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Space Plug-and-Play Architecture (SPA) Standard

System Timing

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Abstract

This document details how common time is provided for SPA systems. Timing synchronization is accomplished through the use of time-at-tone messages and synchronization pulses.

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Foreword

This standard was developed through a partnership of the Air Force Research Laboratory Space Vehicles Directorate, the Air Force Office of Operationally Responsive Space, numerous government contractor teams, independent contractor teams, and academic experts. The System Timing standard is one piece of the Space Plug-and-Play Architecture (SPA) which is a system that aims to reduce the cost and timeline of getting spacecraft into operational use. SPA incorporates the use of design tools, standard interfaces for hardware and software, and standard, modular structures and wiring. The system timing methods described herein provide for common time within the system, allowing for synchronization of processes and functions across the system.

This document describes how common time is provided to components in SPA systems using a time-at-tone (TAT) message and synchronization pulses. Annexes A and B are informational and provide information on timing disruptions, time source priority, and master clock source considerations, with descriptions of timing implementation within a reference model.

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The AIAA Standards Executive Council (VP-Standards Name, Chairman) accepted the document for publication in Month 201X.

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1 Scope

This standard is applicable to systems operating under the Space Plug-and-Play Architecture.

The SPA System Timing Standard establishes a common method for providing common timing within a system of networked SPA components.

Discussions on availability, latency, jitter, and drift provide general guidelines on system timing requirements which are intended to meet the needs of most systems. Systems requiring greater timing accuracy than described herein may be implemented within the Space Plug-and-Play Architecture with enhanced or modified timing provisions as necessary.

2 Tailoring

When viewed from the perspective of a specific program or project context, the requirements defined in this Standard may be tailored to match the actual requirements of the particular program or project. Tailoring of requirements shall be undertaken in consultation with the procuring authority where applicable.

NOTE Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection, and in some exceptional cases, modification and addition of requirements in the standards.

3 Applicable Documents

The following documents contain provisions which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

AIAA S-XXX-X-201X	SPA System Specification
AIAA S-133-3-201X	SPA Logical Interface Standard
AIAA S-XXX-X-201X	SPA Ontology Standard
ANSI/TIA/EIA-422-B	Electrical Characteristics of Balanced Voltage Differential Interface Circuits

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

AIAA	American Institute of Aeronautics and Astronautics
GPS	Global positioning system
PPS	Pulse-per-second
TAT	Time-at-tone
xTEDS	Extensible Electronic Data Sheet

4.2 Terms and Definitions

PnPSat-1, -2
PnPSat-1 is a technology demonstration used to develop and demonstrate SPA components. It was developed at the Air Force Research Laboratory's Space Vehicles Directorate. PnPSat-2 is a more robust, flight-representative system that is used to test SPA technologies for function and compatibility.

SPA Application
A software SPA component

SPA Compliant
Adheres to applicable SPA standards

SPA Component
A SPA compliant hardware or software component

SPA Core Component
A SPA component which provides one or more SPA service

SPA Device
A hardware SPA component

xTEDS
An electronic data sheet used as the SPA component interface specification

5 SPA System Timing

A SPA-compliant system shall provide a method for synchronizing time across all SPA devices, processors, and applications through distribution of a time-at-tone (TAT) message and a synchronization pulse. The format of the TAT message shall be specified in the *SPA Logical Interface Standard* or *SPA SpaceWire (SPA-S) Adaptation Standard*, depending on the implementation for a specific system.

5.1 Pulse-per-Second (PPS) Synchronization

A PPS signal indicates the beginning of a second and is used for precise time-keeping and synchronization. The PPS signal does not contain any time information and must be used in conjunction with a timing or clock source.

5.1.1 PPS Signal

The PPS signal shall be a 1.00Hz square-wave signal conforming to ANSI/TIA/EIA-422 (formerly RS-422).

The active high time of the square-wave pulse shall be a minimum of 10µs and a maximum of 100ms.

The timing event (GPS seconds roll-over) shall be defined by the leading edge of the pulse.

5.2 Time-at-Tone (TAT) Message

The TAT message tells the system what the exact time (in integer seconds) will be at the next synchronization pulse (PPS). The TAT message shall be distributed over the data network to all registered SPA devices.

5.2.1 TAT Message Format

The TAT message is sent through the system using standard SPA messaging format. The TAT message format is specified in the *SPA Logical Interface Standard*.

5.2.2 System Time

The system time shall be specified in the TAT message in GPS Seconds. GPS Seconds is defined as the total elapsed seconds since the GPS epoch of 0000 UT (midnight) on January 6, 1980.

NOTE GPS Seconds have not been adjusted for leap seconds.

5.3 TAT and PPS Sources

5.3.1 GPS Receivers

GPS receivers on the SPA network shall be capable of providing a TAT message and PPS signal whenever a valid GPS signal has been received and processed. It is anticipated that SPA-compliant GPS receivers will provide a range of accuracies depending on factors such as number of satellites used in the timing solution and quality of hand-off algorithms for new satellites. It is not the intention of this standard to impose accuracy requirements on SPA-compliant GPS receivers. However, a SPA GPS receiver shall only output a TAT message and PPS when it has a current and valid time solution based on acquisition of one or more GPS satellites.

The rising edge of the GPS receiver PPS output shall be synchronized with GPS seconds roll-over.

5.3.2 Non-GPS Time Sources

The SPA system may provide a TAT message and PPS signal to SPA devices on the network based on a local oscillator (system clock or real-time clock) during periods when a valid GPS signal is not available.

The system clock or real-time clock shall be synchronized to a valid GPS receiver TAT and PPS output when available from the system.

Non-GPS time sources shall not output a TAT message or PPS when a TAT message is received from an external source. This requirement is imposed to guarantee that GPS-based time sources have priority in a SPA-compliant system.

Non-GPS time sources shall resume production of a TAT message and PPS after no external TAT message has been received for a specified time-out period of 1,000 seconds. This time-out period shall be settable by a command exposed in the system clock xTEDS.

5.4 Time Source Priority

The SPA system shall be designed to provide a single timing reference to the SPA network regardless of the number of GPS receivers or system clocks present on the SPA network.

SPA components that are intended to be sources of TAT messages and PPS signals and components that act as PPS routers shall have internal logic to prevent multiple PPS signals from being distributed to SPA devices.

The SPA system shall be designed for a designated SPA core component to collect the TAT information, distribute it, and inform the selected clock source that it is generating the sync signal.

5.5 System Time Availability

During periods of GPS unavailability, or periods of switch-over from a GPS source to a local oscillator (system clock), the TAT messages and PPS signal may not be continuously available.

SPA devices and applications shall be capable of operating for periods of time when TAT messages and PPS signals are not being actively distributed on the SPA network.

5.6 Time Latency

The PPS will have a latency of less than 100µs when distributed to the SPA devices on the network.

5.7 PPS Jitter

The elapsed time between pulses shall not vary more than +/- 0.1% of the average period for any two consecutive pulses (i.e., +/- 1ms for a pulse-per-second).

5.8 PPS Drift

The PPS will exhibit a drift of less than 10s per day when distributed to the SPA devices on the network.

Annex A Time Discontinuities (Informative)

A.1 Overview

It can be disruptive to software for time to have discontinuous jumps. This is especially true when time jumps backward. This condition can occur with the Space Plug and Play Avionics (SPA) Architecture since a separate signal is used to represent timing. It is possible to have the period of the PPS signal vary by as much as 50 percent for one pulse when a master time source is replaced by its backup. The purpose of this annex is to disclose this possibility, and to provide a reference design from PnPSat-1 as an example of a potential implementation.

NOTE: PnPSat-1 is a reference implementation of SPA concepts. PnPSat-1 was developed in the Air Force Research Laboratory's Responsive Space Testbed (RST) and was used to demonstrate the feasibility of the Space Plug-and-Play Architecture.

A.2 Reference Design: PnPSat-1

In the PnPSat-1 implementation a pulse is always accepted, as long as there is a corresponding SpaceWire time-at-tone message to accompany the pulse. If there is no TAT message, the pulse is discarded. No other validation checks are done.

Annex B PPS Routers (Informative)

B.1 Overview

This annex describes a method of distributing the PPS signal to all SPA Endpoints that was implemented on PnPSat-1. Note although routers were implemented in the reference design, routers are not required for a system to be SPA compliant.

B.2 Reference Design: PnPSat-1

The system provided a network of routers for distribution of the PPS signal to all SPA Endpoints.

The PPS router contained internal logic to sense a PPS provider and distribute this single PPS signal over the entire network. If no PPS provider was present, or a current PPS source was lost, the router initiated a search for a new PPS source.

All SPA infrastructure components that act as PPS routers provide to the system, in the form of a message described in its xTEDS, the status of the PPS source search and the port that is being used as the current source.

Annex C Master Clock Source Selection (Informative)

C.1 Overview

The criteria for selecting of the source for the PPS signal can define the roles of the candidate clock sources that translate into component requirements and subsequently affect design of components in a plug and play system. Because of this situation, a reference design is provided below from PnPSat-1 that suggests one method of selecting and delivering a master clock source in a SPA application.

C.2 Reference Design: PnPSat-1

The components involved with initiating and distributing the PPS on PnPSat-1 were the timing generation circuit and the PPS Router in the Power Hub. Each PPS signal terminating at the PPS Router is bi-directional; therefore the PPS Router must inhibit sending a PPS signal to all users when it is listening for a Master Source.

The timing generation circuit on PnPSat1 that is active at power up of the satellite. Initially, the mode of the PPS Router (in the Power Hub) is set to "listen", then when it acquires the PPS signal from the timing generation circuit, its mode is changed such that the pps signal is delivered to all endpoints.

If another potential PPS source becomes available that the system is programmed to consider more appropriate (i.e. from a GPS receiver), then a message is sent to the PPS Router to acquire its signal as master. The PPS Router reconfigures to "listen", captures the more accurate signal, then changes its mode to deliver the new PPS signal to all endpoints. If the PPS Router senses that the source has dropped out, then its mode changes to listen and it acquires a new PPS source. There is no prioritization of the available sources.

While the PPS Router is not delivering a PPS signal, the individual ASIMs derive a local PPS signal from their own local oscillators. Typically the search for a new PPS source by the PPS Router is less than 10 seconds.