programable outputs (electrical or optical).

Serial Data Stream

155.52MBS Biphased 1550nm

1x4 Splitter

Dual 1x8 Splitter

V800 8 Ch. Delay Gen.

Pulse Width 200ns
Wavelength 850nm
Rep. Rate (Hz) 0.2, 1, 10, 30, 60, 960
The arrival time of a hardware trigger at a diagnostic is determined by the values associated with several delay fields.
Trigger delay fields

- Each Zone has physical delay elements such as
  - Serial Data Stream Path (ITS Zone Delay)
  - Optical Fibers (ITS Cable Delay)
  - V880 Delay Generator (Intrinsic Delay)
  - Fiber path to custom locations (Client Cable Delay)
  - O/E Es to connect optical signals to electrical systems (Client Cable Delay)
  - Diagnostic internal trigger delays (Client Equipment Delay)
  - Detector distance from Target (Channel Offset) [Signal Path]
Example of how each timing field is populated.

<table>
<thead>
<tr>
<th>SHOT_ID</th>
<th>TAXON</th>
<th>ITS ZONE DELAY</th>
<th>ITS CABLE DELAY</th>
<th>ITS INTRINSIC DELAY</th>
<th>CHANNEL OFFSET DELAY</th>
<th>CLIENT DELAY</th>
<th>CLIENT CABLE DELAY</th>
<th>CLIENT EQUIPMENT DELAY</th>
<th>CLIENT LOCAL TO</th>
<th>CHANNEL DELAY SETTING</th>
<th>OFFSET CORRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>N170719-003-999</td>
<td>TIMING</td>
<td>TC090-078</td>
<td>DIM</td>
<td>TRIG3-HTRIG</td>
<td>948629</td>
<td>49596</td>
<td>96000</td>
<td>3087</td>
<td>3000</td>
<td>0</td>
<td>453283</td>
</tr>
</tbody>
</table>

Defined during commissioning.
Values entered in Timing Trigger fields have different effects to the actual trigger arrival time.

**Instrument Sweep Trigger**

If +10ns is added to **Client delay**, **Channel Offset** or **Offset Correction**, the signal will appear earlier in the record.

If +10ns is added to **Client cable** or **Client Equipment delay**, the signal will appear later in the record.
Trigger archive can be used for all commissioned diagnostics to review each trigger delay field.

NIFIT>Data Visualization>Launch QuickLooks>Database>Database Report>Timing Triggers

### TIMING_TRIGGERS

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Fidu System description

• Fiducials provide temporal relationships between time bases of different instruments in the facility.

• Fiducials appear on multiple diagnostics and provide a shot to shot reference.

• Fiducials are optical based timing markers which are injected on required diagnostics.

• The source Fidu signal is generated in the MOR and distributed to the laser bays, diagnostics mezzanines and target area.

• Three Fidu wavelengths are generated, $1\omega$ (1053nm), $2\omega$ (527 nm) & $4\omega$ (263 nm).
Top level Fidu $1\omega$ & $2\omega$ system

FIDU Amplification and Distribution

Diagnostic Building Rack DB:102

E/O mod has 2 triggers
Cross Timing new diagnostic commissioning

- IPRB requirements
- Collaborate with RI/RS for proper Timing & Fidu hardware interfaces
- Provide ICCS Software team Htrig taxon mapping to V880
- Procure hardware
- Update drawings
- Temporal measurements of cabling & infrastructure hardware
- Collect instrument delay, standoff distances and time of flight information
- Build Timing Diagram: compare predicted vs measured data
- Populate datasets, setpoints
- Update data based on post shot analysis
What is a timing diagram

- Purpose of a timing diagram to determine the necessary trigger delay settings needed for the physical signal to appear at the appropriate location on an instrument record.
  - In some instances it is also necessary to predict additional delay such that fidu can simultaneous appear in the record with the signal.

- All fibers, cables, o/e delays are measured for the Fidu, Trigger & signal path
  - Optical Time Domain reflectometer (fiber optic infrastructure)
  - Time Domain reflectometer (copper infrastructure)

- Signal time of flight is provided by the diagnostic RS/RI

- Instrument trigger & monitor delays are provided by instrument RS/RI
  - Measurements are provided with respect of temporal reference position
    - Streak camera reference- center of sweep
    - Gated imager- center of 1st strip

- Operations team will verify timing of an instrument with the Fidu to Monitor time.
  - Absolute arrival times of the fidu, monitor, and are useful during troubleshooting
Timing diagrams describe arrival times of signals at key locations in a diagnostic.
DIM 0,0 fidu & OTS monitor signal
(TDO software tool)

Fidu arrival time uses Midpoint analysis
Monitor arrival time is defined as the 50% of Leading edge
Timing of Diagnostics and Related Issues

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Shahab Khan
X-ray Diagnostic Campaign co-lead
X-ray Streak Camera Responsible Scientist
Shot RI’s must correctly set the timing of a suite of diagnostics in order to obtain the desired data

- X-ray Framing cameras (GXD, HGXD, DIXI) have the shortest time windows and are thus the most critical to timing errors

- Streak Cameras (SPIDER, DISC, VISAR) can be setup with larger measurement windows at the cost of temporal resolution

- The other diagnostics (GLEH, SPBT) that require timing input have their own setup guides and will not be discussed here
  — They are timed using NIF impulses on Timing shots
SPIDER* is used as the constant time reference for other diagnostic timing

- Facility experiments dedicated to timing are rare so we cross-time the framing cameras and DISC with SPIDER
- SPIDER uses the $4\omega$ fiducials generated at the MOR along with measured delay spools to determine its time base
- SPIDER/4$\omega$ fiducials are timed using Facility shots with a gold foil or gold coated sphere – Repeat shots show timing within 10ps

*Streaked Polar Instrumentation for Diagnosing Energetic Radiation
For more information see SPIDER setup guide obtainable through CMT
To time framing cameras, we cross-time implosion emission profiles with SPIDER’s signal

The problems with this method include the assumptions that the NSTEC* measured strip-strip timings are correct, droop correction is valid here, emission profile is Gaussian

The cross-timing values among a set of shots show a variation of ~75ps

*National Security Technology located in Livermore
Calibrates our gated cameras, streak cameras and others
Strip to strip timings and gate velocity measured at NSTEC using UV pulse

- Relative strip timing and strip velocities found by time-stepping the camera and measuring where the UV pulse is detected.
- Uncertainty in measurement arises from camera jitter, strip gain variations, UV vs X-ray gain difference.
- Only a subset of strip configurations are measured.
- One example: HGXD2F Observed delays with 0/250/500/750 settings 0/250/514/743@ 200V bias.
- HGXD6F not recommended to be operated at strip intervals below 250ps.

Check Framing camera guide or ask RS* if thinking of using an usual strip configuration.

*Responsible Scientist: Joe Holder
DISCs* also use shot data to cross time with SPIDER

- Self emission signal from 1D Radiography experiments are cross-timed to SPIDER’s measurement
- In rare occasions, timing shot impulses are used to time the instrument with
- Timing for other streak speeds and other DIM locations can be determined by adding offsets to a cross-timed configuration
- DIM timing deltas come from offsets tabulated for other DISC units or Framing camera units (some found with timing shots and cross timing)

*DIM Insertable/Imaging Streak Camera
DISC/SPIDER sweep windows calibrated at NSTEC using pulses with known time spacing

- Due to imaging system within streak cameras, there is some non-linear warping of the signal when it hits the imager
- A warp correction is generated to linearize the signal in space/time; warp correction also sets the sweep window
- Etalon with known spacing is used to create a train of pulses
- A spatial resolution mask is used to determine warping in space

Figure from: Silbernagel, C. et. al. Proceedings of SPIE Vol 5559, 2004
Instrument Jitter adds uncertainty to timing

- The sweep speeds and timing of streak cameras as well as the strip intervals and timing of gated cameras fluctuates shot to shot due to the inherent design as well as constantly changing physical conditions.

- Electronic jitter is adds an uncertainty to absolute timing of about 50ps.

- Using SPIDER’s 4w fidu, the range of measured sweep duration observed is about 4% from nominal; i.e. the 10ns sweep can actually be 9.8-10.2ns.
When we determine/adjust timing for a diagnostic we update two different datasets

- First dataset is the feedback monitor – This is a signal from the diagnostic which specifies when it actually triggered
  - Streak cameras: Trace of voltage across sweep plates
  - Gated cameras: Representation of gate pulse through each strip

- Second dataset is the Client Equipment Delay (part of ITS) which offsets when the instrument triggers relative to NIF time zero

- When Shot RI’s specify a time to trigger an instrument in CMT/SST, the actual time it fires is determined by ITS. However, the TDO’s can make adjustments during the shot based on when the feedback monitor signal is expected (dataset RS’s provide)
SPIDER is the time reference instrument on NIF for X-rays since it is the most accurate and repeatable diagnostic.

Both gated framing cameras and DISC use timing shots and implosion data cross-timed with SPIDER to determine their time base.

Gated camera strip intervals and Streak camera sweep speeds determined at NSTEC (SPIDER uses $4\omega$ 4idu for shot to shot sweep speed).

There is added uncertainty in timing due to electronic jitter.

Two quantities are updated when timing an instrument: Expected monitor time and Client Equipment Delay (affects trigger).
Au Sphere Timing shots can provide absolute timing as well as strip to strip intervals

We hit a Au coated sphere at many locations with 100ps pulses with known times

Plot of intensities of spot gives us independent timing of strips