Critical Design Review (CDR)
Of

ULTRA VIOLET IMAGING TELESCOPE (UVIT)

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Time Stamping

UVIT-CDR-00-07

Indian Institute of Astrophysics
Bangalore-560034

Time Stamping in UVIT

(UVIT-CDR-00-07; 06-Jun-2011b)

This document provides details about the time stamping scheme followed in the UVIT payload so that the data obtained during scientific observations using UVIT as well as its routine health monitoring can be correlated with absolute time. This is also important for the time correlation among co-observations between the different instruments on board the ASTROSAT spacecraft.

The spacecraft bus regularly provides a hardware pulse once every 1.024 seconds (of 64 milli-second duration) to all the payloads (hereafter PPS). The absolute times corresponding to each rising edge of the PPS are known independently.

Three internal clocks :

The entire hardware for each of the three channels of UVIT, viz., Far-UV (FUV), Near-UV (NUV) & Visible (VIS), are completely independent. This enables complete flexibility of operating, at any given time, only one channel of UVIT, or any two of the three channels of UVIT or all the three channels of UVIT. The UVIT has 3 independent internal crystal clocks (one each for FUV, NUV & VIS channels) whose readings have a least count of 1 milli-second. Stability of these clocks are ~25 ppm over the entire operational range of temperature (as well as including the aging effects). These 3 clocks are asynchronous (they drift relative to each other, in general).

Master clock :

Although each channel of UVIT has an independent clock, it is much simpler to have all 3 channels to follow a single clock. All 3 clocks are made available to each channel and choice of any one of these 3 clocks is available through command selection. Normally, clock of one particular channel is selected as the “master clock” for all the 3 channels. [This is not mandatory though.]

Time stamping in telemetry data (LBT) :

The regular monitoring of various house-keeping parameters of each channel of UVIT is carried out by the spacecraft's Bus Management Unit (BMU) using the 1553B protocol. The BMU requests for a telemetry frame and the UVIT's channel responds by providing the requested frame. There are 4 distinct telemetry frames : (i) Image parameters, (ii) Monitor-1 (voltages/ currents), (iii) Monitor-2 (temperatures) & (iv) Command acknowledgment frame, each consisting of 32 lines (each line in turn contains 16-bits of information). The 6 lines out of these 32, always contain time related information as described below.

Time of Response, data lines 2 and 3 :

These two 16-bit data words are the number of milliseconds since the timing master channel in the Detector Subsystem was turned on. It is latched at the beginning of the 1553B telemetry frame.

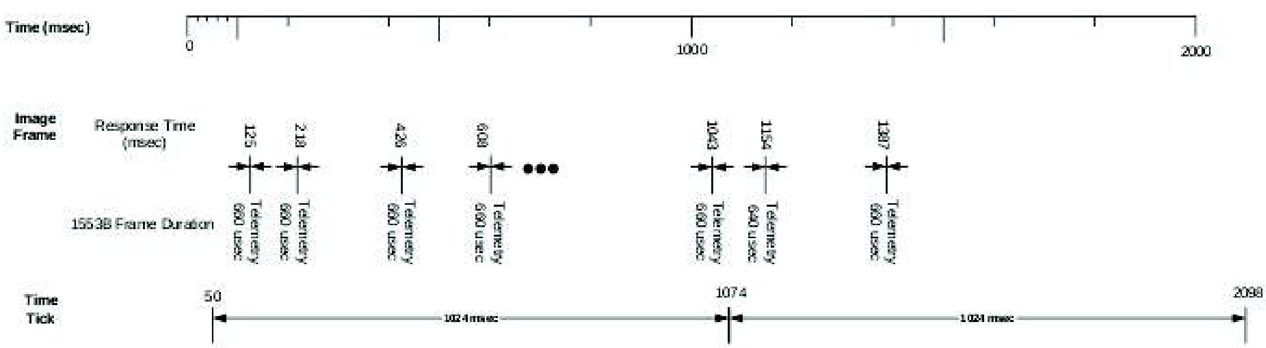
Time of Last Tick, data line 4 and 5 :

These two 16-bit data words are the time in milli-seconds from the selected master clock, when the rising edge of the spacecraft generated PPS (64-millisecond pulse, with a period of 1.024 seconds; hereafter “Time Tick”) was received. This is latched at the beginning of the 1553B telemetry frame.

Time Tick Count, data line 6 and 7 :

A running count of the number of 1.024-second Time Ticks received by the subsystem is indicated in these two 16-bit data words. Note that the three different channels, depending on when they were powered up [or RESET by command] could each have a different “Time Tick Count”. It is latched at the beginning of the 1553B telemetry frame.

Figure 1 below demonstrates the time stamping scheme of the LBT through an example.



Frame Type	Time of Response	Time of Last Tick	Tick Count
Telemetry	125	50	0
Telemetry	218	50	0
Telemetry	426	50	0
Telemetry	608	50	0
Telemetry	1043	50	0
Telemetry	1154	1074	1
Telemetry	1387	1074	1

Time stamping in Science data stream (via BDH) :

The science data stream from individual exposures of each channel of UVIT is passed on to the spacecraft's BDH system as a sequence of "segments" of a fixed size (2048 bytes). This is valid for both kinds of measurements – Photon Counting as well as Integration. Each of these "segments" contain time related information as a part of its header as described below.

Image Frame Time, Data Lines 7 and 8 :

These two 16-bit data words are the number of milliseconds since the timing master channel in the Detector Subsystem was turned on. It is latched into the first science data segment at the beginning of the Star250 image frame read (after the integration time). The entire Star250 image frame has the same time (i.e. all segments containing data from the same exposure, have identical time related information).

Time Tick, Data Lines 9 and 10 :

These two 16-bit data words are the time in milli-seconds from the selected master clock, when the rising edge of the spacecraft generated PPS (64-millisecond pulse, with a period of 1.024 seconds; "Time Tick") was received. It is latched into the first science data segment at the beginning of the Star250 image frame read (after the integration time). The entire Star250 image frame has the same time (i.e. all segments containing data from the same exposure, have identical time related information).

Tick Count, Data Lines 11 and 12 :

A running count of the number of 1.024-second Time Ticks received by the channel in question, is indicated in these two 16-bit data words. Note that the three different channels, depending on when they were powered up [or RESET by command] could each have a different values of the "Time Tick Count". It is latched into the first science data segment at the beginning of the Star250 image frame read (after the integration time). The entire Star250 image frame has the same time (i.e. all segments containing data from the same exposure, have identical time related information).

Figure 2 below demonstrates the time stamping scheme of the science stream data through an example.

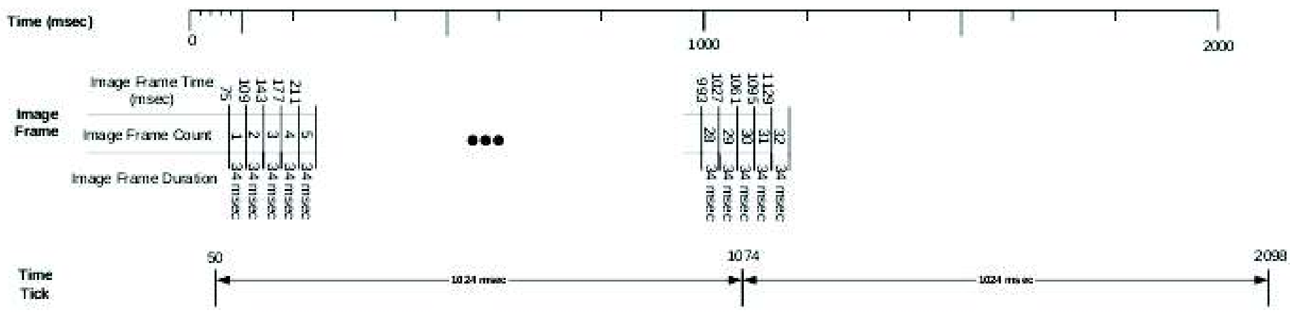


Image Frame Count	Image Frame Time	Tick Time	Tick Count
1	75	50	0
2	109	50	0
3	143	50	0
4	177	50	0
5	211	50	0
●			
●			
28	993	50	0
29	1027	50	0
30	1061	50	0
31	1095	1074	1
32	1129	1074	1

Calibration of UVIT master clock :

In order to ensure a continuous absolute calibration of the selected master clock/(s) of UVIT, the BMU will execute the following scheme. About 512 milli-second after each rising edge of the PPS pulse, BMU queries over the 1553B protocol to each of the 3 channels of UVIT. This ensures a ~ 1 Hz sampling of the absolute time calibration and provide a drift model for all the selected master clock/(s) thorough interpolation.

The above scheme ensures that in case different master clocks have been selected for different channels, all those selected master clocks will get calibrated.

Non Compliance :

Based on detailed tests involving choices of “Master clock” while running all the 3 channels, the following operational issue was detected & its fix identified :

(i) Clock Master Lost -

It was observed that, (a) if the channels have been run as their own internal masters, and there after they are run using an external master, there is no occasion of “Clock Master Lost” alarm; (b) if the channels have been run using external masters, there after they are run using a different external master, then the clock master MUST be started imaging first. Otherwise a slave channel can be attempting to use a master that suddenly becomes a slave and stops sending out time stamps. This leads to “Clock Master Lost” alarm.

In order to avoid “Clock Master Lost” situation, the Clock Master channel should always start imaging first, then only the slave channels. Implementation of this is trivial (only requires correct sequencing of the commands).

(ii) Occasional incorrect time stamp in slave channels -

It was observed that occasionally the slave channels show erroneous time stamps in one or at most 2 successive image frames (most often in the image frame time & rarely in the tick time). Note: other contents of the data are unaffected – only the time stamps are in error. Detailed analysis led to the identification of two types of errors : (a) the time stamp binary data is shifted one bit to the left; (b) the time stamp binary data has no recognizable pattern. While “a” is the more common error, “b” is very rare.

The error of type “a” was traced to be a firmware issue and a fix was developed. However, on implementing the fix, some other anomaly was observed. Hence, the fix was abandoned.

As the incorrect time stamps were quite infrequent (< 1.5%) and each such events could be detected and “corrected” on ground, by comparing previous and successive image frames, no changes were planned.

It may be noted that this error can be completely avoided by selecting each channel to be its own master. However, in this case, all 3 clocks need to be calibrated and tracked.