



PROTEMPIS® ACUTIME 720™

MULTI-GNSS L1+L5 SMART ANTENNA

USER GUIDE

For use with:

- Acutime 720 multi-GNSS L1+L5 smart antenna (P/N 121224-XX)
- Acutime 720 Starter Kit (P/N 123889-XX)

Firmware Version 1.00 and later

Version 1.00
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Legal Notices

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- your name, address, and telephone numbers
- proof of purchase
- a copy of this Protempis warranty
- a description of the nonconforming Product including the model number
- an explanation of the problem

The customer service representative may need additional information from you depending on the nature of the problem. Any expenses incurred in the making of a claim under this warranty will be borne by you.

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Notices

Class B Statement - Notice to Users. This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communication. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Changes and modifications not expressly approved by the manufacturer or registrant of this equipment can void your authority to operate this equipment under Federal Communications Commission rules.

Canada

This digital apparatus does not exceed the Class B limits for radio noise emissions from digital apparatus as set out in the radio interference regulations of the Canadian Department of Communications, ICES-003.

Le présent appareil numérique n'émet pas de bruits radioélectriques dépassant les limites applicables aux appareils numériques de Classe B prescrites dans le règlement sur le brouillage radioélectrique édicté par le Ministère des Communications du Canada, ICES-003.

Europe

This product has been tested and found to comply with the requirements for a Class B device pursuant to European Council Directive 89/336/EEC on EMC, thereby satisfying the requirements for CE Marking and sale within the European Economic Area (EEA). These requirements are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential or commercial environment.



Notice to Our European Union Customers

At Protempis, we recognize the importance of minimizing the environmental impacts of our products. We endeavor to meet your needs, not only when you purchase and use our products, but also when you are ready to dispose of them. That is why Protempis is actively pursuing, and will continue to pursue, the expanded use of environmentally friendly materials in all its products, and why we have established a convenient and environmentally friendly recycling program.

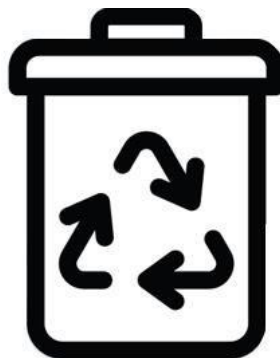
As Protempis makes additional recycling facilities available for your use, we will post their locations and contact information to our website.

Recycling in Europe:

To recycle Protempis WEEE:

Spectra Precision GmbH C/O RCL EHV

Ekkersrijt 2066, 5692 BA Son, Netherlands



For product recycling instructions and more information, go to www.protempis.com/Compliance

Declaration of Conformity

We, Protempis, United States of America declare under sole responsibility that the product: Acutime 720 complies with Part 15B of FCC Rules.

Operation is subject to the following two conditions:

- (1) this device may not cause harmful interference, and
- (2) this device must accept any interference received, including interference that may cause undesired operation

Document History

| Version | Date | Author | Changes |
|----------------|-------------|---------------|------------------------------------|
| V1.00 Rev A03 | March 2025 | MR | Added new TSIP 0xA1-22 |
| V1.00 Rev A01 | Aug. 2022 | FAE | Initial version for firmware v1.00 |

Safety Information

Warnings and cautions

An absence of specific alerts does not mean that there are no safety risks involved. Always follow the instructions that accompany a Warning or Caution. The information it provides is intended to minimize the risk of personal injury and/or damage to property. In particular, observe safety instructions that are presented in the following format:

WARNING - This alert warns of a potential hazard which, if not avoided, could result in severe injury or even death.

CAUTION - This alert warns of a potential hazard or unsafe practice which, if not avoided, could result in injury or property damage or irretrievable data loss.

CAUTION - Electrical hazard - risk of damage to equipment. Make sure all electrostatic energy is dissipated before installing or removing components from the device. An electrostatic discharge (ESD) can cause serious damage to the component once it is outside the chassis.

NOTE - An absence of specific alerts does not mean that there are no safety risks involved.

Operation and storage

WARNING - Operating or storing the Acutime 720 antenna outside the specified temperature range can damage it. For more information, see the product specifications on the data sheet.

Routing any cable

CAUTION - Be careful not to damage the cable. Take care to avoid sharp bends or kinks in the cable, hot surfaces (for example, exhaust manifolds or stacks), rotating or reciprocating equipment, sharp or abrasive surfaces, door and window jambs, and corrosive fluids or gases.

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Introduction

The Protempis® Acutime 720™ dual-band GNSS Smart antenna offers an industry-leading, value-engineered solution for carrier-grade timing products. It is designed to meet the resilient timing requirements mandated by the *United States Government: Executive Order 13905, Strengthening National Resilience Through Responsible Use of Positioning, Navigation, and Timing (PNT) Services*.

The Acutime 720™ dual-band GNSS Smart antenna integrates the latest dual-band multi-GNSS technology into a rugged, self-contained antenna unit that provides optimal GNSS timing performance, in all weather conditions, with continuous operation, long-term reliability, ease of operation, and simple installation.

The Acutime 720™ (referred to in this document as a Smart antenna) offers unparalleled accuracy to meet the stringent synchronization needs of the next-generation networks in various industry verticals including 5G X-Haul, Smart Grid, Data Center, SATCOM, Calibration Services and Industrial Automation applications.

Key features

- Including Dual-band (L1 and L5) multi-constellation GNSS timing receiver
- Nanosecond-level timing accuracy (5 ns 1-sigma) when using both L1 and L5 constellations
- Protection against jamming and spoofing with the Protempis Smart GNSS Assurance™ technology
- Advanced security features that includes secure boot, and T-RAIM
- Supports industry standard protocols NMEA and TSIP for configuration and control
- Advanced multipath mitigation capabilities to distinguish and process directly received signal from reflected signals



Timing features

The timing features include the following:

- Automatic self-survey of position for static operation
- Over-determined timing mode
- Ultra-precise one pulse-per-second (1PPS) output can be configured as an even-second output, RS-422 signal compatible.
- Accuracy <5 ns (1 sigma) with respect to GNSS-time or UTC-time when using both L1 and L5 constellations under the open sky view.

NOTE - Requires accurate cable delays, completed survey position with better than PDOP of 2 (or position error < 1 m). Conditional under minimal ionospheric anomalies.

- T-RAIM (Timing Receiver Autonomous Integrity Monitoring)
- Position Integrity Monitoring
- Cable delay compensation
- Anti-Jamming function/Anti-Spoofing
- Time keeping from a single satellite
- Time (re-)acquisition from a minimum of two satellites

Hardware features

The Acutime 720 contains the following in a sealed, weatherproof housing:

- An active patch L1/L5 Dual-Band multi-GNSS antenna with a proprietary pre-amp design and integrated band-pass filtering
- Dual-band L1/ L5 multi-constellation GNSS timing receiver
- A connector that supports both the power and data interface connection.
- Two user-configurable RS-422 I/O communication ports.
- 1PPS timing signal output
- Operates with a +7 to +36 VDC power supply with protection against reverse polarity.
- IP67 grade weather proof and corrosion resistant housing.
- Extended operating temperature range(-40°C to +85°C).
- Up to 1000 m (3280 feet) for cable length with AWG22 cable.

Dual-band multi-constellation capability

With dual-band multi-constellation capability, the Acutime 720 reduces the timing error under clear skies to 5 nanosecond without the need for an external GNSS correction service.

NOTE - Requires accurate cable delays, completed survey position with better than PDOP of 2 (or position error < 1 m). Conditional under minimal ionospheric anomalies.

Additionally, the Acutime 720 offers the benefit of higher power L5 signals (twice as much power as L1) with its greater bandwidth, and advanced signal design lowers the risk of interference and improves multi-path protection. The multi-band capability of the Acutime 720 allows it to compensate for the ionosphere error while reducing the timing error under clear skies to few nanoseconds without further need for correction.

The Acutime 720 includes a dual-band(L1 & L5) multi-GNSS antenna inside. It uses dual SAW filters for exceptional signal selectivity and out-of- band attenuation thus providing the best total cost to performance ratio.

Nanosecond-level accuracy

The Acutime 720 offers precision time synchronization with 5 nanosecond accuracy in normal mode of operation. The Acutime 720 antenna is designed to meet stringent timing requirements of critical infrastructure and help operators maximize the performance of their networks and optimize the return on their infrastructure investments.

NOTE - Requires accurate cable delays, completed survey position with better than PDOP of 2 (or position error < 1 m). Conditional under minimal ionospheric anomalies.

Smart GNSS Assurance

To protect against today's sophisticated attacks and signal meaconing, Protempis dual-band multi-GNSS receiver offers automatic detection and fail-over with highly reliable anti-jamming and anti-spoofing capabilities.

Advanced security features

With the ideals of zero trust security, the Acutime 720 provides secure boot and anti-tampering features by default. Additionally, the Acutime 720 Smart antenna offers T-RAIM to provide the highest level timing integrity.

Protocols and configuration

Protempis Smart antenna supports industry standard NMEA (National Marine Electronics Association) and TSIP (Protempis Standard Interface Protocol) for configuration and control.

Detailed Data Sheet

- ▶ [Data sheet](#)
- ▶ [Recommended operating conditions](#)
- ▶ [Physical specifications](#)
- ▶ [Environmental specifications](#)
- ▶ [Protection against Electrostatic Discharge \(ESD\)](#)
- ▶ [Surge protection](#)
- ▶ [EMI](#)

Data sheet

| Features | Specifications |
|-------------------------------|---|
| Bands | |
| L1 - 1602 Mhz and 1575.42 MHz | GPS L1C/A, GLONASS L1OF, Galileo E1, QZSS L1 SAIF |
| L1 - 1561.098 MHz | BeiDou B1 |
| L5 - 1176.45 MHz | GPS L5, Galileo E5a, BeiDou B2a, QZSS L5, NavIC SPS |
| Receiver performance | |
| Navigation update rate | 1 Hz |
| L1 and L5 position accuracy | 1 m CEP acquisition |
| Acquisition time | |
| Cold start | 30 s |
| Hot start | 2 s |
| Sensitivity | |
| Tracking and navigation | -160 dBm |
| Reacquisition | -160 dBm |
| Hot starts | -157 dBm |
| Cold starts | -148 dBm |
| A-GNSS/A-GPS | GNSS data aiding service (such as ephemeris, time, coarse position) for a faster Time To First Fix (TTFF) |

| Features | Specifications |
|--|--|
| Smart GNSS and security | |
| Anti-jamming | Active CW detection and removal. The product has Dual on-board band pass filters. |
| Anti-spoofing | Advanced anti-spoofing algorithms. Detects meaconing of signal and provide fallback capabilities. |
| Multipath mitigation | |
| Timing | |
| Acutime 720 Accuracy (Standard Deviation) | <5 ns (1-sigma, clear sky, absolute mode) |
| | NOTE - Requires a constant temperature, accurate cable delays, completed self-survey position with better than PDOP of 2 (or position error < 1 m), multi-frequency signal measurements. Conditional under minimal ionospheric anomalies. |
| Integrity reports | 1. T-RAIM active, phase uncertainty. 2. Time pulse rate/duty-cycle, inter-constellation biases |
| Survey-in period | Configurable |
| Timing output | |
| 1 PPS output physical interface | RS-422 |
| 1 PPS pulse width | 10 milliseconds (default); user programmable from 1 millisecond to 500 milliseconds |
| 1 PPS on-time edge | Rising edge on time(default); user configurable rising or falling resolution : < 5 nanoseconds |
| PP2S | Even second PPS; configurable instead of 1PPS in the same interface |
| Environmental data, quality and reliability | |
| Ingress protection | IP 67 |
| RoHS compliant (lead-free) | |
| Green (halogen-free) | |
| ETSI-RED compliant | |
| Manufactured and fully tested in ISO/TS 16949 certified production sites | |

| Features | Specifications |
|-------------------------------------|--|
| High vibration and shock resistance | |
| UL-94-V0 Flammability Rated | |
| ESD protection | IEC-61000-4-2 compliant |
| Surge protection | IEC-61000-4-5 compliant |
| Electrical data | |
| Supply voltage | 12VDC(7VDC ~ 36VDC) |
| Power consumption | 50mA @ 12 V, 0.6W (typical), < 1W maximum |
| Interfaces | |
| UART | 2 |
| Protocols | TSIP v1.0, NMEA v4.11 |
| Miscellaneous | |
| Connector | 12-pin round, waterproof |
| Weight | 154g (5.4oz) |
| Mounting | 1"-14" straight thread or 3/4" pipe thread |

Recommended operating conditions

Minimum and maximum limits apply over the full operating temperature range unless otherwise noted.

| Symbol | Parameter | Min | Typ | Max | Unit |
|------------------|--|------|------|-----|------|
| V _{CC} | DC supply voltage (referenced to GND) | +7 | +12 | +36 | V |
| I _{CC} | DC supply current | | 50 | 80 | mA |
| V _{OD} | Output drive voltage (R _L = 100 Ω) | 2 | 2.3 | | V |
| V _{OC} | Common-mode output voltage (V _{CC} =3.3V) | 1 | 1.65 | 3 | |
| V _{TH+} | Positive-going input threshold voltage | +200 | | | mV |
| V _{TH-} | Negative-going input threshold voltage | -200 | | | mV |

Physical specifications

| | |
|------------|---|
| Dimensions | 95 mm(Diameter) x 72.5 mm(Height) |
| Weight | 154 g |
| Mounting | 1"-14 straight thread or 3/4" pipe thread |

Environmental specifications

| Parameter | Condition |
|-----------------------|--|
| Operating temperature | -40 °C to + 85 °C (-40°F to 185°F) |
| Storage temperature | -55 °C to + 105 °C (-67°F to 221°F) |
| Vibration | 0.008 g ² /Hz : 5Hz to 20Hz 0.05 g ² /Hz : 20Hz to 100Hz -3 dB/octave : 100Hz to 900Hz |
| Mechanical shock | ±40 g operational, ±75 g non-operational |
| Operating humidity | 95% RH, non-condensing at 60°C (140°F) EMC |
| Operating altitude | -400 m to 10000 m Mean Sea Level |
| Ingress protection | IP 67 |

Protection against Electrostatic Discharge (ESD)

ESD testing was performed using test standard IEC 1000-4-2. All input and output pins are protected to ±500 V ESD level (contact discharge).

Appropriate care and protection against ESD, according to JEDEC standard JESD625-A (EIA 625) and IEC 61340-5-1, must be taken when handling the product.

Surge protection

The Acutime 720 includes a surge protection circuit and it complies with IEC-61000-4-5, so the Smart antenna is protected from nearby lightning hits that come along with high energy.

EMI

The unit meets all requirements and objectives of IEC 61000 and FCC Part 15 Subpart J Class B.

Hardware

- ▶ [Acutime 720 Block diagram](#)
- ▶ [Acutime 720 Serial port interface](#)
- ▶ [Mechanical Outline Drawing](#)
- ▶ [Start-up checklist](#)

The Protempis® Acutime 720 contains a highly integrated System-in-Package (SiP), low-power, RFSoc GPS receiver with an application processor, GPS L1 and L5 receiver, a power management unit (PMU), 32 Mbit flash, 32 Mbit Pseudo SRAM (PSRAM), and 64 Mbit SPI Flash.

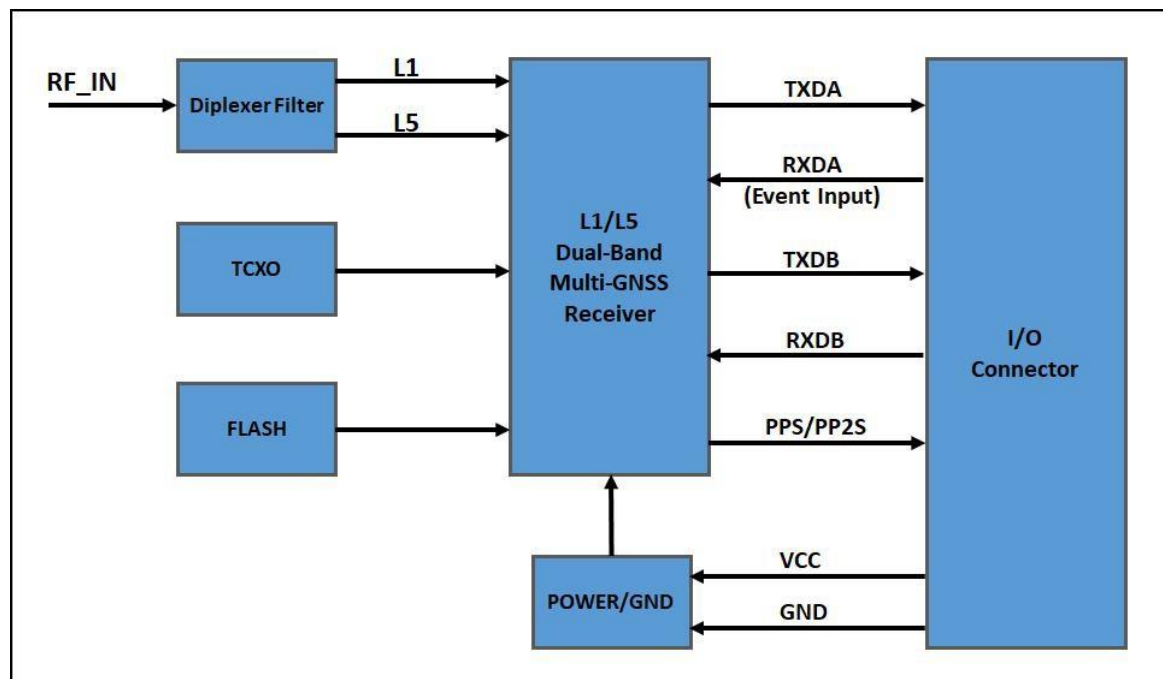
The module contains an ARM® Cortex® M4 processor that utilizes internal frequencies of 26, 192, 384 and 530MHz.

The GPS subsystem contains the RF and baseband circuits, which can track L1 and L5 satellites at the same time, and search GPS satellites using the L1 circuit.

The Acutime 720 is a ruggedized weatherproof dual-band (L1 & L5) multi-constellation receiver for timing that integrates antenna and receiver in Radome shape enclosure ideal for outdoor applications.

It provides a built-in dual-band receiver with 1PPS/PP2S output through the RS-422 interface that can be transmitted up to 1000 m (3280 feet) with a data rate of 115kbits/s. The product eliminates the need for timing receivers to be integrated in embedded system.

Acutime 720 Block diagram



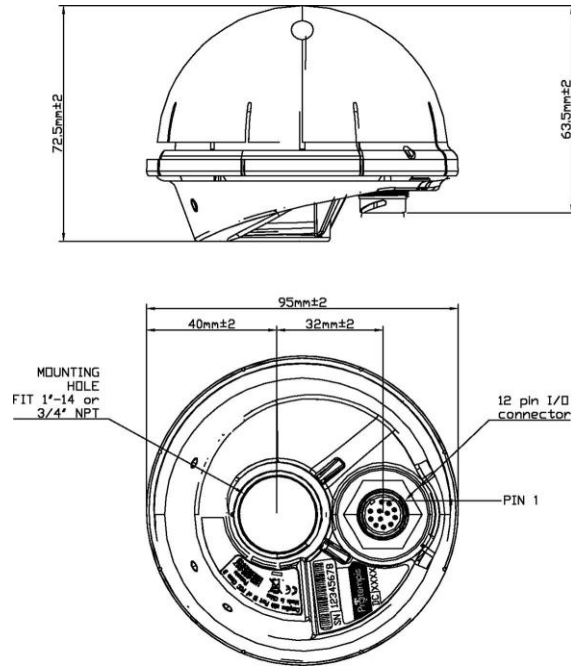
Acutime 720 Serial port interface

| Connector Pin# | Wire Color | Pin Name | DB-25 Pin# | Function / Protocol |
|----------------|------------|--------------------|------------|--|
| Pin 1 | Red | DC Power | Pin 1 | +7 to +36VDC |
| Pin 2 | Violet | Port B: Receive - | Pin 25 | Serial Port (Default TSIP, NMEA configurable), RS-422 |
| Pin 3 | Orange | Port B: Receive + | Pin 13 | Serial Port (Default TSIP, NMEA configurable), RS-422 |
| Pin 4 | Brown | Port B: Transmit - | Pin 11 | Serial Port (Default TSIP, NMEA configurable), RS-422 |
| Pin 5 | Yellow | Port B: Transmit + | Pin 23 | Serial Port (Default TSIP, NMEA configurable), RS-422 |
| Pin 6 | White | Port A: Receive - | Pin 24 | Serial Port (Default for Event Input, TSIP or NMEA configurable), RS-422 |
| Pin 7 | Gray | Port A: Receive + | Pin 12 | Serial Port (Default for Event Input, TSIP or NMEA configurable), RS-422 |

| | | | | |
|--------|--------------------------|-----------------------|--------|---|
| Pin 8 | Green | Port A: Transmit - | Pin 10 | Serial Port (Default NMEA, TSIP configurable), RS-422 |
| Pin 9 | Black | DC Ground | Pin 7 | Ground |
| Pin 10 | Blue | Port A: Transmit + | Pin 22 | Serial Port (Default NMEA, TSIP configurable), RS-422 |
| Pin 11 | Orange with white stripe | 1 PPS: Transmit + | Pin 21 | 1PPS, RS-422 |
| Pin 12 | Black with white stripe | 1 PPS: Transmit - | Pin 9 | 1PPS, RS-422 |

Mechanical Outline Drawing

Below is the Acutime 720 mechanical drawing. All dimensions are in mm.



Below is the Acutime 720 visual appearance (conceptual image - see chapter Label for the label design and content).



Start-up checklist

Antenna placement for Timing receivers

Select an antenna location

- The Smart antenna is designed for a pole mount
- Select an outdoor location for the antenna, like the roof of your building, or any location that has a relatively unobstructed view of the horizon.
- Install the Smart antenna vertically to the earth.
- Dense wood, concrete, heavy foliage, or metal structures will shield the antenna from satellite signals.
- GNSS signals can be reflected by objects, where metal, walls and shielded glass parts are reflectors. The antenna should not be placed near a wall, window or other large vertical objects.
- The Smart antenna is an active antenna. For optimal performance, locate the antenna as far as possible from transmitting antennas, including radars, satellite communication equipment, and cellular and pager transmitters.
- When locating the antenna near a radar installation, ensure that the antenna is positioned outside of the radar's cone of transmission. Follow the same guideline when installing the antenna near satellite communication equipment.
- For the best results, mount the antenna below and at least 3 m (10 feet) away from satellite communication equipment.
- The length of cable run from your management system to the Smart antenna location should not degrade the supply voltage below the minimum requirement of the antenna.

The Timing GNSS operation

Start-up

- When the Smart antenna is turned on, it automatically begins to acquire and track GNSS satellite signals.
- It usually obtains its first fix in under one minute.
- During the satellite acquisition process, the Smart antenna outputs periodic TSIP status messages.
- These status messages confirm that the receiver is working.

Automatic operation

- When the Smart antenna has acquired and locked onto a set of satellites that pass the mask criteria and has obtained a valid ephemeris for each satellite, it performs a self-survey.
- After 2,000 position (default) fixes the self-survey is complete.

- By default, the position is saved to memory.
- At that time, the Smart antenna automatically switches to overdetermined (OD) mode.

Satellite masks

- The Smart antenna continuously tracks and uses any enabled L1 or L5 satellite that has been configured by the 0x91-01 command, in an overdetermined clock solution. The satellites must pass the mask criteria to be included in the solution.
- The following table lists the default satellite masks used by the Smart antenna. These masks serve as the screening criteria for satellites used in fix computations and ensure that solutions meet a minimum level of accuracy.

| Mask | Setting | Notes |
|-----------|---------|---------------------------------------|
| Elevation | 10° | Satellite elevation above the horizon |
| C/N0 | 30 | Signal strength |
| PDOP | 6 | Self-survey only |

Elevation mask

- By default, Satellites below 10° elevation are not used in the solution. Generally, signals from low elevation satellites are of poorer quality than signals from higher elevation satellites. These signals travel farther through the ionospheric and tropospheric layers and undergo distortion due to these atmospheric conditions.

C/N0 mask

- If the Smart antenna has a clear view of the sky (outdoor antenna placement), a C/N0 mask of 30 dB-Hz is recommended for optimal results.
- For indoor use or operation with an obscured view of the sky, the mask must be low enough to allow valid weak signals to be used. For indoor operation, an CN0 mask of 0 dB-Hz (zero) is recommended.

Low SNR values can result from low-elevation satellites, partially obscured signals (for example, dense foliage), or multi-reflected signals (multipath).

NOTE - C/No and Elevation masks affect both the positioning and timing solutions.

PDOP mask

Position Dilution of Position (PDOP) is a measure of the error caused by the geometric relationship of the satellites used in the position solution. Satellite sets that are tightly clustered or aligned in the sky have a high PDOP and contribute to lower position accuracy.

- For timing applications, a PDOP mask of six offers a satisfactory trade-off between accuracy and GNSS coverage.

NOTE - PDOP is only applicable during self-survey or whenever the receiver is performing position fixes.

Commissioning the antenna

The steps below enable you to determine if the Smart antenna can produce a reliable PPS by:

- making sure the received signal strength is adequate(> 35 dBm).
 - determining that the Smart antenna completes the self-survey.
 - confirming the position has been stored.
 - determining that the Smart antenna stays in overdetermined (OD) mode.
 - testing that the system is stable and available for a 24-hour period.
1. Install the Smart antenna in a proper position.
 2. Apply power to the Smart antenna.
 3. Monitor the **0xA3-11** packet, byte 6. See [Receiver Status \(0xA3-11\)](#).
 - While the GNSS receiver is in self-survey mode, the value will be 0x03.
 - While the GNSS receiver is in overdetermined mode, the value will be 0x06.
 4. Monitor the **0xA3-00** packet, bytes 6-9 for 24 hours. See [System Alarms \(0xA3-00\)](#).
 5. During the first 40 minutes of operation some bits will be set high. This is because the following needs to be achieved:
 1. Find and track satellites to get a fix.
 2. Collect an almanac.
 3. Complete the self-survey.
 4. Save the surveyed position.
 6. After 40 minutes (depending on GNSS coverage) all bits of byte 6-9 should be 0.

NOTE - Possible exception is bit 2 maybe set if a leap second is due for an update.

7. Monitor the **0xA3-11** packet bytes 6 and 7 for 24 hours.

NOTE - After the receiver has had time to transition to overdetermined mode, these bytes should always be 6 and 0xFF respectively.

Checklist

| Checklist from the start-up | Yes | No | Comment |
|------------------------------------|-----|----|---|
| Antenna in clear view of sky | | | |
| 0xA3-00 bytes 6-9 (Minor Alarms) | | | Describe and account for any bits left at 1. |
| Bit 0: Reserved | | | Reserved |
| Bit 1: Reserved | | | Reserved |
| Bit 2: Leap second pending | | | Is set to "1" to provide notice that a leap second is to be applied in the near future. Check with the constellation authority for latest leap second status information, e.g., GPS is at https://www.iers.org/IERS/EN/Publications/Bulletins/bulletins.html . |
| Bit 3: Almanac not complete = 0 | | | Almanac complete for all tracked constellations. Wait for at least 15 minutes of continuous tracking of all enabled constellations after the first fix for this bit to clear from "1" to "0". |
| Bit 4: Survey-in progress = 0 | | | Should be "1" for 40 minutes(default) after first power up, then "0". It may take longer in poor coverage. |
| Bit 5: GPS almanac status | | | GPS almanac available if constellation is tracked. |
| Bit 6: GLONASS almanac status | | | GLONASS almanac available if constellation is tracked. |
| Bit 7: Beidou almanac status | | | BeiDou almanac available if constellation is tracked. |
| Bit 8: Galileo almanac status | | | Galileo almanac available if constellation is tracked. |
| 0xA3-00 bytes 14-17 (major alarms) | | | |
| Bit 0: Not tracking satellites | | | Check for adequate view of the sky. |
| Bit 1: PPS bad | | | If not zero, then investigate presence of other alarms and RF signal quality. |

| Checklist from the start-up | Yes | No | Comment |
|---|-----|----|---|
| Bit 2: PPS not generated | | | If not zero, then investigate presence of other alarms and RF signal quality. |
| Bit 3 - Bit 6 - Reserved | | | Reserved |
| Bit 7 - Spoofing / multipath | | | Check for sources of signal reflection in particular areas with high buildings. |
| Bit 8: Reserved | | | Reserved |
| 0xA3-11 byte 6 | | | |
| Automatic = 3 | | | Should be 3 while doing the self-survey. If not, check the antenna position. |
| Have GPS time fix (overdetermined mode) = 6 | | | Should be 6 while in overdetermined mode. If not, check the antenna position. |
| 0xA3-11 byte 7 | | | |
| Doing position fixes = 0 | | | |
| Have GPS time fix (overdetermined mode) =FF | | | |

NOTE -

- Except for bits 2 and 3 of 0xA3-00, bytes 6-9 all other parameters should be able to maintain a zero value for a period of over 24 hours.
- Bits 0, 1, 2, 7, and 8 of 0xA3-00 bytes 14-17 should also remain zero value.
- If there is a problem and there is a non-zero value, then the antenna position should be changed for a better GPS signal.

Software

- ▶ System Operation
- ▶ Communication parameters
- ▶ Updating the firmware
- ▶ Protempis Standard Interface Protocol(TSIP)
- ▶ NMEA 0183 Protocol
- ▶ GNSS identification table for NMEA v4.1

System Operation

This section describes the operating characteristics of the Smart antenna including start-up, satellite acquisition, operating modes, serial data communication, and the timing pulse output.

The Protempis[®] Acutime 720 Smart antenna receives amplified GNSS signals from its internal antenna and gain front-end and passes them to an internal RF down-converter. A highly stable crystal reference oscillator is used by the down-converter to produce the signals used by the digital signal processor (DSP). The DSP acquires and tracks the GNSS signals and extracts the carrier phase and code information as well as the navigation data.

Operation of the tracking channels is controlled by navigation processing software. The software tracking channels track up to 78 satellite signals that meet the tracking masks. The navigation processing software then uses the optimum satellite combination to compute a position. The navigation processing software also manages gathering and decoding of the ephemeris and almanac data for all of the satellites, and timing processing software accepts the tracking information from the navigation software and provides surveying and optimized over-determined clock solutions.

- ▶ [GNSS timing](#)
- ▶ [Time references](#)
- ▶ [GNSS constellation configuration](#)
- ▶ [PPS availability](#)
- ▶ [Startup](#)
- ▶ [Automatic operation](#)
- ▶ [Operating modes](#)
- ▶ [Integrity monitoring](#)
- ▶ [Cable delay compensation](#)
- ▶ [Smart antenna performance](#)
- ▶ [Acquiring the correct time](#)
- ▶ [Customizing operations](#)

GNSS timing

For many timing applications, such as time & frequency standards, site synchronization systems, and wireless voice and data networks, the Acutime 720 smart antenna can be used to steer a local reference oscillator. The steering algorithm combines the short-term stability of the oscillator with the long-term stability of the GNSS PPS. An accurate GNSS PPS allows the use of cost-effective crystal oscillators, which have less stability than expensive, high-quality oscillators, such as Oven Controlled Crystal Oscillators (OCXO).

The GNSS system consists of several GPS, GLONASS, BeiDou, Galileo and other regional constellation orbiting satellites. Unlike most telecommunications satellites, most GNSS satellites are not geostationary, so satellites in view are constantly changing. Each GNSS satellite contains redundant highly-stable atomic clocks, which are continuously monitored and corrected by the controlling regional body control segment. For example, the GPS constellation can be considered a set of 24 orbiting "clocks" with worldwide 24-hour coverage.

NOTE - There are geo-stationary satellites for GNSS augmentation and regional coverage.

In addition to serving as highly-accurate stand-alone time sources, GNSS timing modules are used to synchronize distant clocks in communication or data networks. This is possible because all GNSS satellites are corrected to a common master clock. Therefore, the relative clock error is the same, regardless of which satellites are used. For synchronization applications requiring a common clock, GNSS is the ideal solution.

GNSS Error Correction: ITU-T technical paper '**GSTR-GNSS**' suggested different error correction mechanisms for various physical and environmental condition that may impede signal reception and processing. Protempis recommends that the those guideline are followed for the implementation of error correction mechanisms.

Time references

All GNSS satellite systems have their own master clock to which all atomic clocks inside of this system's space vehicles are synchronized. These master clocks provide traceability to the world's UTC (Universal Time Coordinated) clock ensemble, which consists of many individual atomic clocks in many countries. The synchronization among all those clock ensembles causes small steering offsets.

GNSS time differs from UTC (Universal Coordinated Time) by a small, sub-microsecond offset and an integer second offset. The small offset is the steering offset between the GNSS master clock ensemble and the UTC clock ensemble. The large offset is the cumulative number of leap seconds since 1 January 1980, which, on 1 January 2017, was increased from 17 to 18 seconds. Historically, the offset increases, or decreases by one second approximately every 18 to 24 months, just before midnight on 30 June or 31 December. System designers should note whether the output time is UTC or GNSS time. GNSS receivers do not support time zones because they depend on national regulations.

GNSS constellation configuration

The Protempis® Acutime 720 Smart antenna can be configured (TSIP packet 0x91-01) to use one of the constellation combinations shown in the following table.

The table below shows the Protempis recommended constellation options you can select.

| Combination | L1 GPS | L5 GPS | E1 GAL | E5a GAL | G1 GLO | B1 BD | B2a BD | NavIC | L1 QZSS | L5 QZSS |
|--------------|-----------|-----------|-----------|------------|-----------|----------|-----------|-------|------------|------------|
| GPS only | √ | √ | | | | | | | √ | √ |
| Galileo only | | | √ | √ | | | | | | |
| GLONASS only | | | | | √ | | | | | |
| BeiDou only | | | | | | √ | √ | | | |
| NavIC only | | | | | | | | √ | | |
| GPS/Galileo | √ | √ | √ | √ | | | | | √ | √ |
| GPS/BeiDou | √ | √ | | | | √ | √ | | √ | √ |
| GPS/GLO | √ | √ | | | √ | | | | √ | √ |
| GPS/NavIC | √ | √ | | | | | | √ | √ | √ |
| G3B(Default) | √ | √ | √ | √ | √ | √ | √ | | | |

NOTE - QZSS can not be enabled by itself but it can be enabled any combinations with GPS as QZSS uses the same frequency band with GPS.

NOTE - Acutime 720 allows dual-band or L1 only operation. If using L1 all signals must be set to L1. If any dual-band constellation is enabled to include L5 then the unit is configured to dual-band and all enabled dual-band constellations will be dual-band.

PPS availability

Protempis cannot guarantee that the PPS is 100% available or a pulse is generated each and every second. The receiver's ability to generate the PPS depends on various factors, including, but not limited to, the local signal conditions at the place of antenna installation and on the health and validity of the GNSS signals that are broadcasted by the satellites. Protempis has neither control over the GNSS systems nor over the conditions at the place of installation, therefore the PPS may not be available at all times.

Startup

The first time the Acutime 720 Smart antenna is powered-up, it searches for satellites from a cold start (no almanac, time, ephemeris, or stored position). During the satellite acquisition

process, the Smart antenna outputs periodic TSIP status messages. These status messages confirm that the receiver is working.

While the receiver will begin to compute position solutions in less than one minute, the receiver must continuously track satellites for approximately 15 minutes to download complete almanacs. The almanac contains, amongst others, the UTC leap second value. Smart antenna can only compute UTC time after this leap second value was received from the satellites. Therefore, a complete and current almanac is essential for correct UTC output. The initialization process with almanac download should not be interrupted.

The Smart antenna is ready to accept TSIP commands approximately 10 seconds after power-up. If a command is sent to the receiver within this 10 second window, the receiver may ignore the command. The Acutime 720 Smart antenna may not respond to commands sent within the 10 second window and may discard any associated command data.

Automatic operation

When the Acutime 720 antenna has acquired and locked onto a set of satellites that pass the mask criteria listed below, and has obtained a valid ephemeris for each tracked satellite, and there is no stored position, or the position has changed from the last stored position by more than 100 meters, then it performs a self-survey. After a number of valid position fixes, the self-survey is complete. At that time, the Acutime 720 antenna automatically switches to a time-only mode (overdetermined clock mode).

Satellite masks

The following table lists the default satellite masks used by the Acutime 720 antenna. These masks serve as the screening criteria for satellites used in fix computations and ensure that solutions meet a minimum level of accuracy. The satellite masks can be adjusted using the TSIP protocol described in .

| Mask | Default Setting | Description |
|----------------|-----------------|--|
| Elevation | 10° | Satellite elevation above horizon |
| C/N0 [dBHz] | 30 | Signal strength (carrier-to-noise power ratio) |
| PDOP | 6 | Position Dilution of Precision (PDOP), used for self-survey only |

Elevation mask

Generally, signals from low-elevation satellites are of poorer quality than signals from higher elevation satellites. These signals travel farther through the ionospheric and tropospheric layers and undergo distortion due to these atmospheric conditions. For example, an elevation mask of 10° excludes very low satellites from position fix computations and reduces the likelihood of potential errors induced by using those signals.

PDOP mask

Position Dilution of Precision (PDOP) is a measure of the error caused by the geometric relationship of the satellites used in the position solution. Satellite sets that are tightly clustered or aligned in the sky have a high PDOP and contribute to lower position accuracy.

NOTE - PDOP is applicable only during self-survey or whenever the receiver is performing position fixes.

Operating modes

- Self-survey mode (position fix operating mode)
- Overdetermined clock mode

After establishing a reference position in self-survey mode, the Acutime 720 automatically switches to overdetermined (OD) clock mode.

Self-survey mode

At power-on, the Acutime 720 performs a self-survey by averaging position fixes, default of 2,000 fixes will be averaged.

The number of position fixes until survey completion is configurable.

The default mode during self-survey is 3D Automatic, where the receiver must obtain a three-dimensional (3D) position solution. The very first fix in 3D Automatic mode must include at least five satellites. After a successful first fix, only four satellites are required. If fewer than the required number of satellites are visible, the Acutime 720 suspends the self-survey. 3D mode may not be achieved when the receiver is subjected to frequent obscuration or when the geometry is poor due to an incomplete constellation.

Overdetermined clock mode

Overdetermined clock mode is used only in stationary timing applications. This is the default mode for the Acutime 720 once a surveyed (or user input) position is determined. After the receiver self-surveys its static reference position, it stores the surveyed reference position automatically and switches to overdetermined clock mode and determines the clock solution. The timing solution is qualified by T-RAIM (Time Receiver Autonomous Integrity Monitoring) algorithm, which automatically detects and rejects faulty satellites from the solution.

A minimum of two satellites is required for an initial PPS fix in overdetermined clock mode. Once PPS alignment has been determined only a single satellite is required to maintain that time. If all satellites are lost, then a minimum of two satellites is again required to re-establish PPS alignment.

Integrity monitoring

Using a voting scheme based on pseudo-range residuals, the T-RAIM (Time Receiver Autonomous Integrity Monitoring) algorithm automatically updates the self-survey information by removing the worst satellite with the highest residual errors from the solution set if that satellite's residual is above the current constellation average.

In addition to T-RAIM, the Smart antenna implements position integrity checking on startup, in case the receiver has been moved to a new location. When the receiver is powered up with a surveyed (or user input) position in memory, it will compare position fixes computed from the GNSS satellites to the surveyed position. If it finds that the surveyed position is off by more than 100 meters (approximately) horizontally or vertically in the first 60 consecutive GNSS fixes, it

will delete the surveyed position from memory (including non-volatile storage) and restart the self-survey.

Anti-jamming

GNSS jamming is generally caused by intentional or unintentional generation of a signal that interferes at or very near the transmitted frequency of the GNSS satellite signals. This signal causes some background noise of the received signal and a decrease in the received signal-to-noise ratio (C/N0), causing poor tracking and data decoding. This is mitigated in the receivers by the use of filtering to attempt to greatly reduce the jamming signal so that it does not adversely affect the signal. Jamming can be very difficult to protect against because, if the signal is too strong, the front-end RF section of the receiver will be completely overwhelmed and filtering is ineffective.

The Acutime 720 antenna protects against anti-jamming with hardware filtering and software algorithms.

About hardware filtering

- During the design process of the GNSS receiver great care is taken to avoid the component parts like oscillators and microprocessors producing signals that can jam the RF signal path. This can occur by either transmission over the air or conducted along the copper PCB traces.
- Protempis takes into account component choice using low-noise, high-spec parts.
- Component layout
- PCB trace layout
- Grounding techniques

About the software algorithms

- T-RAIM is used in OD mode using stringent thresholds to improve anti-jamming detection and mitigation.
- T-RAIM discards inconsistent information that would degrade the combined overdetermined solution.
- Tracked multiple satellite integrity checks.
- Doppler measurements are examined for consistency with each other. Satellites with Doppler measurements that are far away from the median Doppler measurement are not used to improve anti-jamming detection and mitigation.
- Pseudorange measurements are examined for consistency with each other. Satellites with pseudorange measurements that are far away from the median pseudorange measurement are removed, or their effect reduced in the fix.
- Filter for SV noise and pseudorange offsets. Protempis measures from the median pseudorange value instead of the last value.

The Acutime 720 antenna has anti-jamming enabled as a default configuration; ***it cannot be disabled.***

Below is the minimum number of satellites required to be tracked for each startup condition.

| Condition | Anti-jamming enabled? | Minimum number of satellite tracking |
|--|-----------------------|--------------------------------------|
| Position NOT validated before (self-surveying) | YES | ≥ 5 SVs |
| Position validated before | YES | ≥ 4 SVs |
| First timing fix after all SVs drop | YES | ≥ 2 SVs |
| Timing fix | YES | ≥ 1 SVs |

If the Acutime 720 antenna drops all the satellites (SV count is 0) after position validated, it needs ≥ 2 satellites to re-establish a time relationship for the first timing fix again and If it drops to ≥ 1, it will continue working indefinitely before it discards all satellites with enabling anti-Jamming.

Spoofing and Multi-path

Spoofing

Spoofing is generally an intentional generation of a signal that matches that of the transmitted GNSS signal. This will include satellite data and, for all practical purposes, looks like a "real" GNSS satellite. This technique is generally used in an attempt to force the receiver to generate incorrect behavior, thereby causing failure in the receiver application.

A spoofing attack attempts to deceive a GNSS receiver by broadcasting incorrect GNSS signals, structured to resemble a set of normal GNSS signals, or by rebroadcasting genuine signals captured elsewhere or at a different time.

These spoofed signals may be modified in such a way as to cause the receiver to estimate its position to be somewhere other than where it actually is, or to be located where it is but at a different time, as determined by the attacker.

This can cause lots of noise and incorrect computations within the receiver, depending on which signal is acquired at any point in time.

The Protempis T-RAIM system includes cross constellation validation to attempt to mitigate these spoofing attacks.

Multi-path

Multi-path is a form of spoofing caused by the GNSS signal reflecting off of a surface and being received simultaneously with the non-reflected (line of sight) signal, or it may be the only signal available. This can have the same effects as spoofing in that the receiver computes incorrect position or timing solutions.

Alarm conditions of Spoofing and Multi-path

The Acutime 720 antenna detects Spoofing and Multi-path with internal software algorithms and alerts alarms at the Spoofing/Multi-path Bit 7 to major alarms in System Alarms (0xA3-00).

- Compares CNo values across constellations. If all CNo values are within 2dB then the signal is assumed to be spoofed and the spoofed alarm will be set.
- Compares the timing solution of constellations against other constellations. If the difference is more than 30 meters (~100ns) then the constellation is marked as spoofed and removed from the timing solution.
- Compares surveyed position against current position solution. If position has changed more than 30 meters then the spoofing alarm flag is set.

NOTE - Spoofing is a complex signal degradation technique that cannot effectively be automatically mitigated. That is why the Acutime 720 raises an alarm to signal potential spoofing conditions. It is up to the user equipment to decide if it wants to use the resultant timing solution or not in these alarm conditions.

Cable delay compensation

The default configuration of the Smart antenna provides optimal timing accuracy. The only item under user- or host-control that can affect the receiver's absolute PPS accuracy is the delay introduced by the antenna cable. For long cable runs, this delay can be significant. TSIP packet 0x91-01 / NMEA packet PS sets the cable delay parameter, which can be saved in non-volatile memory. For the best absolute PPS accuracy, adjust the cable delay to match the installed cable length (check with your cable manufacturer for the delay for a specific cable type). Generally, the cable delay is about 5.9 nanoseconds per meter of cable.

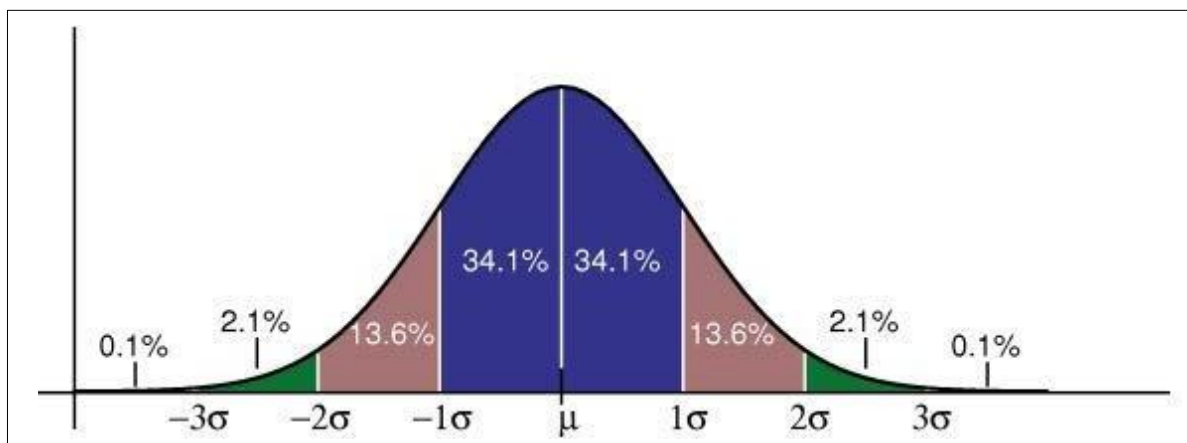
NOTE - To offset the propagation delay inherent in the antenna cable typically 5.9 ns per meter from the antenna to the receiver and further improve the accuracy, determine the length of the cable and enter the offset based on the specific cable type.

NOTE - Another source of delay that can affect high accuracy is antenna group delay. This is an effect generated by an antenna or signal splitter that causes different delays at different frequencies. For high-accuracy those delays must be accounted for and entered into the system with the "group delay" command (0x91-06).

Smart antenna performance

The time reference can be configured by the user with the 0x91-03 TSIP command. See [Timing Configuration \(0x91-03\)](#).

The PPS time accuracy is approximately three times worse, around 20 ns (1 sigma), when the receiver is computing position fixes during self-survey or when it's configured for 3D mode. The accuracy of the PPS is specified as a statistical Gaussian distribution. The plot below shows the likelihood function of a Gaussian distribution.



A definition of a parameter with 1 sigma (1σ) means that 68.2% of all samples are within the specified range, but 31.8% of all samples are outside. A definition with statistical notation also implies that there's no specified minimum or maximum. This applies also to Protempis's accuracy specifications of the Smart antenna.

Acquiring the correct time

It is recommended that the time information is derived from the timing messages in the TSIP or NMEA protocols. The time reported in position packets is a time-tag for this particular position fix, but not necessarily the time of the preceding PPS pulse.

| Protocol | Timing message |
|----------|-----------------------|
| TSIP | Report packet 0xA1-00 |
| NMEA | ZDA message |

- Ensure that the almanac is complete and the receiver is generating 3D fixes or reporting an overdetermined clock mode. This will eliminate the UTC offset jump.
- The time of the PPS pulse comes in the TSIP packet 0xA1-00 (see [page 93](#)) or NMEA packet ZDA following the PPS pulse.
- The leading edge of the PPS occurs on-time with the GNSS second. This can be either the rising edge (when the rising edge on-time is selected in TSIP packet 0x91-03) (see [page 64](#)) or the falling edge.
- If using TSIP, capture the time from TSIP packet 0xA1-00 (see [page 93](#)). If using NMEA, capture the time from NMEA packet ZDA (see [page 158](#)).
- Ensure that no alarm flags are raised by the receiver, which could indicate an uncertain or invalid time output.
- Once time is acquired, on the next PPS add 1 to the whole second to read the correct time.

NOTE - The smallest time resolution is one second.

Customizing operations

The Acutime 720 Smart antenna provides a number of user configurable parameters to customize the operation of the unit. These parameters can be stored in non-volatile storage (NVS) to be retained during loss of power and through resets with TSIP command 0x91-02 (see [page 83](#)). At reset or power-up, the receiver configures itself based on the parameters stored in the flash memory. You can change the value of these parameters to achieve the desired operations using a variety of TSIP packets. The Smart antenna configures itself based on the new parameter immediately, but the new parameter value is not automatically saved to flash. You must use the Save command to retain the parameters changed values in flash.

Send packet 0x91-02 to direct the Smart antenna to save the current parameter values to the flash. To save or delete the stored position, use command packet 0x91-04 (see [page 68](#)). You can also direct the receiver to set the parameter values to their factory default settings (and to erase the stored position) with packet 0x92-00.

In brief, to customize the Smart antenna operations for your application:

- Configure the receiver using TSIP command packets until the desired operation is achieved.
- Use TSIP packet 0x91-02 to save the settings in nonvolatile storage (flash). Check for the TSIP packet 0x91-02 response to verify the settings were saved successfully.
- If the position was not automatically saved during the self-survey or if it was manually entered, the position can be saved to flash memory using TSIP packet 0x91-04.

The new settings will control receiver operations whenever it is reset or power cycled.

Communication parameters

The Protempis® Acutime 720 Smart antenna supports two message protocols: TSIP and NMEA.

Communicating with the receiver is through serial ports. The port characteristics can be modified to accommodate your application requirements. The protocol settings and options are stored in Random Access Memory (RAM). They can be saved into the non-volatile memory (Flash), which does not require back-up power, if required, using command .

Protocols

The following protocols are available:

| Protocol | Specification | Direction |
|----------|---------------------------------------|-----------------------------|
| TSIP | Protempis proprietary binary protocol | Input / Output |
| NMEA | NMEA 0183 v4.1 | Input ¹ / Output |

¹Requires use of Protempis-proprietary NMEA messages.

Serial port default settings

The Acutime 720 Smart antenna supports two serial ports. The default settings are:

| Port | Port | Pin Number | Protocol | Characteristic | | | | |
|------|------|------------|----------------------|----------------|-----------|--------|-----------|--------------|
| | | | | Baud rate | Data bits | Parity | Stop bits | Flow control |
| A | UART | Diff. pair | | | | | | |
| | TXDA | 8, 10 | Not set ¹ | 115 kbps | 8 | None | 1 | None |
| B | RXDA | 6, 7 | Not set ¹ | 115 kbps | 8 | None | 1 | None |
| | TXDB | 4, 5 | TSIP out | 115 kbps | 8 | None | 1 | None |
| | RXDB | 2, 3 | TSIP in | 115 kbps | 8 | None | 1 | None |

¹Use the TSIP 0x91-00 command (see [page 53](#)) on Port A to configure protocol for Port B, and then use the TSIP 0x91-02 command (see [page 62](#)) to save the configuration.

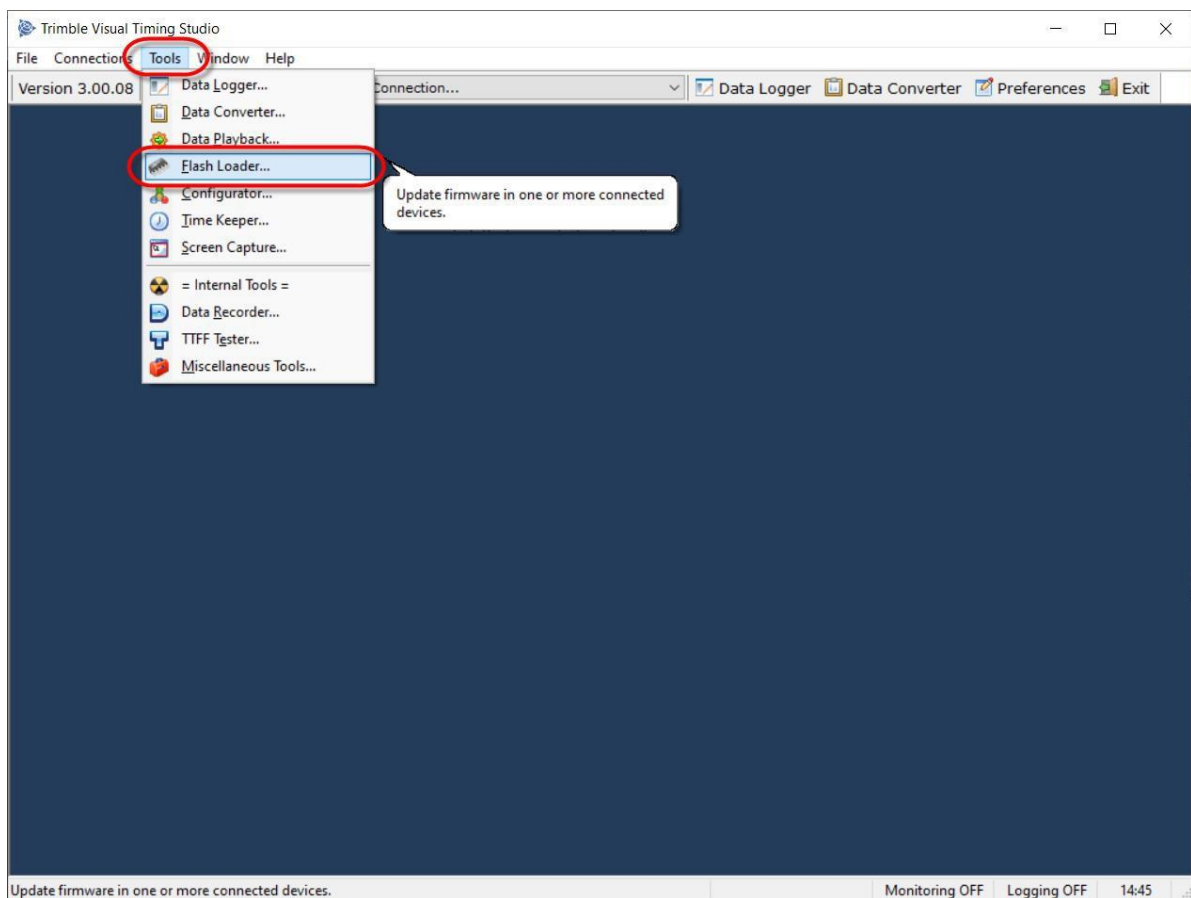
- Baud rate, data bits, parity, and stop bits are user configurable.
- Flow control is not available on the serial ports.

Updating the firmware

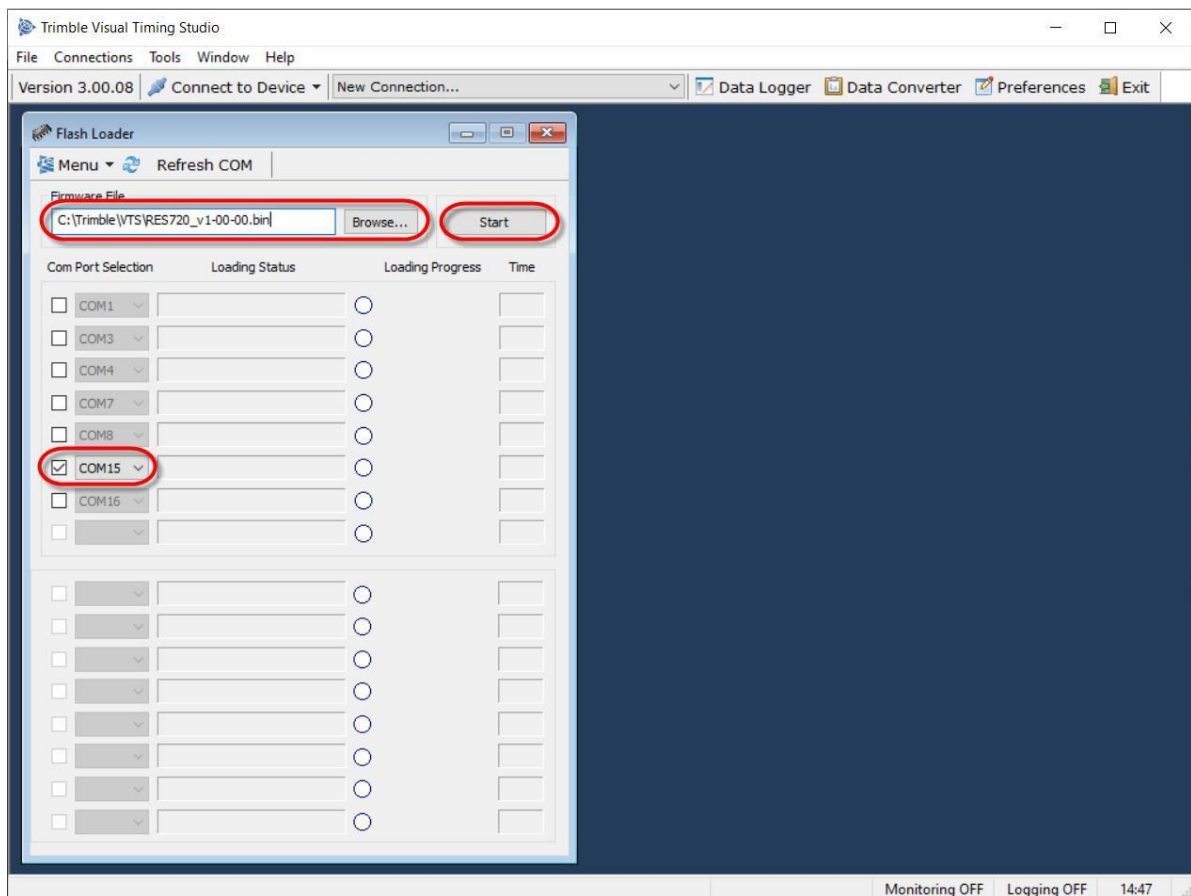
Use the VTS(v3.01.04 or higher) Flashloader tool to load firmware to the Acutime 720 Smart antenna.

As a preparation, connect the receiver to a computer that runs the Microsoft® Windows 10 operating system. Turn on the receiver and make a note of the COM port that connects to port A of the unit.

1. Start Protempis Visual Timing Studio.
2. From the **Tools** menu, select **Flash Loader**:



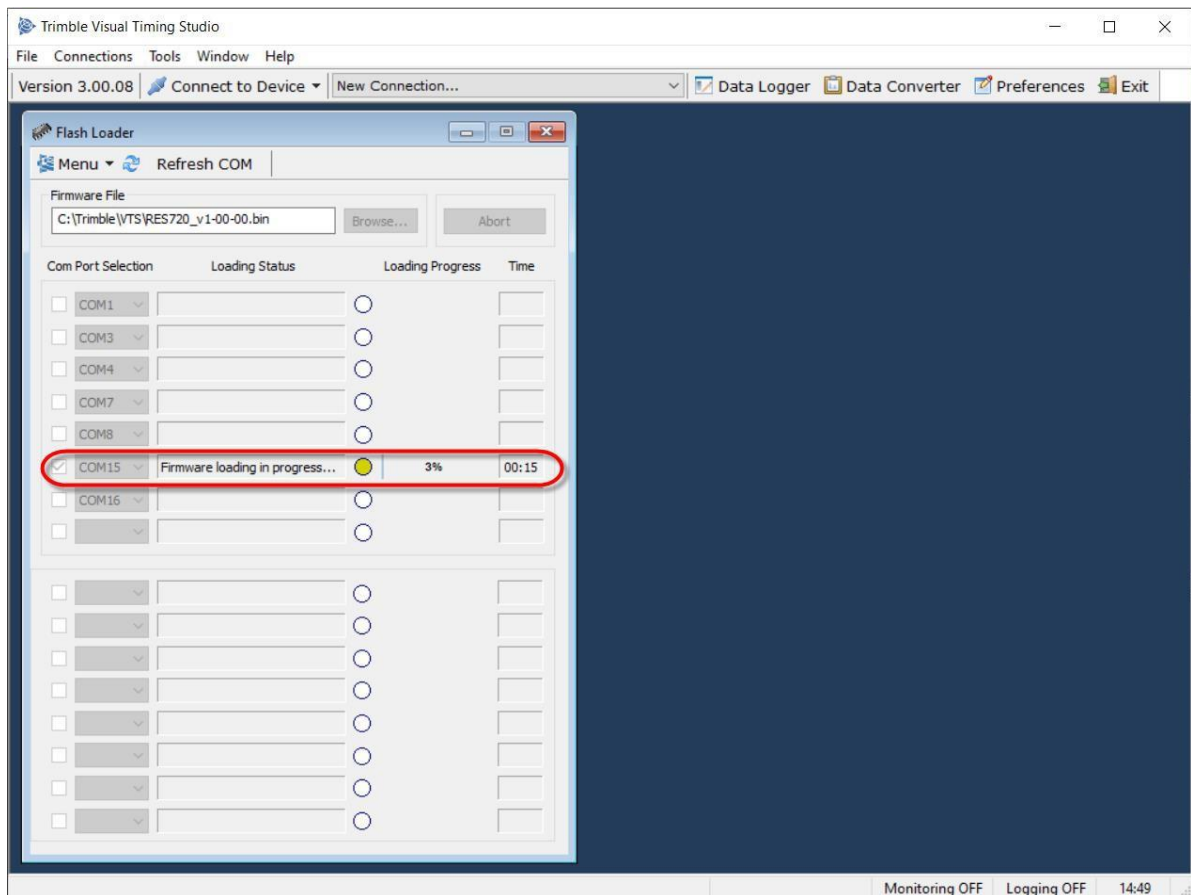
The following dialog appears:



3. Select the check box of the COM port that is connected to port A of the Smart antenna. Selecting a COM port in the Flash Loader software that is currently connected to a Monitor window automatically makes the Monitor window idle.
4. Click **Browse** and locate a valid firmware file for the Smart antenna. Double-check that you have selected the correct firmware file.

CAUTION - Loading an invalid file to the receiver may, in a worst case scenario, cause irreversible damage to the device.

5. When the COM port and firmware file are selected and the receiver is turned on, click **Start**. The file loading process starts:

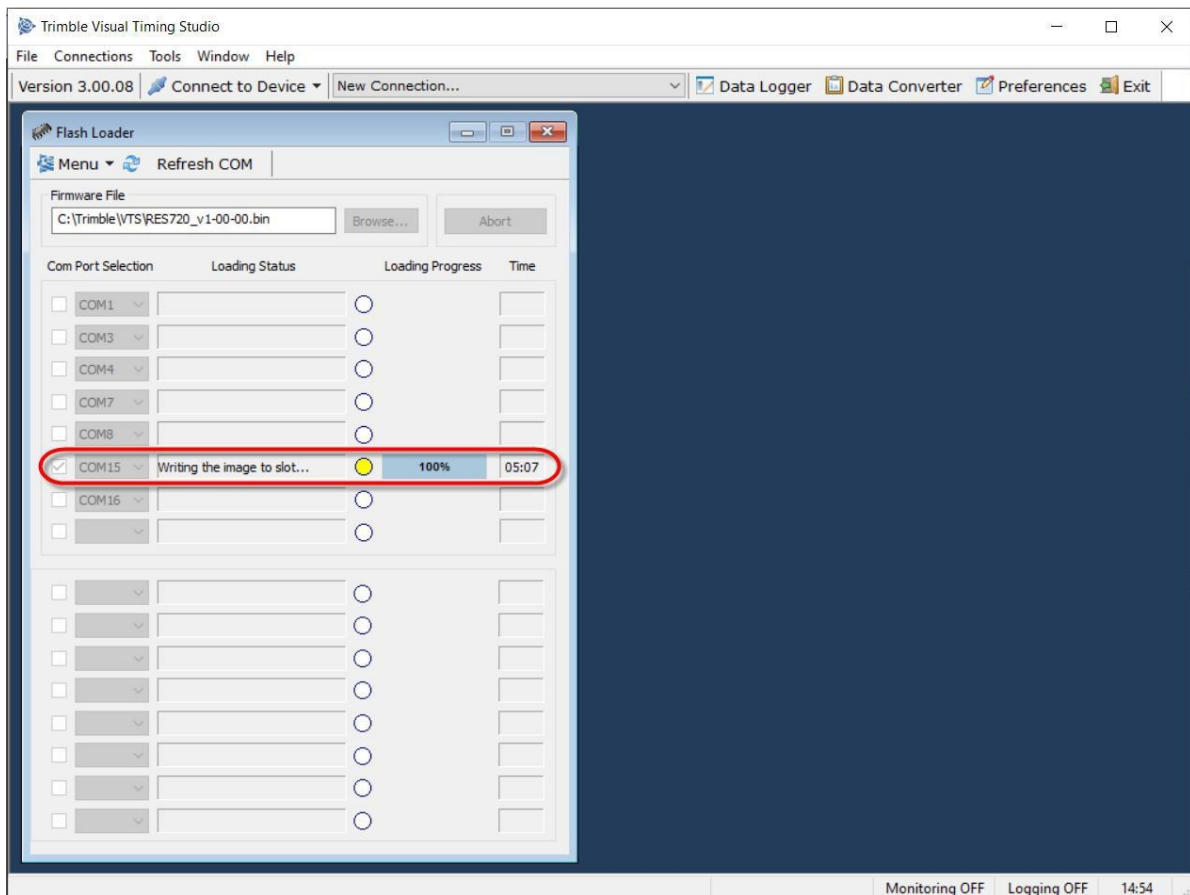


You will see the loading status, the loading progress and the time elapsed in the respective fields.

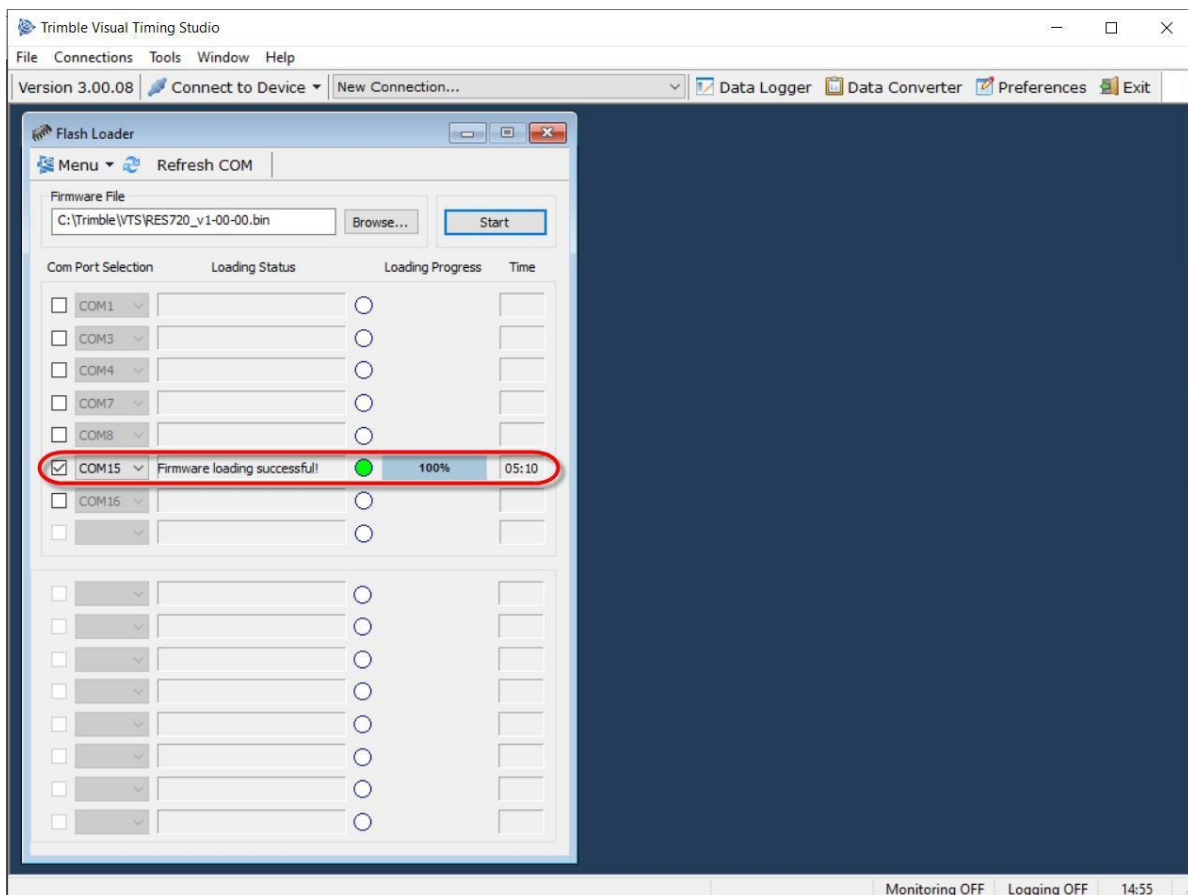
The receiver continues to operate normally during the file upload process. The firmware file is stored in a separate memory area and is not used before the upload process is 100% complete and successful.

Interrupting the firmware upload process does not cause any harm to the receiver as it still has the previous firmware in the active memory slot. An interrupted firmware upload process cannot be resumed, but you can repeat the file transfer from the start until it finishes with 100% success.

After the firmware has been successfully loaded to the receiver, it will be moved to the actual firmware slot, which is indicated by the *Loading Status*.



When the transfer to the firmware slot is finished, the *Loading Status* will show that the firmware loading was successful and the receiver will restart from the new firmware slot.



The time for the image upload takes several minutes, depending on the COM port speed. The time needed for writing the firmware to the firmware slot is very short, though. The actual service outage due to the firmware loading is basically just the normal TTFF time for the restart plus a few seconds for the firmware writing.

The firmware update process is very secure because the previous firmware is still the second firmware slot of the receiver. If for some reason, the new firmware does not correctly start up, it is still possible to roll back to the previous firmware version.

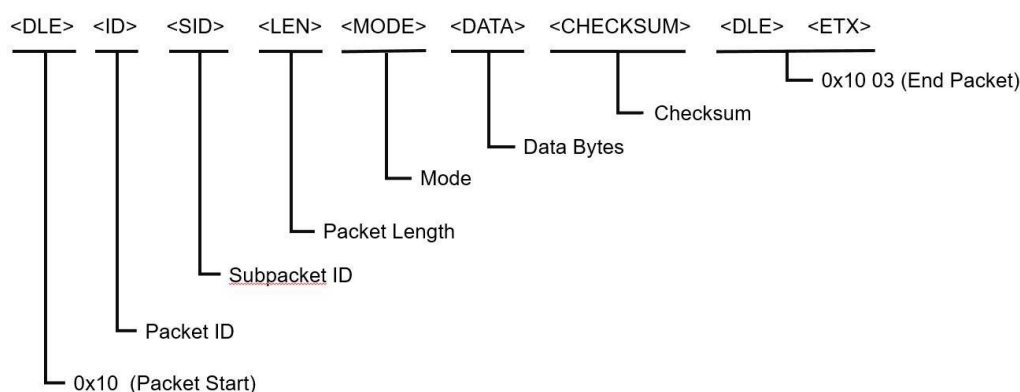
After the firmware loading, you can close the Flash Loader window and reconnect the Monitor window to Acutime 720 Smart antenna. Ensure that you are seeing the new firmware version in the software version information fields in the Monitor window.

Protempis Standard Interface Protocol(TSIP)

The Protempis[®] Acutime 720 Smart antenna introduces TSIP v1.0. While closely resembling the original TSIP, this version adds data length and checksum information, making it incompatible with legacy TSIP, but both can be interpreted with the same packet parsing routines. All packets have a packet ID as well as a subpacket ID. TSIP v1.0 packets can be identified by their packet ID.

TSIP v1.0 (Protempis Standard Interface Protocol v1.0) packet structure

The basic structure of a TSIP packet is the same for both command and report packets.



A typical v1.0 packet will look like the following format:

| Description | Value |
|------------------------|--------|
| Start of packet, <DLE> | 0x10 |
| Packet ID | 0x90 |
| Subpacket ID | 0x00 |
| Length (16-bit) | 0x0003 |
| Mode | 0x00 |
| Data | 0x04 |
| Checksum | 0x12 |
| End of packet 1, <DLE> | 0x10 |
| End of packet 2, <ETX> | 0x03 |

- <DLE> is the byte 0x10
- <ETX> is the byte 0x03
- Packets with similar information type are grouped together and have the same packet ID.

- Information in the packets is differentiated using subpacket IDs. Some of the groups are version, receiver configuration, PVT.
- All multi-byte values are sent big-endian.
- To prevent confusion with the starting and ending frame sequences, <DLE> <ID> and <DLE> <ETX> respectively, every <DLE> byte in the <data bytes> of a packet is preceded by an extra <DLE> stuffing byte. These extra <DLE> bytes must be added (stuffed) before sending a packet and removed (unstuffed) after receiving the packet.

Length

Length will be all bytes starting from Mode up to and including Checksum. Note that length is computed before padding of delimiter bytes (0x10).

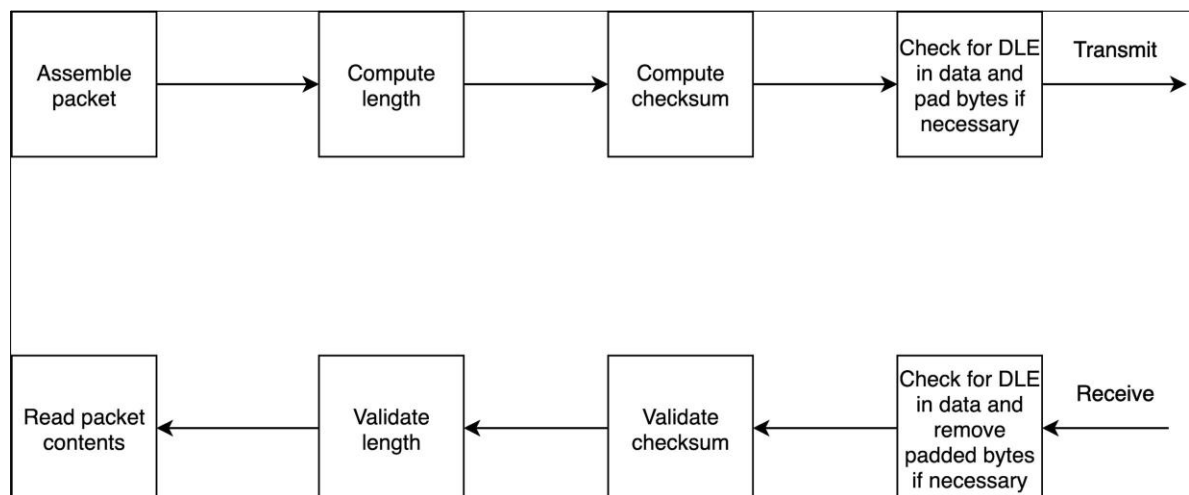
Mode

Mode for each command will be either one of Query (0x00) or Set (0x01) or Response (0x02). All packets do not support all of the modes; check packet description for supported modes.

Checksum

Checksum computation is a simple NMEA-like XOR of all bytes starting from packet ID up to and including the last data byte. Note that the TSIP delimiters are left out from the Checksum computation. Note that Checksum is computed before padding of delimiter bytes (0x10).

High-level packet flow



Packet groups

| Value | Name | Description |
|-------|---------------------|---|
| 0x90 | Version Information | Contains packets with firmware version, hardware code, production information etc |

| Value | Name | Description |
|-------|------------------------------|--|
| 0x91 | Receiver Configuration | Contains packets that can set baud rate etc |
| 0x92 | Resets | Contains packets with resets and reset cause |
| 0x93 | Production and Manufacturing | Contains board serial number and production data |
| 0xA0 | Firmware Upload | Contains packets related to firmware upload |
| 0xA1 | PVT | Contains packets with timing alarms, PPS status, and position |
| 0xA2 | GNSS information | Contains satellite tracked/used, signal level, azimuth elevation, prn etc |
| 0xA3 | Alarms and Status | Contains packets with major, minor and different receiver status information |
| 0xA4 | AGNSS | Contains packets that allow assisted GNSS loading of receiver |
| 0xA5 | Miscellaneous | |

Protocol Version (0x90-00)

Use TSIP 0x90-00 packet to obtain the protocol version being applied in the current FW version.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x90 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | Checksum of packet |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 90 00 00 02 00 92 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|--------------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x90 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | NMEA Major Version | UINT8 | Any | NMEA Major Version |
| 7 | NMEA Minor Version | UINT8 | Any | NMEA Minor Version |
| 8 | TSIP Version | UINT8 | Any | Protempis TSIP Version |

| Byte | Item | Type | Value | Description |
|------|------------------------|-------|-------|------------------------|
| 9 | Protempis NMEA Version | UINT8 | Any | Protempis NMEA Version |
| 10 | Reserved | UINT8 | Any | |
| 11 | Reserved | UINT8 | Any | |
| 12 | Reserved | UINT8 | Any | |
| 13 | Reserved | UINT8 | Any | |
| 14 | Reserved | UINT8 | Any | |
| 15 | Checksum | UINT8 | Any | Checksum of packet |
| 16 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 17 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

10 90 00 00 0B 02 04 01 01 01 FF FF FF FF FF 63 10 03

Receiver Version Information (0x90-01)

Use TSIP 0x90-01 packet to obtain the firmware version, HW version, Product name and etc.
The product name is Acutime 720.

.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x90 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

10 90 01 00 02 00 93 10 03

Response

| Byte | Item | Type | Value | Description |
|------|---------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x90 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Major Version | UINT8 | Any | Firmware Major Version |
| 7 | Minor Version | UINT8 | Any | Firmware Minor Version |
| 8 | Build Number | UINT8 | Any | Firmware Build Number |
| 9 | Month | UINT8 | 1-12 | Firmware Build Month |
| 10 | Day | UINT8 | 1-31 | Firmware Build Day |

| Byte | Item | Type | Value | Description |
|---------|------------------------|----------|--------|---|
| 11-12 | Year | INT16 | Any | Firmware Build Year |
| 13-14 | Hardware ID | UINT16 | | Hardware code |
| 15 | Length of Product Name | UINT8 | Any | The length of product name (L1) |
| 16 | Product Name | L1 bytes | String | Product name in ASCII |
| 16 + L1 | Product Capabilities | UNIT32 | Any | Bit-map of the product capabilities (default 0): Bit 0 : Single-frequency Bit 1 : NavIC enabled Bit2-31 : reserved (0) |
| 20 + L1 | Checksum | UINT8 | Any | |
| 21 + L1 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 22 + L1 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

10 90 01 00 14 02 00 01 00 0A 19 07 E3 0B F9 08 50 61 72 61 73 52 65 66 8B 10 03

Port Configuration (0x91-00)

Use TSIP packet 0x91-00 to set the port characteristics. You can enable or disable each port and both port can be enabled simultaneously.

TSIP or NMEA is configurable and user can change the serial port setup for each interface.

NOTE - After changing the serial port setup, save the configuration so that module can start up with the saved configuration after power cycles.

NOTE - If you lose your serial port setup, you can not connect the module. In this case, please use "auto detect" feature in the VTS tool.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-----------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Port | UINT8 | 0-1, 0xFF | 0: PORT A 1: PORT B 255: Current port |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 19 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 91 00 00 03 00 00 92 10 03
```

```
10 91 00 00 03 00 FF 6D 10 03
```

Set

| Byte | Item | Type | Value | Description |
|------|------------|-------|-------|-----------------|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-----------|---|
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6 | Port | UINT8 | 0-1, 255 | 0: Port A 1: Port B 255: Current port |
| 7 | Port Type | UINT8 | 0 | 0: UART Currently only UART is supported |
| 8 | Protocol | UINT8 | 2, 4, 255 | 2: TSIP 4: NMEA 255: Ignore |
| 9 | Baud Rate | UINT8 | 0-255 | 7: 9600 8: 19200 9: 38400 10: 57600 11: 115200 12: 230400 13: 460800 14: 921600 255: Ignore |
| 10 | Data Bits | UINT8 | 3, 255 | 3: 8 bits 255: Ignore |
| 11 | Parity | UINT8 | 0-2, 255 | 0: None 1: Odd 2: Even 255: Ignore |
| 12 | Stop Bits | UINT8 | 0-1, 255 | 0: 1 bit 1: 2 bits 255: Ignore |
| 13-16 | Reserved | UINT32 | Any | |
| 17-20 | Reserved | UINT32 | Any | |
| 21 | Checksum | UINT8 | Any | |
| 22 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 23 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set example to set TSIP protocol at baud rate of 115200 8N1

10 91 00 00 11 01 00 00 02 0B 03 00 00 FF FF FF FF FF FF FF 8B 10 03

Response

Response will be sent with the current settings and then the new settings will be applied.

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total Length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Port | UINT8 | 0-1 | 0: Port A 1: Port B |
| 7 | Port Type | UINT8 | 0 | 0: UART Currently only UART is supported |
| 8 | Protocol | UINT8 | 2, 4 | 2: TSIP 4: NMEA |
| 9 | Baud Rate | UINT8 | 7-14 | 7: 9600 8: 19200 9: 38400 10: 57600 11: 115200 12: 230400 13: 460800 14: 921600 |
| 10 | Data Bits | UINT8 | 3 | 3: 8 bits |
| 11 | Parity | UINT8 | 0-2 | 0: None 1: Odd 2: Even |
| 12 | Stop Bits | UINT8 | 0-1 | 0: 1 bit 1: 2 bits |
| 13-16 | Reserved | UINT32 | Any | |
| 17-20 | Reserved | UINT32 | Any | |
| 21 | Checksum | UINT8 | Any | |
| 22 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 23 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

GNSS Configuration (0x91-01)

Use TSIP packet 0x91-01 to set the GNSS configuration. Each constellation can be set with each bit mask.

NOTE - To get the verified combinations of GNSS constellation, please refer to the "GNSS Constellation Configuration" chapter.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

10 91 01 00 02 00 92 10 03

Set

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |

| Byte | Item | Type | Value | Description |
|------|---------------|--------|-------|--|
| 6-9 | Constellation | UINT32 | Any | Bit 0 - GPS L1C Bit 1 - GPS L2 (not supported, for future use) Bit 2 - GPS L5 Bit 3 - Reserved Bit 4 - GLONASS G1 Bit 5 - GLONASS G2 (not supported, for future use) Bit 6,7 - Reserved Bit 8 - SBAS Bit 9 - Reserved Bit 10 - Reserved Bit 11 - Reserved Bit 12 - Beidou B1 Bit 13 - Beidou B2i (not supported, for future use) Bit 14 - Beidou B2a Bit 15 - Reserved Bit 16 - Galileo E1 Bit 17 - Galileo E5a Bit 18 - Galileo E5b (not supported, for future use) Bit 19 - Galileo E6 (not supported, for future use) Bit 20 - Reserved Bit 21 - QZSS L1C Bit 22 - QZSS L2C (not supported, for future use) Bit 23 - QZSS L5 Bit 24 - Reserved Bit 25 - Reserved Bit 26 - NavIC L5 Bit 27 - Reserved Bit 28 - Reserved Bits 29-31 - Reserved Set bits indicate enabled constellation and frequency 0xFFFFFFFF indicates that this field needs to be ignored |

| Byte | Item | Type | Value | Description |
|-------|---------------------|--------|--------|--|
| 10-13 | Elevation Mask | SINGLE | 0-90 | In degrees Lowest satellite elevation for fixes only when the receiver is operating in the overdetermined clock mode 0xFF indicates this fields needs to be ignored. |
| 14-17 | Signal/CNO Mask | SINGLE | 0-37 | In dB-Hz Minimum signal level for fixes., used when the receiver is operating in the overdetermined clock mode 0xFF indicates this fields needs to be ignored |
| 18-21 | PDOP Mask | SINGLE | 0 - 10 | Maximum PDOP for fixes -1: Ignore field |
| 22 | Anti-jamming | UINT8 | 1 | 1: Enabled (ignored) For potential future use, In this product Anti-jamming is always enabled as the algorithms are augmented so that the meaning is no longer valid. 0xFF indicates this fields needs to be ignored |
| 23 | Fix Rate | UINT8 | 0 | 0: 1 Hz (ignored) For future use, currently we only support 1 Hz 0xFF indicates this fields needs to be ignored |
| 24-27 | Antenna cable delay | SINGLE | 0-1e-6 | In seconds |
| 28-31 | Reserved | UINT32 | Any | |
| 32 | Checksum | UINT8 | Any | |
| 33 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 34 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set example:

10 91 01 00 1C 01 00 03 50 15 40 A0 00 00 41 F0 00 00 40 C0 00 00 01 00 00 00 00 00 FF FF
FF FF 1B 10 03

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|-------|----------------|--------|-------|--|
| 6-9 | Constellation | UINT32 | Any | Bit 0 - GPS L1C Bit 1 - GPS L2 (not supported, for future use) Bit 2 - GPS L5 Bit 3 - Reserved Bit 4 - GLONASS G1 Bit 5 - GLONASS G2 (not supported, for future use) Bit 6,7 - Reserved Bit 8 - SBAS Bit 9 - Reserved Bit 10 - Reserved Bit 11 - Reserved Bit 12 - Beidou B1 Bit 13 - Beidou B2i (not supported, for future use) Bit 14 - Beidou B2a Bit 15 - Reserved Bit 16 - Galileo E1 Bit 17 - Galileo E5a Bit 18 - Galileo E5b (not supported, for future use) Bit 19 - Galileo E6 (not supported, for future use) Bit 20 - Reserved Bit 21 - QZSS L1C Bit 22 - QZSS L2C (not supported, for future use) Bit 23 - QZSS L5 Bit 24 - Reserved Bit 25 - Reserved Bit 26 - NavIC L5 Bit 27 - Reserved Bit 28 - Reserved Bits 29-31 - Reserved Set bits indicate enabled constellation and frequency |
| 10-13 | Elevation Mask | SINGLE | 0-90 | In degrees Lowest satellite elevation for fixes only when the receiver is operating in the overdetermined clock mode |

| Byte | Item | Type | Value | Description |
|-------|---------------------|--------|--------|--|
| 14-17 | Signal Mask | SINGLE | 0-37 | In dB-Hz Minimum signal level for fixes. Used when the receiver is operating in the overdetermined clock mode |
| 18-21 | PDOP Mask | SINGLE | 0-10 | Maximum PDOP for fixes |
| 22 | Anti-jamming | UINT8 | 1 | 1: Enabled |
| 23 | Fix Rate | UINT8 | 0 | 0: 1 Hz |
| 24-27 | Antenna cable delay | SINGLE | 0-1e-6 | In seconds |
| 28-31 | Reserved | UINT32 | Any | |
| 32 | Checksum | UINT8 | Any | |
| 33 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 34 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

```
10 91 01 00 1C 02 00 00 00 05 41 C8 00 00 42 14 00 00 40 40 00 00 01 00 34 04 7F EF FF FF
FF FF F5 10 03
```

NVS Configuration (0x91-02)

Use TSIP packet 0x91-02 to set the NVS(Non-volatile storage) configuration. User can save the current configuration in the internal flash memory.

NOTE - To start up the user configuration from power cycles, please use TSIP packet to save the user configuration.

Set

| Byte | Item | Type | Value | Description |
|------|-------------------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x02 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6 | Save User Config to NVS | UINT8 | 0-1 | 1: Save user config to NVS |
| 7-10 | Reserved | UINT32 | Any | |
| 11 | Checksum | UINT8 | Any | |
| 12 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 13 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response

| Byte | Item | Type | Value | Description |
|------|-------------------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x02 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Save User Config Status | UINT8 | 0-1 | 0: Save failed 1: User config save successful |

| Byte | Item | Type | Value | Description |
|------|-------------|--------|-------|-----------------|
| 7-10 | Reserved | UINT32 | Any | |
| 11 | Checksum | UINT8 | Any | |
| 12 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 13 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Timing Configuration (0x91-03)

Use TSIP packet 0x91-03 to set the timing configuration of the receiver.

Time base and PPS base can be configurable from each constellation with PPS availability mask.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x03 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 91 03 00 02 00 90 10 03
```

Set

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x03 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |

| Byte | Item | Type | Value | Description |
|-------|-------------|--------|-------|---|
| 6 | Time base | UINT8 | Any | Bit 2:0 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) |
| 7 | PPS base | UINT8 | Any | Bit 2:0 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) |
| 8 | PPS Mask | UINT8 | Any | Bit 2:0 0: PPS off 1: PPS always on 2: PPS fix based 3: PPS when valid Bit 3 0: Positive PPS polarity 1: Negative PPS polarity Bit 4: 0: 1PPS 1: Even PP2S Bit 5: Reserved |
| 9-12 | reserved | UNIT32 | Any | |
| 13-14 | Width | UINT16 | Any | In milliseconds, $1 < \text{width} \leq 500$, value must be value |
| 15-22 | Offset | DOUBLE | Any | In seconds, $-0.25 \leq \text{offset} \leq +0.25$ (set to 0 if $\text{offset} \geq \text{pulse width of resultant frequency}$) |
| 23 | Checksum | UINT8 | Any | |
| 24 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 25 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set example:

10 91 03 00 13 01 00 00 01 FF FF FF FF 00 C8 00 00 00 00 00 00 00 00 49 10 03

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x03 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Time base | UINT8 | Any | Bit 2:0 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) |
| 7 | PPS base | UINT8 | Any | Bit 2:0 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) |

| Byte | Item | Type | Value | Description |
|-------|-------------|--------|-------|---|
| 8 | PPS Mask | UINT8 | Any | Bit 2:0 0: PPS off 1: PPS always on 2: PPS fix based 3: PPS when valid Bit 3 0: Positive PPS polarity 1: Negative PPS polarity Bit 4: 0: 1PPS 1: Even PP2S Bit 5: Reserved |
| 9-12 | Reserved | UINT32 | Any | |
| 13-14 | PPS Width | UINT16 | Any | In milliseconds |
| 15-22 | PPS offset | DOUBLE | Any | In seconds |
| 23 | Checksum | UINT8 | Any | |
| 24 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 25 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

```
10 91 03 00 13 02 00 00 01 FF FF FF FF 00 C8 00 00 00 00 00 00 00 00 4A 10 03
```

Self-Survey Configuration (0x91-04)

Use TSIP packet 0x91-04 to set the self-survey configuration.

Self-survey Length field to specify the number of position fixes that are to be averaged together to form the self-surveyed position used for clock-only fixes.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x04 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 91 04 00 02 00 97 10 03
```

Set

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x04 | Subpacket ID |
| 3-4 | Length | UINT16 | 11 | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |

| Byte | Item | Type | Value | Description |
|-------|------------------------|--------|---------------------------------------|---|
| 6 | Self-Survey Mask | UINT8 | Any | Bit 0: 0: Ignore 1: Restart self-survey Bit 1: 0: Disable self-survey 1: Enable self-survey Bit 3: 0: Don't save position 1: Save self-surveyed position at the end of the survey |
| 7-10 | Self-survey Length | UINT32 | values between 1 and 172800 inclusive | Number of fixes to average and enter overdetermined mode (default : 2000 fixes) |
| 11-12 | Horizontal Uncertainty | UINT16 | >=3 <=1000 | Horizontal position uncertainty, meters (default 40 meter) |
| 13-14 | Vertical Uncertainty | UINT16 | >=3 <=1000 | Vertical position uncertainty, meters (default 40 meter) |
| 15 | Checksum | UINT8 | Any | |
| 16 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 17 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set example:

10 91 04 00 0B 01 0A 00 00 00 C8 00 28 00 28 5D 10 03

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x04 | Subpacket ID |
| 3-4 | Length | UINT16 | 11 | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|-------|------------------------|--------|---------------|--|
| 6 | Self-Survey Mask | UINT8 | Any | Bit 0: 0: Ignore 1: Restarted self-survey, only returned in response to set command, 0 otherwise Bit 1: 0: Self-survey disabled 1: Self-survey enabled Bit 3: 0: Don't save position 1: Save self-surveyed position at the end of the survey |
| 7-10 | Self-survey Length | UINT32 | Any | Number of fixes to average and enter overdetermined mode |
| 11-12 | Horizontal Uncertainty | UINT16 | >=3 <=1000 | Horizontal position uncertainty, meters |
| 13-14 | Vertical Uncertainty | UINT16 | >=3 <=1000 | Vertical position uncertainty, meters |
| 15 | Checksum | UINT8 | Any | |
| 16 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 17 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

10 91 04 00 0B 02 0A 00 00 00 C8 00 28 00 28 5E 10 03

Receiver Configuration (0x91-05)

Use TSIP packet 0x91-05 to set the receiver configuration and bit mask the automatic output messages.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-----------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x05 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Port | UINT8 | 0-1, 0xFF | 0: PORT A 1: PORT B 255: Current port |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-----------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x05 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6 | Port | UINT8 | 0-1, 0xFF | 0: PORT A 1: PORT B 255: Current port |

| Byte | Item | Type | Value | Description |
|-------|----------------|--------|-------|--|
| 7-10 | Type of output | UINT32 | Any | Settings: 00: Query mode 01: Event mode 10: Periodic mode 11: Ignored Bit positions: 0-1: 0xA1-00 Timing information 2-3: Reserved 4-5: 0xA1-11 Position information 6-7: 0xA3-00 System alarms 8-9: 0xA3-11 Receiver status 10-11: 0xA2-00 Satellite information 12-13: 0xA1-06 Event Capture *Only event capture information is a true event mode. For the others, event mode and periodic mode are the same. |
| 11-14 | Type of output | UINT32 | Any | Reserved |
| 15-18 | Type of output | UINT32 | Any | Reserved |
| 19-22 | Type of output | UINT8 | Any | Reserved |
| 23 | Checksum | UINT8 | Any | |
| 23 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 24 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

NOTE - By default, only timing information (0xA1-00) is in periodic mode on port A.

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x05 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|-------|----------------|--------|-----------|---|
| 6 | Port | UINT8 | 0-1, 0xFF | 0: PORT A 1: PORT B 255: Current port |
| 7-10 | Type of output | UINT32 | Any | Settings: 00: Query mode 01: Event mode 10: Periodic mode 11: Ignored Bit positions: 0-1: 0xA1-00 Timing information 2-3: Reserved 4-5: 0xA1-11 Position information 6-7: 0xA3-00 System alarms 8-9: 0xA3-11 Receiver status 10-11: 0xA2-00 Satellite information |
| 11-14 | Type of output | UINT32 | Any | Reserved |
| 15-18 | Type of output | UINT32 | Any | Reserved |
| 19-22 | Type of output | UINT32 | Any | Reserved |
| 23 | Checksum | UINT8 | Any | |
| 23 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 24 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Group Delay Configuration (0x91-06)

Use TSIP 0x91-06 to set the group delay configuration of each GNSS frequency band.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x06 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x06 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6-7 | L1 delay | INT16 | Any | 1575.42 MHz group-delay, 1/10 ns. This is for GPS, Galileo, and QZSS L1 signals. |
| 8-9 | G1 delay | INT16 | Any | 1602.00 MHz group-delay, 1/10 ns. This is for GLONASS L1 signals. |
| 10-11 | B1 delay | INT16 | Any | 1561.098 MHz group-delay, 1/10 ns. This is for BeiDou B1 signals. |
| 12-13 | L5 delay | INT16 | Any | 1176.45 MHz group-delay, 1/10 ns. This is for GPS L5, Galileo E5a, BeiDou B2a, and QZSS L5 signals. |
| 14 | Checksum | UINT8 | Any | |

| Byte | Item | Type | Value | Description |
|------|-------------|-------|-------|-----------------|
| 15 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 16 | Delimiter 2 | UINT8 | 0x13 | End of packet 2 |

Response

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x06 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6-7 | L1 delay | UNIT16 | > 0 | 1575.42 MHz group-delay, 1/10 ns. This is for GPS, Galileo, and QZSS L1 signals. This is a delay , so must be > 0. 0xFFFF means "unchanged". |
| 8-9 | G1 delay | UINT16 | > 0 | 1602.00 MHz group-delay, 1/10 ns. This is for GLONASS L1 signals. This is a delay , so must be > 0. 0xFFFF means "unchanged". |
| 10-11 | B1 delay | UINT16 | > 0 | 1561.098 MHz group-delay, 1/10 ns. This is for BeiDou B1 signals. This is a delay , so must be > 0. 0xFFFF means "unchanged". |
| 12-13 | L5 delay | UINT16 | > 0 | 1176.45 MHz group-delay, 1/10 ns. This is for GPS L5, Galileo E5a, BeiDou B2a, and QZSS L5 signals. This is a delay , so must be > 0. 0xFFFF means "unchanged". |
| 14 | Checksum | UINT8 | Any | |
| 15 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 16 | Delimiter 2 | UINT8 | 0x13 | End of packet 2 |

Event Capture Configuration (0x91-07)

Use TSIP 0x91-07 packet to set the event capture configuration.

This configuration allows outputting timing packet when an event input is captured.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x07 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 91 07 00 02 00 94 10 03
```

Set

| Byte | Item | Type | Value | Description |
|------|--------------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x07 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6 | Event capture mode | UNIT16 | 0-1 | 0: Disable 1: Enable 0xFF indicates this fields needs to be ignored |
| 7-10 | Offset | UNIT32 | Any | Offset to be compensated in nanoseconds 0xFF indicates this field needs to be ignored |

| Byte | Item | Type | Value | Description |
|-------|-------------------|--------|-------|--|
| 11 | Clear event count | UNIT8 | 1 | 1: Clear event count 0xFF indicates this field needs to be ignored. |
| 12-15 | Reserved | UNIT32 | Any | |
| 16 | Checksum | UINT8 | Any | |
| 17 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 18 | Delimiter 2 | UINT8 | 0x13 | End of packet 2 |

Set example:

10 91 07 00 0C 01 01 00 00 00 00 FF FF FF FF FF 65 10 03

Response

| Byte | Item | Type | Value | Description |
|-------|--------------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x07 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Event capture mode | UNIT16 | 0-1 | 0: Disabled 1: Enabled |
| 7-10 | Offset | UINT32 | Any | Offset to be compensated in nanoseconds |
| 11-14 | Reserved | UNIT32 | Any | |
| 15 | Checksum | UINT8 | Any | |
| 16 | Delimiter 2 | UINT8 | 0x10 | End of packet 1 |
| 17 | Delimiter 2 | UNIT8 | 0x03 | End of packet 2 |

Response example:

10 91 07 00 0B 02 01 00 00 00 00 FF FF FF FF 9E 10 03

Position Info Configuration (0x91-08)

Use TSIP 0x91-08 packet to set the position information configuration.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x08 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

10 91 08 00 02 00 9B 10 03

Set

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x08 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |

| Byte | Item | Type | Value | Description |
|------|---------------|-------|-------|---|
| 6 | Position mask | UINT8 | 0-15 | Bit 0 0: Real-time position 1: Surveyed position Bit 1 0: LLA 1: XYZ ECEF Bit 2 0: HAE 1: MSL Bit 3 0: Velocity ENU 1: Velocity ECEF |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x13 | End of packet 2 |

Set example:

10 91 08 00 03 01 00 9B 10 03

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x08 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|------|---------------|--------|-------|---|
| 6 | Position mask | UNIT16 | 0-1 | Bit 0 0: Real-time position 1: Surveyed position Bit 1 0: LLA 1: XYZ ECEF Bit 2 0: HAE 1: MSL Bit 3 0: Velocity ENU 1: Velocity ECEF |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 2 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UNIT8 | 0x03 | End of packet 2 |

Response example:

10 91 08 00 03 02 00 98 10 03

NMEA Output Configuration (0x91-13)

Use TSIP 0x91-13 packet to set the NMEA output configuration.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x13 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Port | UINT8 | Any | 0: Port A 1: Port B 255: Current Port |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x13 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6 | Port | UINT8 | Any | 0: Port A 1: Port B 255: Current Port |
| 7 | Interval | UINT8 | 1-255 | Output interval (seconds) Default is 1 second |

| Byte | Item | Type | Value | Description |
|------|-------------|--------|-------|---|
| 8-11 | Output mask | UNIT32 | Any | Bit 0: GGA Bit 1: GLL Bit 2: VTG Bit 3: GSV Bit 4: GSA Bit 5: ZDA Bits 6-7: Reserved Bit 8: RMC Default is 0x3D |
| 12 | Checksum | UINT8 | Any | |
| 13 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 14 | Delimiter 2 | UINT8 | 0x13 | End of packet 2 |

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x91 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x13 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Port | UINT8 | 0-1 | 0: Port A 1: Port B |
| 7 | Interval | UINT8 | 1-255 | Output interval (seconds) |
| 8-11 | Output mask | UNIT32 | Any | Bit 0: GGA Bit 1: GLL Bit 2: VTG Bit 3: GSV Bit 4: GSA Bit 5: ZDA Bit 8: RMC Default is 0x3D |
| 12 | Checksum | UINT8 | Any | |
| 13 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 14 | Delimiter 2 | UINT8 | 0x13 | End of packet 2 |

Receiver Reset (0x92-00)

Use TSIP 0x92-00 to set the receiver reset configuration.

A cold reset will clear the GNSS data (almanac, ephemeris, etc.) stored in RAM but retain the surveyed position and saved user configuration.

A hot reset will initiate the module but not erase any stored information.

A factory reset will additionally restore the factory defaults of all configuration parameters stored in flash memory.

A warm reset will clear ephemeris and oscillator uncertainty but retains the last position, time and almanac.

A system reset will clear the GNSS data (almanac, ephemeris, etc.) stored in RAM but retain the surveyed position and saved user configuration.

NOTE - Before applying reset, please be sure that the current configuration has stored in the NVS so that the current configuration can bring up during start-up.

NOTE - If the Factory reset were applied, all current configuration will be back to the factory default, so the serial port setup also will be back to default set.

Set

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x92 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6 | Reset Type | UINT8 | 0-5 | 1: Cold reset 2: Hot reset 3: Warm reset 4: Factory Reset 5: System Reset |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Reset Cause (0x92-01)

Use TSIP 0x92-01 to obtain the reset cause.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x92 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x92 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Reset Cause | UINT8 | 0-8 | 0: No reset 1: Cold reset 2: Hot reset 3: Warm reset 4: Factory reset 5: System reset 6: Power cycle 7: Watchdog 8: Hardfault/other |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

NOTE - This packet is sent by the unit on every start-up and can also be queried.

Production Information (0x93)

Use TSIP packet 0x93 to obtain the production information of the receiver.

This packet includes serial number information, build date information, production information and etc.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x93 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response

| Byte | Item | Type | Value | Description |
|-------|----------------|-----------|------------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0x93 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 2: Response |
| 6 | Reserved | UINT8 | 0xFF | |
| 7-10 | Serial No. | UINT8 | Any | Board serial number |
| 11-26 | Ext Serial No. | UINT8[16] | Any | Board extended serial number |
| 27 | Build Day | UINT8 | 1-31 | Day of board build day. |
| 28 | Build Month | UINT8 | 1-12 | Month of board build date |
| 29-30 | Build Year | UINT16 | 2020-65535 | Year of board build date |

| Byte | Item | Type | Value | Description |
|-------|------------------|-----------|-------------|--|
| 31 | Build Hour | UINT8 | 0-23 | Hour of board build day |
| 32-33 | Machine ID | UINT16 | | Machine ID |
| 34-49 | Hardware ID | UINT8[16] | Any | Hardware ID string |
| 50-65 | Product ID | UINT8[16] | Any | Product ID string |
| 66-69 | Premium Options | UINT32 | Any | Premium product options |
| 70-73 | Reserved | UINT32 | 0xFF | Reserved |
| 74-77 | Osc search range | FLT | 0.001-8.000 | Default oscillator search range in PPM |
| 78-81 | Osc offset | FLT | 0.001-8.000 | Default oscillator offset in PPM |
| 82 | Checksum | UINT8 | Any | |
| 83 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 84 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Firmware Upload (0xA0)

Use TSIP packet 0xA0 to upload firmware.

Assumptions:

- Only one of the two application ports can be used to upgrade firmware at a time. Simultaneous upload is not permitted.
- If frame size is 256 bytes and image size is 257 bytes, data will not be padded. Frame 1 will have 256 bytes and frame 2 will have one byte.
- Image size should be less than than 3 MB.

Firmware Upload Request

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|----------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA0 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 1 | 1: Set |
| 6 | Command | UINT8 | Any | 0x00: Firmware Upload Request |
| 7-8 | Frame Size | UINT16 | 256/1024 | Individual frame size in bytes For baud rates < 115200, only 256 is allowed For baud rates >= 115200, 256 and 1024 are both allowed |
| 9-12 | Reserved | UINT32 | Any | |
| 13-16 | Reserved | UINT32 | Any | |
| 17 | Checksum | UINT8 | Any | |
| 18 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 19 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Send Data Frame

| Byte | Item | Type | Value | Description |
|----------------------------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA0 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 1: Set |
| 6 | Command | UINT8 | Any | 0x01: Send Data frame |
| 7-10 | Frame Number | UINT32 | | Frame Number starting from 1 to (including) N |
| 11-14 | Total Frames | UINT32 | | |
| 15 - (15 +frame size) (=X) | Data | | Any | Image that needs to be loaded |
| X + 1 - X + 2 | Checksum | UINT8 | Any | |
| X + 3 - X + 4 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| X + 5 - X + 6 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Firmware Upload ACK/NACK

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA0 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|------|-------------|--------|--------|---|
| 6 | Command | UINT8 | Any | Command for which ACK/NACK is sent NOTE - For the final ACK or timeout NACK, this field will have a value of 0x01 (program slot) |
| 7 | Status | UINT8 | 0-0x2C | 0x00: ACK (for fw request) 0x01: ACK for frame N 0x02: ACK for successful write to slot N 0x03: ACK for successful slot erase 0x20: NACK for invalid file checksum, stop update process 0x21: NACK for extra data in frame or less data, resend frame with requested frame size 0x22: NACK for timeout, stop update process 0x23: NACK for frame size 0x24: NACK for frame number, resend frame 0x25: NACK for invalid command 0x26: NACK for unsuccessful slot erase 0x27: NACK for unsuccessful write to slot N, stop update 0x28: NACK, update in process 0x29: NACK for invalid image checksum, stop update process 0x2A: NACK for invalid file header ID, stop update process 0x2B: NACK for invalid image header name, stop update process 0x2C: NACK for invalid number of images in file 0x2D: NACK for number of retries exceeded NOTE - In case of packet checksum error, host will receive checksum error message and host will have to resend frame. |
| 8-11 | Frame | UINT32 | Any | Contents valid only if status is 0x01, 0x21, 0x24. For all other status return contents is undefined. |
| 12 | Checksum | UINT8 | Any | |
| 13 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 14 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

After the last data frame is sent the unit will generate an additional ACK. The ACK for successful write to Slot N is sent only if the slot was erased and programmed successfully. Else, the corresponding NACK status is sent (0x20, 0x26 or 0x29).

Switch slots and restart (0xA0-01)

Use TSIP packet 0xA0-01 to switch the active firmware slot being used by the system. This will reset the system and start from the inactive slot

Set

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA0 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0-1 | 1: Set |
| 6-9 | Reserved | UINT32 | Any | |
| 10-13 | Reserved | UINT32 | Any | |
| 14 | Checksum | UINT8 | Any | |
| 15 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 16 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Set example:

```
10 A0 01 00 0A 01 00 00 00 00 00 00 00 00 00 AA 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA0 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0-2 | 2: Response |
| 6 | Status | UINT8 | 0-1 | 0x00 : Restarting receiver 0x01 : Running latest firmware |

| Byte | Item | Type | Value | Description |
|------|-------------|-------|-------|-----------------|
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Timing Information (0xA1-00)

Use TSIP packet 0xA1-00 to obtain the timing information of the receiver.

This packet provides Week number, Time-of-week (TOW), UTC integer offset, time flags, data and time-of-day (TOD), PPS Quantization error and Bias/Bias Rate information.

If this packet is queried, a response will be transmitted shortly after the PPS pulse to which it refers.

This packet will generate once per second automatically as a default set and you can clear the automatic output on [Receiver Configuration \(0x91-05\)](#).

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 A1 00 00 02 00 A3 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6-9 | Time of Week | UINT32 | Any | Time of week |

| Byte | Item | Type | Value | Description |
|-------|------------------------|--------|-------|---|
| 10-11 | Week Number | UINT16 | Any | Week number |
| 12 | Hours | UINT8 | 0-23 | Hours |
| 13 | Minutes | UINT8 | 0-59 | Minutes |
| 14 | Seconds | UINT8 | 0-59 | Seconds |
| 15 | Month | UINT8 | 1-12 | Month |
| 16 | Day of month | UINT8 | 1-31 | Day of month |
| 17-18 | Year | UINT16 | Any | Four digits of year |
| 19 | Time base | UINT8 | Any | Bit 2:0: 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) |
| 20 | PPS base | UINT8 | Any | Bit 2:0: 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) |
| 21 | Flags | UINT8 | | Bit 0: 0: UTC invalid 1: UTC valid Bit 1: 0: Time invalid 1: Time valid |
| 22-23 | UTC Offset | SINT16 | Any | UTC offset from chosen constellation time |
| 24-27 | PPS Quantization Error | SINGLE | Any | Quantization error, in nanoseconds. |
| 28-31 | Bias | SINGLE | Any | In seconds |
| 32-35 | Bias rate | SINGLE | Any | In seconds/second |

| Byte | Item | Type | Value | Description |
|------|-------------|-------|-------|-----------------|
| 36 | Checksum | UINT8 | Any | |
| 37 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 38 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response Example:

10 A1 00 00 20 02 00 05 29 98 08 50 15 3A 30 0A 15 07 E4 00 00 03 00 12 3F B3 9E 72 40 42
37 EB 42 79 87 11 8E 10 03

Timing UTC Offsets (0xA1-01)

Use TSIP packet 0xA1-01 to obtain the timing UTC Offsets.

Response packet returns the time and phase offset computed from the transmitted UTC parameters.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Type | UINT8 | Any | Timebase of UTC offset desired. One of : 0xFF : Time base defined in 0x91-03 configuration 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 A1 01 00 03 00 0F AC 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|--------------|-------|-------|-----------------|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x01 | Subpacket ID |

| Byte | Item | Type | Value | Description |
|-------|-------------|--------|----------|---|
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Time base | UINT8 | Any | Time base of UTC offset returned: 0: GPS 1: GLO 2: BDS 3: GAL 4: NAV |
| 7 | Valid | UINT8 | 0-1 | 1 if valid data, 0 if invalid. If invalid rest of fields are meaningless |
| 8-9 | Week Number | UINT16 | Any | Week number for offset computation |
| 10-13 | TOW | UINT32 | 0-604799 | Time of week for offset computation |
| 14 | DeltaLS | UINT8 | Any | Current transmitted (not computed) leap second offset, positive or negative (seconds) |
| 15-22 | Offset | DBL | Any | Current UTC offset for this constellation to the country of origin UTC(ns) |
| 23 | Checksum | UINT8 | Any | |
| 24 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 25 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Timing Transmitted Clock Corrections (0xA1-02)

Use TSIP packet 0xA1-02 is to obtain the timing transmitted clock corrections.

Allows querying of the currently transmitted clock offsets between GPS and other constellations. This data is only available if constellations other than just GPS (or QZSS) are enabled.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x02 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 A1 02 00 02 00 A1 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x02 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|-------|--------------------|--------|----------|---|
| 6 | Valid flags | UINT8 | Any | Bit flags of valid data. If bit is set then offset value indicated is valid: Bit 0 : GPS (for completeness only) Bit 1: GLO Bit 2: BDS Bit 3: GAL Bit 4: NAV |
| 7-8 | Week Number | UINT16 | Any | Week number for computation |
| 9-12 | TOW | UINT32 | 0-604799 | Time of week for computation |
| 13-16 | GPS-GPS offset, ns | SINGLE | Any | Transmitted offset between GPS and GPS, always '0.0', for completeness only |
| 17-20 | GPS-GLO offset, ns | SINGLE | Any | Transmitted offset between GPS and GLONASS, nanoseconds |
| 21-24 | GPS-BDS offset, ns | SINGLE | Any | Transmitted offset between GPS and Beidou, nanoseconds |
| 25-28 | GPS-GAL offset, ns | SINGLE | Any | Transmitted offset between GPS and Galileo, nanoseconds |
| 29-32 | GPS-NAV offset, ns | SINGLE | Any | Transmitted offset between GPS and Navic, nanoseconds |
| 33 | Checksum | UINT8 | Any | |
| 34 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 35 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Event Capture Information (0xA1-06)

Use TSIP 0xA1-06 packet to obtain the event capture configuration.

This packet provide timing information when an event input is captured or queried.

This packet will generate once per second automatically if it is set to enable on [Receiver Configuration \(0x91-05\)](#).

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x06 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 A1 06 00 02 00 A1 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x06 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6-9 | Event Count | UINT32 | Any | Event count for this event, if unchanged from last response then no new event |

| Byte | Item | Type | Value | Description |
|-------|-------------------|--------|-------|--|
| 10-17 | Fractional Second | Double | Any | Time elapsed since last PPS in seconds |
| 18-21 | Time of Week | UINT32 | Any | Time of week of last PPS in seconds |
| 22-23 | Week Number | UINT16 | Any | Week number of last PPS |
| 24 | Hours | UINT8 | 0-23 | Hours |
| 25 | Minutes | UINT8 | 0-59 | Minutes |
| 26 | Seconds | UINT8 | 0-59 | Seconds |
| 27 | Month | UINT8 | 1-12 | Month |
| 28 | Day of month | UINT8 | 1-31 | Day of month |
| 29-30 | Year | UINT16 | Any | Four digits of year |
| 31 | Time base | UINT8 | | Bit 2:0 0: GPS 1: GLO 2: BDS 3: GAL Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) Timebase set via 0x91-03 |
| 32 | PPS base | UINT8 | | Bit 2:0 0: GPS 1: GLO 2: BDS 3: GAL Bit 3 - UTC (UTC according to the constellation set in bit 0-bit 2) |
| 33 | Checksum | UINT8 | Any | |
| 34 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 35 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Position Information (0xA1-11)

Use TSIP 0xA1-11 packet to obtain the position information of the receiver.

Query

| Byte | Item | Type | Value | Description |
|------|---------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x11 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Position Mask | UINT8 | Any | Bit 0 0: Real time position 1: Surveyed position Bit 1 0: LLA 1: XYZ ECEF Bit 2 0: HAE 1: MSL Bit 3 0: Velocity ENU 1: Velocity ECEF 0xFF to use position mask from device 0xFF assumed if field not present |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

10 A1 11 00 03 00 00 B3 10 03

10 A1 11 00 03 00 04 B7 10 03

10 A1 11 00 03 00 02 B1 10 03

Response

| Byte | Item | Type | Value | Description |
|-------|------------------------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x11 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Position Mask | UINT8 | Any | Bit 0 0: Real time position 1: Surveyed position Bit 1 0: LLA 1: XYZ ECEF Bit 2 0: HAE 1: MSL Note: Ignore if bit 1 is 1 Bit 3 0: Velocity ENU 1: Velocity ECEF |
| 7 | Fix Type | UINT8 | 0-2 | 0: No fix 1: 2D fix 2: 3D Fix |
| 8-15 | Latitude/X | DOUBLE | Any | Latitude in degrees X in meters |
| 16-23 | Longitude/Y | DOUBLE | Any | Longitude in degrees Y in meters |
| 24-31 | Altitude/Z | DOUBLE | Any | Altitude in meters Z in meters |
| 32-35 | X Velocity/ East Velocity | SINGLE | Any | Both in meters/second East velocity: + For east, - for west |

| Byte | Item | Type | Value | Description |
|-------|----------------------------------|--------|-------------|---|
| 36-39 | Y Velocity/ North Velocity | SINGLE | Any | Both in meters/second North velocity: + For north, - for south |
| 40-43 | Z Velocity/ Up Velocity | SINGLE | Any | Both in meters/second Up velocity: + For up, - for down |
| 44-47 | PDOP | SINGLE | Any | If surveyed position is queried this field will report the value below which fixes were included. For example, 10 indicates all fixes included in surveying of position had a PDOP below 10. Else, this field indicates current measurement PDOP. |
| 48-51 | Horizontal Uncertainty | SINGLE | >0 <=100 | Horizontal position uncertainty If surveyed position is queried this field will report the value below which fixes were included. For example, 10 indicates all fixes included in surveying of position had horizontal uncertainty below 10. Else, this field indicates current measurement uncertainty |
| 52-55 | Vertical Uncertainty | SINGLE | >0 <=100 | Vertical position uncertainty If surveyed position is queried this field will report the value below which fixes were included. For example, 10 indicates all fixes included in surveying of position had vertical uncertainty below 10. Else, this field indicates current measurement uncertainty |
| 56 | Checksum | UINT8 | Any | |
| 57 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 58 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

```
10 A1 11 00 34 02 04 02 40 42 AB 47 39 7A 75 11 C0 5E 7F 70 73 9B 02 4F 40 42 C8 10 62 4D
D2 F2 BA 9A A0 86 BA F8 FA 41 3B 83 12 6F 3F 54 7A E1 40 25 71 67 40 DD 3F 7D CE 10 03
```


Measured offsets between constellations and frequencies Information (0xA1-22)

Use TSIP 0xA1-22 packet to obtain Measured offsets between constellations and frequencies

To provide customers with a metric that can indicate spoofing we can return the current measured offsets between constellations.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UNIT8 | 0x03 | End of packet 2 |

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA1 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6-9 | Valid flags | UINT32 | Any | Bit flags of valid data. If bit is set then offset value indicated is valid: Bit 0 - GPS L1C Bit 1 - Reserved Bit 2 - GPS L5 Bit 3 - Reserved Bit 4 - GLONASS G1 Bit 5 - Reserved Bit 6,7 - Reserved Bit 8 - Reserved Bit 9 - Reserved Bit 10 - Reserved Bit 11 - Reserved Bit 12 - Beidou B1 |

| | | | | |
|-------|--------------------|--------|----------|---|
| | | | | Bit 13 - Reserved Bit 14 - Beidou B2a Bit 15 - Reserved Bit 16 - Galileo E1 Bit 17 - Galileo E5a Bit 18 - Reserved Bit 19 - Reserved Bit 20 - Reserved Bit 21 - QZSS L1C Bit 22 - Reserved Bit 23 - QZSS L5 Bit 24 - Reserved Bit 25 - Reserved Bit 26 - NavIC L5 Bit 27 - Reserved Bit 28-31 - Reserved |
| 10-11 | Week Number | UNIT16 | Any | Week number for computation |
| 12-15 | TOW | UNIT32 | 0-604799 | Time of the week computation |
| 16-19 | GPS L1 offset | SINGLE | Any | Measured offset between GPS L1 and the bias estimate, nanoseconds |
| 20-23 | GPS L5 offset | SINGLE | Any | Measured offset between GPS L5 and the bias estimate, nanoseconds |
| 24-27 | GLONASS offset | SINGLE | Any | Measured offset between GLONASS and the bias estimate, nanoseconds |
| 28-31 | Beidu B1 offset | SINGLE | Any | Measured offset between Beidou B1 and the bias estimate, nanoseconds |
| 32-35 | Beidou B2a offset | SINGLE | Any | Measured offset between Beidou B2a and the bias estimate, nanoseconds |
| 36-39 | Galileo E1 offset | SINGLE | Any | Measured offset between Galileo E1 and the bias estimate, nanoseconds |
| 40-43 | Galileo E5a offset | SINGLE | Any | Measured offset between Galileo E5a and the bias estimate, nanoseconds |
| 44-47 | QZSS L1 offset | SINGLE | Any | Measured offset between QZSS L1 and the bias estimate, nanoseconds |
| 48-51 | QZSS L5 offset | SINGLE | Any | Measured offset between QZSS L5 and the bias estimate, nanoseconds |
| 52-55 | NavIC L5 offset | SINGLE | Any | Measured offset between NavIC L5 and the bias estimate, nanoseconds |
| 56 | Checksum | UINT8 | Any | |
| 57 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |

| | | | | |
|----|-------------|-------|------|-----------------|
| 58 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |
|----|-------------|-------|------|-----------------|

Query:

10 A1 22 00 02 00 81 10 03

Response example:

10 A1 22 00 34 02 00 03 50 15 09 34 00 06 5E 37 42 2B 26 DA 42 2B 94 FA 42 13 66 C7 42 12 33 B6 42
10 54 C3 42 34 03 0E 42 35 50 38 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 B7 10 03

Satellite Information (0xA2-00)

Use TSIP 0xA2-00 packet to obtain the satellite tracking information for GPS L1, GPS L5, GLONASS, Beidou B1, Beidou B2a, Galileo E1, Galileo E5a, NavIC L5, QZSS L1 and QZSS L5.

This packet will generate once per second automatically if it is set to enable on [Receiver Configuration \(0x91-05\)](#).

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | SV Type | UINT8 | | 0 - All satellites 1 - GPS L1C 2 - GPS L2 (Not supported, for future use) 3 - GPS L5 4 - Reserved 5 - GLONASS G1 6 - GLONASS G2 7,8 - Reserved 9 - SBAS 10,11,12 - Reserved 13 - Beidou B1 14 - Beidou B2i (Not supported, for future use) 15 - Beidou B2a 16 - Reserved 17 - Galileo E1 |

- 18 - Galileo E5a
 - 19 - Galileo E5b (Not supported, for future use)
 - 20 - Galileo E6 (Not supported, for future use)
 - 21 - Reserved
 - 22 - QZSS L1
 - 23 - QZSS L2C (Not supported, for future use)
 - 24 - QZSS L5
 - 25 - Reserved
 - 26 - NavIC L5
 - 27 - 255 - Reserved
-

| Byte | Item | Type | Value | Description |
|------|-------------|-------|-------|---|
| 7 | SV PRN | UINT8 | 0-32 | 0 - All satellites in selected SV type non-zero - SV PRN |
| 8 | Checksum | UINT8 | Any | |
| 9 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 10 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

10 A2 00 00 04 00 00 00 A6 10 03

Response

| Byte | Item | Type | Value | Description |
|------|----------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Message Number | UINT8 | Any | Message number starting from 1 |

| Byte | Item | Type | Value | Description |
|-------|-----------------|--------|-------|--|
| 7 | SV Type | UINT8 | Any | 1 - GPS L1C 2 - GPS L2 (Not supported, for future use) 3 - GPS L5 4 - Reserved 5 - GLONASS G1 6 - GLONASS G2 7,8 - Reserved 9 - SBAS 10,11,12 - Reserved 13 - Beidou B1 14 - Beidou B2i (Not supported, for future use) 15 - Beidou B2a 16 - Reserved 17 - Galileo E1 18 - Galileo E5a 19 - Galileo E5b (Not supported, for future use) 20 - Galileo E6 (Not supported, for future use) 21 - Reserved 22 - QZSS L1 23 - QZSS L2C (Not supported, for future use) 24 - QZSS L5 25 - Reserved 26 - NavIC L5 27 - 255 - Reserved |
| 8 | SV PRN | UINT8 | Any | Non-zero - SV PRN |
| 9-12 | Azimuth angle | SINGLE | | In degrees |
| 13-16 | Elevation angle | SINGLE | | In degrees |
| 17-20 | Signal Level | SINGLE | | dB-Hz |

| Byte | Item | Type | Value | Description |
|-------|--------------------------|--------|-------|---|
| 21-24 | Flags | UINT32 | | Bit 0- 0: Not acquired 1: Acquired Bit 1- 0: Not used in position fix 1: Used in position fix Bit 2- 0: Not used in timing fix 1: Used in timing fix Bit 15 - Bit 8- Satellite status, see table "Satellites Status Meaning" below. |
| 25-28 | Time of last measurement | UINT32 | | TOW in seconds |
| 29 | Checksum | UINT8 | Any | |
| 30 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 31 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

NOTE - There will be one message per satellite sent by the receiver.

If data is not available or 0 satellites:

10 A2 00 00 02 02 A2 10 03

Table. Satellite Status Meaning

| Description | Value | Comment |
|----------------|-------|--|
| No Error | 0 | Satellite fully usable in timing solution. |
| No Measurement | 1 | No measurement currently available. This is due to any reason, other than jam, but means that there is not even a low-level tracking indication for this satellite (could be an unused channel). |
| No Time | 2 | No timing information available from the satellite. |
| No Ephemeris | 3 | No Ephemeris information available (unused). |
| No Bit Sync | 4 | No bit sync possible with the satellite. |
| Low Elevation | 5 | Satellite is below the elevation mask. |
| Low C/N0 | 6 | Satellite signal level is below the CNo mask. |

| | | |
|------------------------|----|--|
| Not usable | 7 | Satellite is being tracked, but no observable information is available. |
| Rate Reject | 8 | Satellite is being tracked, but the measured range-rate is not valid. This is usually an indication of spoofing/multi-path. |
| Bias Reject | 9 | Satellite is being tracked, but the measured range is not valid. This is usually a spoofing/multi-path indication. |
| Millisecond error | 10 | Satellite has a millisecond error relative to other satellites. This can be due to jamming, spoofing or multi-path conditions. |
| Low sat count | 11 | Number of satellites being tracked is below the minimum satellite track level so this satellite is "rejected". |
| Invalid SV # | 12 | The satellite is being tracked, but the computed SV Id is not valid. This may be due to spoofing, or that the satellite corrections are not available for this satellite (i.e. it isn't supposed to be there at all according to other satellite information). |
| Unhealthy | 13 | The satellite is marked unhealthy. |
| Invalid Range | 14 | PR measurement is not valid. |
| Invalid Doppler | 15 | System unable to make valid Doppler measurements. |
| Invalid Position | 16 | No valid position is available so satellite cannot be used. |
| No Code/Carrier lock | 17 | Unable to establish both code and carrier lock to the satellite. |
| Lock stable count | 18 | Satellite is locked but the lock status has not been stable long enough to validate (SV_MIN_LOCK_TIME_MS). |
| No dual-frequency info | 19 | There is not dual-frequency information for this satellite (like GLONASS or GPS that has no L5). |

| | | |
|-----------------------|----|--|
| Not primary frequency | 20 | This is a placeholder as the satellite cannot be used twice in a computation of timing information. The secondary frequency is used to compute offsets, but the satellite information cannot be used twice in the solution (or the solution will not be correct). This is also used as the system, currently, will only use secondary frequency as an augmentation of the primary. |
| No residual | 21 | The satellite residual computation could not be made. This is generally due to missing, or invalid information, from the satellite. This will normally correct itself once data is gathered, unless it is caused by spoofing that is invalidating the data. |
| Invalid range | 22 | The range computation was unable to be made due to data errors. This will normally correct itself. |
| High multi-path | 23 | A multi-path level that is too high to allow valid satellite decode has been detected. |
| Jammed | 24 | Jamming conditions have been detected on this satellite. The carrier can be tracked, but there is no meaningful data. |
| Spoofed | 25 | Spoofing conditions have been detected on this satellite. This can be across entire constellations if there is a discrepancy of a single constellation relative to others. |
| Sat disabled | 26 | This satellite has been disabled. |

Raw UTC Parameters (0xA2-20)

Use TSIP packet 0xA2-20 to obtain the raw UTC parameters.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x20 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | SV Type | UINT8 | 0-4 | 0: GPS 1: GLONASS 2: BeiDou 3: Galileo 4: NavIC |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

GPS: 10 A2 20 00 03 00 00 81 10 03

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x20 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|-------|-------------------|-------|---|---|
| 6 | SV Type | UINT8 | 0-4 | 0: GPS 1: GLONASS 2: BeiDou 3: Galileo 4: NavIC |
| 7 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data If 0, ignore rest of data |
| 8-11 | A0 | INT32 | GPS: 2 [^] -30 GLO: 2 [^] -31 BEI: 2 [^] -30 GAL: 2 [^] -30 NAV: 2 [^] -35 | Delta time due to current leap seconds (seconds) |
| 12-15 | A1 | INT32 | GPS: 2 [^] -50 BEI: 2 [^] -50 GAL: 2 [^] -50 NAV: 2 [^] -51 | UTC rate (seconds/second) |
| 16 | ΔT_{LS} | INT8 | - | Delta time due to current leap seconds (seconds) |
| 17 | ΔT_{LSF} | INT8 | - | Delta time after leap second change (seconds) |
| 18 | TOT | UINT8 | GPS: 2 [^] 12 GAL: 3600 NAV: 16 | Reference time of week (seconds) |
| 19 | WN _T | UINT8 | - | Reference week number (weeks) |
| 20 | WN _{LSF} | UINT8 | - | Week when the leap second change occurs (weeks) |
| 21 | DN | UINT8 | - | Day at end of which leap second changes (days) |
| 22 | Checksum | UINT8 | Any | |

| Byte | Item | Type | Value | Description |
|------|-------------|-------|-------|-----------------|
| 23 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 24 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example for invalid GPS or not retrieved yet:

10 A2 20 00 12 02 01 00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF 90 10 03

Almanac Health Report (0xA2-21)

Use TSIP packet 0xA2-21 to obtain the Almanac health report.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x21 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | SV Type | UINT8 | 0-4 | 0: GPS 1: GLONASS 2: BeiDou 3: Galileo 4: NavIC |
| 7 | Checksum | UINT8 | Any | |
| 8 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 9 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

GPS: 10 A2 21 00 03 00 00 81 10 03

GPS, GLONASS, Galileo, and NavIC Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|---------------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x21 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 0, 1, 3, or 4 | 0: GPS 1: GLONASS 3: Galileo 4: NavIC |

| Byte | Item | Type | Value | Description |
|--------|-----------------------|-------|-------|----------------------------|
| 7 | Satellite Count | UINT8 | Any | Depends on SV Type |
| 8 | Health of satellite 1 | UINT8 | Any | 0: Healthy, > 0: Unhealthy |
| 9 | Health of satellite 2 | UINT8 | Any | See byte 8 |
| ... | ... | ... | ... | ... |
| X + 7 | Health of satellite X | UINT8 | Any | See byte 8 |
| X + 8 | Checksum | UINT8 | Any | |
| X + 9 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| X + 10 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

BeiDou Response

| Byte | Item | Type | Value | Description |
|---------|-----------------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x21 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 2 | 2: BeiDou |
| 7 | Satellite Count | UINT8 | 63 | BeiDou satellite count |
| 8-9 | Health of satellite 1 | UINT16 | Any | 0: Healthy, > 0: Unhealthy |
| 10-11 | Health of satellite 2 | UINT16 | Any | See byte 8-9 |
| ... | ... | ... | ... | ... |
| 132-133 | Health of satellite X | UINT16 | Any | See byte 8-9 |
| 134 | Checksum | UINT8 | Any | |
| 135 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 136 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Raw Almanac (0xA2-22)

Use TSIP packet 0xA2-22 to obtain the raw almanac data of each GNSS satellite.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | SV Type | UINT8 | 0-4 | 0: GPS 1: GLONASS 2: BeiDou 3: Galileo 4: NavIC |
| 7 | SV PRN | UINT8 | Any | Satellite number |
| 8 | Checksum | UINT8 | Any | |
| 9 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 10 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

GPS Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 0 | 0: GPS |
| 7 | SV PRN | UINT8 | 1-32 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |

| Byte | Item | Type | Value | Description |
|-------|-----------------|--------|------------------|---|
| 9 | WN _a | UINT8 | Any | Almanac reference week number |
| 10 | Health | UINT8 | Any | Health of the satellite. See table 20-VII in ICD for more info. 0 is all data good. |
| 11 | T _{oa} | UINT8 | 2 ¹² | Almanac reference time (seconds) |
| 12-13 | e | UINT16 | 2 ⁻²¹ | Eccentricity (dimensionless) |
| 14-17 | √A | UINT32 | 2 ⁻¹¹ | Square root of semi-major axis (√m) |
| 18-19 | δ _i | INT16 | 2 ⁻¹⁹ | Correction of orbit reference inclination at reference time (semi-circles) *i ₀ relative to 0.30 semi-circles |
| 20-21 | Ω̇ | INT16 | 2 ⁻³⁸ | Rate of right ascension (semi-circles/second) |
| 22-25 | Ω ₀ | INT32 | 2 ⁻²³ | Longitude of ascending node of orbital plane according to reference time (semi-circles) |
| 26-29 | | INT32 | 2 ⁻²³ | Argument of perigee (semi-circles) |
| 30-33 | M ₀ | INT32 | 2 ⁻²³ | Mean anomaly at ref time (semi-circles) |
| 34-35 | a _{ro} | INT16 | 2 ⁻²⁰ | Satellite clock bias (seconds) |
| 36-37 | a _{ri} | INT16 | 2 ⁻³⁸ | Satellite clock rate (seconds/second) |
| 38 | Checksum | UINT8 | Any | |
| 39 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 40 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

GLONASS Response

| Byte | Item | Type | Value | Description |
|------|------------|-------|-------|-----------------|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-----------|--|
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 1 | 1: GLONASS |
| 7 | SV PRN | UINT8 | 1-24 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 9-10 | N | UINT16 | 1-1461 | Reference calendar day number of almanac within the four-year period (days) |
| 11 | C | UINT8 | 0-1 | Flag at instant of upload 0: Inoperable 1: Operable |
| 12 | L | UINT8 | 0-1 | Flag for health 0: Healthy 1: Malfunction |
| 13 | M | UINT8 | 0-3 | Type of satellite: "00" is GLONASS, "01" is GLONASS-M |
| 14 | H | UINT8 | 0-31 | Carrier frequency number of navigation RF signal |
| 15-16 | tau | UINT16 | 2^{-18} | Coarse time correction to GLONASS time (seconds) |
| 17-20 | t_a | UINT32 | 2^{-5} | Time of first ascending node passage (seconds) |
| 21-22 | e | UINT16 | 2^{-20} | Eccentricity (dimensionless) |
| 23-26 | Δi | INT32 | 2^{-20} | Correction to mean value of inclination (semi-circles) |
| 27-30 | λ | INT32 | 2^{-20} | Longitude of first ascending node of satellite orbit in PZ-90 coordinate system (semi-circles) |

| Byte | Item | Type | Value | Description |
|-------|--------------|-------|-----------|---|
| 31-34 | ΔT | INT32 | 2^{-9} | Correction to mean value of Draconian period (seconds/orbital period) |
| 35 | $\Delta^* T$ | INT8 | 2^{-14} | Rate of change of Draconian period (seconds/orbital period ²) |
| 36-37 | | INT16 | 2^{-15} | Argument of perigee (semi-circles) |
| 38 | Checksum | UINT8 | Any | |
| 39 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 40 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

BeiDou Response

| Byte | Item | Type | Value | Description |
|-------|-----------------|--------|-----------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 2 | 2: BeiDou |
| 7 | SV PRN | UINT8 | 1-63 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 9 | WN _a | UINT8 | Any | Almanac reference week |
| 10-13 | SOW | UINT32 | Any | Seconds of week |
| 14 | T _{oa} | UINT8 | 2^{12} | Almanac reference time (seconds) |
| 15-18 | e | UINT32 | 2^{-21} | Eccentricity (dimensionless) |
| 19-22 | \sqrt{A} | UINT32 | 2^{-11} | Square root of semi-major axis (\sqrt{m}) |

| Byte | Item | Type | Value | Description |
|-------|----------------|-------|-----------|---|
| 23-24 | δ_i | INT16 | 2^{-19} | Correction of orbit reference inclination at reference time (semi-circles) |
| 25-28 | $\dot{\alpha}$ | INT16 | 2^{-38} | Rate of right ascension (semi-circles/second) |
| 29-32 | Ω_0 | INT32 | 2^{-23} | Longitude of ascending node of orbital plane according to reference time (semi-circles) |
| 33-36 | | INT32 | 2^{-23} | Argument of perigee (semi-circles) |
| 37-40 | M_0 | INT32 | 2^{-23} | Mean anomaly at ref time (semi-circles) |
| 41-42 | a_0 | INT16 | 2^{-20} | Satellite clock bias (seconds) |
| 43-44 | a_1 | INT16 | 2^{-38} | Satellite clock rate (seconds/second) |
| 45 | Checksum | UINT8 | Any | |
| 46 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 47 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Galileo Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 3 | 3: Galileo |
| 7 | SV PRN | UINT8 | 1-36 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 9-10 | WN | UINT16 | Any | Sequential week number from the GST start epoch |

| Byte | Item | Type | Value | Description |
|-------|--------------------|--------|------------------|--|
| 11 | E1-B _{HS} | UINT8 | Any | Satellite E1-B/C signal health status |
| 12 | E5b _{HS} | UINT8 | Any | Satellite E5b signal health status |
| 13-14 | e | UINT16 | 2 ⁻¹⁶ | Eccentricity (dimensionless) |
| 15-16 | $\Delta\sqrt{A}$ | UINT16 | 2 ⁻⁹ | Difference between the square root of semi-major axis and square root of nominal semi-major axis (29,600km) (\sqrt{m}) |
| 17-18 | δ_i | INT16 | 2 ⁻¹⁴ | Inclination at reference time relative to $i_0 = 56^\circ$ (semi-circles) |
| 19-20 | $\dot{\alpha}$ | INT16 | 2 ⁻³³ | Rate of right ascension (semi-circles/second) |
| 21-22 | Ω_0 | INT16 | 2 ⁻¹⁵ | Longitude of ascending node of orbital plane at weekly epoch (semi-circles) |
| 23-24 | | INT16 | 2 ⁻¹⁵ | Argument of perigee (semi-circles) |
| 25-26 | M_0 | INT16 | 2 ⁻¹⁵ | Mean anomaly at ref time (semi-circles) |
| 27-28 | a_{r0} | INT16 | 2 ⁻¹⁹ | Satellite clock bias “truncated” (seconds) |
| 29-30 | a_{r1} | INT16 | 2 ⁻³⁸ | Satellite clock rate “truncated” (seconds/second) |
| 31 | Checksum | UINT8 | Any | |
| 32 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 33 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

NavIC Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x22 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |

| Byte | Item | Type | Value | Description |
|-------|-------------------------|--------|------------------|--|
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 4 | 4 : NavIC |
| 7 | SV PRN | UINT8 | 1-36 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 9-10 | WN _a | UINT8 | Any | Almanac reference week number |
| 11-12 | T _{oa} | UINT1 | 2 ⁴ | Almanac reference time (seconds) |
| 13-14 | e | UINT16 | 2 ⁻²¹ | Eccentricity (dimensionless) |
| 15-18 | √A | UINT32 | 2 ⁻¹¹ | Square root of semi-major axis (√m) |
| 19-22 | i ₀ | INT32 | 2 ⁻²³ | Inclination (semi-circles) |
| 23-24 | Ω̇ | INT16 | 2 ⁻³⁸ | Rate of RAAN (semi-circles/second) |
| 25-28 | Ω ₀ | INT32 | 2 ⁻²³ | Longitude of ascending node (LAN) (semi-circles) |
| 29-32 | | INT32 | 2 ⁻²³ | Argument of perigee (semi-circles) |
| 33-36 | M ₀ | INT32 | 2 ⁻²³ | Mean anomaly at ref time (semi-circles) |
| 37-38 | a ₀ | INT16 | 2 ⁻²⁰ | Satellite clock bias (seconds) |
| 39-40 | a _{r1} | INT16 | 2 ⁻³⁸ | Satellite clock rate (seconds/second) |
| 41 | Inter Signal Correction | INT8 | 2 ⁻³¹ | (seconds) |
| 42 | Checksum | UINT8 | Any | |
| 43 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 44 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Raw Ephemeris (0xA2-23)

Use TSIP packet 0xA2-23 to obtain the raw ephemeris data of each GNSS satellite.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x23 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | SV Type | UINT8 | 0-3 | 0: GPS 1: GLONASS 2: BeiDou 3: Galileo 4: NavIC |
| 7 | SV PRN | UINT8 | Any | Satellite number |
| 8 | Checksum | UINT8 | Any | |
| 9 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 10 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

GPS Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x23 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 0 | 0: GPS |
| 7 | SV PRN | UINT8 | 1-32 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |

| Byte | Item | Type | Value | Description |
|-------|------------|--------|------------------------|--|
| 9-10 | WN | UINT16 | Any | Data sequence propagation week number |
| 11 | Health | UINT8 | Any | SV health |
| 12 | IODE | UINT8 | Any | Issue of Data, Ephemeris |
| 13-14 | IODC | UINT16 | Any | Issue of Data, Clock |
| 15 | URA | UINT8 | Any | User Range Accuracy Index |
| 16 | Fit | UINT8 | Any | Fit interval flag |
| 17-18 | t_{oc} | UINT16 | 2^4 0-604,784 | Clock data reference time (seconds) |
| 19-20 | t_{oe} | UINT16 | 2^4 0-604,784 | Ephemeris reference time (seconds) |
| 21 | T_{GD} | INT8 | 2^{-31} | Group delay differential (seconds) |
| 22-25 | a_{r0} | INT32 | 2^{-31} | Time polynomial coefficient 0 (seconds) |
| 26-27 | a_{r1} | INT16 | 2^{-43} | Time polynomial coefficient 1 (seconds/second) |
| 28 | a_{r2} | INT8 | 2^{-55} | Time polynomial coefficient 2 (seconds/second ²) |
| 29-30 | Δ_n | INT16 | 2^{-43} | Mean motion difference from computed value (semi-circles/second) |
| 31-34 | M_0 | INT32 | 2^{-31} | Mean anomaly at reference time (semi-circles) |
| 35-38 | e | UINT32 | 2^{-33} 0-0.03 | Eccentricity (dimensionless) |
| 39-42 | \sqrt{A} | UINT32 | 2^{-19} 2530-8192 | Square root of the semi-major axis (meters ^{0.5}) |

| Byte | Item | Type | Value | Description |
|-------|----------------|-------|---------------------------|--|
| 43-46 | I_0 | INT32 | 2^{-31} | Inclination angle at reference time (semi-circles) |
| 47-48 | C_{rs} | INT16 | 2^{-5} | Amplitude of the sine harmonic correction term to the orbit radius (meters) |
| 49-50 | C_{rc} | INT16 | 2^{-5} | Amplitude of the cosine harmonic correction term to the orbit radius (meters) |
| 51-52 | C_{us} | INT16 | 2^{-29} | Amplitude of the sine harmonic correction term to the argument of latitude (radians) |
| 53-54 | C_{uc} | INT16 | 2^{-29} | Amplitude of the cosine harmonic correction term to the argument of latitude (radians) |
| 55-56 | C_{is} | INT16 | 2^{-29} | Amplitude of the sine harmonic correction term to the angle of inclination (radians) |
| 57-58 | C_{ic} | INT16 | 2^{-29} | Amplitude of the cosine harmonic correction term to the angle of inclination (radians) |
| 59-62 | | INT32 | 2^{-31} | Argument of perigee (semi-circles) |
| 63-66 | Ω_0 | INT32 | 2^{-31} | Longitude of ascending node of orbit plane at weekly epoch (semi-circles) |
| 67-70 | $\dot{\Omega}$ | INT32 | 2^{-43} $-6.33e-7-0$ | Rate of right ascension (semi-circles/second) |
| 71-72 | IDOT | INT16 | 2^{-43} | Rate of inclination angle (semi-circles/second) |
| 73 | Checksum | UINT8 | Any | |
| 74 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |

| Byte | Item | Type | Value | Description |
|------|-------------|-------|-------|-----------------|
| 75 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

GLONASS Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|---|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x23 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 1 | 1: GLONASS |
| 7 | SV PRN | UINT8 | 1-24 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 9 | M | UINT8 | 0-3 | Type of satellite: "00" is GLONASS, "01" is GLONASS-M |
| 10 | B | UINT8 | 0-7 | Health flag |
| 11 | L | UINT8 | 0-1 | Health flag (1 is malfunction) |

| Byte | Item | Type | Value | Description |
|------|---------|-------|-------|--|
| 12 | P flags | UINT8 | Any | <p>P indicates satellite operation mode with respect to time parameters.</p> <p>P1 indicates a time interval between two adjacent values of tb parameter (in minutes)</p> <p>P2 is a flag of oddness ("1") or evenness ("0") of the value of tb (for intervals 30 or 60 minutes)</p> <p>P3 is a flag indicating a number of satellites for which almanac is transmitted within a given frame: 1 corresponds to five satellites and 0 corresponds to four satellites.</p> <p>P4 is a flag to show that ephemeris parameters are present. "1" indicates that updated ephemeris or frequency/time parameters have been uploaded by the control segment</p> <p>Bit mapping: 0,1: P 2,3: P1 4: P2 5: P3 6: P4</p> |

| Byte | Item | Type | Value | Description |
|-------|-----------------|--------|--|---|
| 13-14 | T_k | UINT16 | 0-23 hours 0-59 mins 0 or 30 seconds | Time into the current date that this data was first decoded. First five MSB bits are hours, next six bits are minutes, and LSB is seconds. |
| 15 | T_b | UINT8 | 15 | Index of a time interval within current day according to UTC(SU) (minutes) |
| 16-17 | NT | UINT16 | 0-1461 | Current date, calendar number of day within four-year interval starting from the 1-st of January in a leap year (days) |
| 18 | FT | UINT8 | Any | User range accuracy |
| 19-22 | T_{au} | INT32 | 2^{-30} | SV clock bias (seconds) |
| 23 | ΔT_{au} | INT8 | 2^{-30} | Time difference between L2 and L1 band (seconds) |
| 24 | E | UINT8 | 0-31 | Characterizes "age" of a current information, that is the time slice which has transited from the moment of calculation at instant T_b (days) |
| 25-26 | y | INT16 | 2^{-40} | Relative carrier frequency deviation |
| 27-30 | x | INT32 | 2^{-11} | x coordinate (PZ-90.02) of SV on an instant t_b |
| 31-34 | y | INT32 | 2^{-11} | y coordinate (PZ-90.02) of SV on an instant t_b |
| 35-38 | z | INT32 | 2^{-11} | z coordinate (PZ-90.02) of SV on an instant t_b |
| 39-42 | dx | INT32 | 2^{-20} | x component (PZ-90.02) of vector velocity of SV on an instant t_b |

| Byte | Item | Type | Value | Description |
|-------|-------------|-------|------------------|--|
| 43-46 | dy | INT32 | 2 ⁻²⁰ | y component (PZ-90.02) of vector velocity of SV on an instant t _b |
| 47-50 | dz | INT32 | 2 ⁻²⁰ | z component (PZ-90.02) of vector velocity of SV on an instant t _b |
| 51 | ddx | INT8 | 2 ⁻³⁰ | x component (PZ-90.02) speedups of SV on an instant t _b |
| 52 | ddy | INT8 | 2 ⁻³⁰ | y component (PZ-90.02) speedups of SV on an instant t _b |
| 53 | ddz | INT8 | 2 ⁻³⁰ | z component (PZ-90.02) speedups of SV on an instant t _b |
| 54 | Checksum | UINT8 | Any | |
| 55 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 56 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

BeiDou Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x23 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 2 | 2: BeiDou |
| 7 | SV PRN | UINT8 | 1-63 | Satellite number GEO: 1-5, 59-63 MEO: 6-58 |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |

| Byte | Item | Type | Value | Description |
|-------|------------|--------|--|---|
| 9-10 | WN | UINT16 | Any | Data sequence propagation week number |
| 11-14 | SOW | UINT32 | Any | Seconds of week that have occurred since last Sunday, 00:00:00 of BDT. (MEO only, GEO is 0) |
| 15 | Health | UINT8 | Any | Autonomous satellite health flag (0 is good) |
| 16 | AODE | UINT8 | Any | Age of data, ephemeris |
| 17 | AODC | UINT8 | Any | Age of data, clock |
| 18 | URAI | UINT8 | Any | User Range Accuracy Index |
| 19-22 | t_{oc} | UINT16 | 2^4 0-604,784 | Clock data reference time (seconds) |
| 23-26 | t_{oe} | UINT16 | 2^4 0-604,784 | Ephemeris reference time (seconds) |
| 27-28 | T_{GD1} | INT16 | 0.1 | Equipment group delay differential (nanoseconds) |
| 29-30 | T_{GD2} | INT16 | 0.1 | Equipment group delay differential (nanoseconds) |
| 31-34 | a_0 | INT32 | 2^{-33} | Time polynomial coefficient 0 (seconds) |
| 35-38 | a_1 | INT32 | 2^{-50} | Time polynomial coefficient 1 (seconds/second) |
| 39-40 | a_2 | INT16 | 2^{-66} | Time polynomial coefficient 2 (seconds/second ²) |
| 41-42 | Δ_n | INT16 | 2^{-43} $\pm 3.73 \times 10^{-9}$ | Mean motion difference from computed value (pi/second) |

| Byte | Item | Type | Value | Description |
|-------|------------|--------|--|--|
| 43-46 | M_0 | INT32 | $2^{-31} \pm 1$ | Mean anomaly at reference time (π) |
| 47-50 | e | UINT32 | 2^{-33} 0 - 0.5 | Eccentricity (dimensionless) |
| 51-54 | \sqrt{A} | UINT32 | 2^{-19} 0-8,192 | Square root of the semi-major axis (meters ^{0.5}) |
| 55-58 | I_0 | INT32 | $2^{-31} \pm 1$ | Inclination angle at reference time (π) |
| 59-62 | C_{rs} | INT32 | $2^{-6} \pm 2048$ | Amplitude of the sine harmonic correction term to the orbit radius (meters) |
| 63-66 | C_{rc} | INT32 | $2^{-6} \pm 2048$ | Amplitude of the cosine harmonic correction term to the orbit radius (meters) |
| 67-70 | C_{us} | INT32 | 2^{-31} $\pm 6.10 \times 10^{-5}$ | Amplitude of the sine harmonic correction term to the argument of latitude (radians) |
| 71-74 | C_{uc} | INT32 | 2^{-31} $\pm 6.10 \times 10^{-5}$ | Amplitude of the cosine harmonic correction term to the argument of latitude (radians) |
| 75-78 | C_{is} | INT32 | 2^{-31} $\pm 6.10 \times 10^{-5}$ | Amplitude of the sine harmonic correction term to the angle of inclination (radians) |
| 79-82 | C_{ic} | INT32 | 2^{-31} $\pm 6.10 \times 10^{-5}$ | Amplitude of the cosine harmonic correction term to the angle of inclination (radians) |
| 83-86 | | INT32 | $2^{-31} \pm 1$ | Argument of perigee (π) |
| 87-90 | Ω_0 | INT32 | $2^{-31} \pm 1$ | Longitude of ascending node of orbit plane at weekly epoch (π) |

| Byte | Item | Type | Value | Description |
|-------|----------------|-------|---|---------------------------------------|
| 91-94 | $\dot{\alpha}$ | INT32 | 2^{-43} $\pm 9.54 \times 10^{-7}$ | Rate of right ascension (pi/second) |
| 95-96 | IDOT | INT16 | 2^{-43} $\pm 9.31 \times 10^{-10}$ | Rate of inclination angle (pi/second) |
| 97 | Checksum | UINT8 | Any | |
| 98 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 99 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Galileo Response

| Byte | Item | Type | Value | Description |
|-------|---------------------|--------|-----------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x23 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 3 | 3: Galileo |
| 7 | SV PRN | UINT8 | 1-32 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 9-10 | WN | UINT16 | Any | Week number |
| 11-14 | TOW | UINT32 | Any | Time of week |
| 15 | E1-B _{HS} | UINT8 | Any | Satellite E1-B/C signal health status |
| 16 | E5b _{HS} | UINT8 | Any | Satellite E5b signal health status |
| 17-18 | BGD(E1, E5a) | INT16 | 2^{-32} | E1-E5a broadcast group delay (seconds) |
| 19-20 | BGD(E1, E5b) | INT16 | 2^{-32} | E1-E5b broadcast group delay (seconds) |
| 21 | E1-B _{DVS} | UINT8 | Any | 1-B data validity status |

| Byte | Item | Type | Value | Description |
|-------|--------------------|--------|------------------|--|
| 22 | E5b _{DVS} | UINT8 | Any | E5b data validity status |
| 23-24 | IOD _{nav} | UINT16 | Any | Ephemeris and clock correction issue of data |
| 25 | SISA | UINT8 | Any | Signal-in-space-accuracy is a prediction of the minimum standard deviation of the unbiased Gaussian distribution which overbound the signal-in-space-error (SISE) for all possible user locations within the satellite coverage area |
| 26-27 | t _{oc} | UINT16 | 60 | Clock data reference time of week (seconds) |
| 28-29 | t _{oe} | UINT16 | 60 | Ephemeris reference time (seconds) |
| 30-33 | a _{r0} | INT32 | 2 ⁻³⁴ | SV clock bias correction coefficient (seconds) |
| 34-37 | a _{r1} | INT32 | 2 ⁻⁴⁶ | SV clock drift correction coefficient (seconds/seconds) |
| 38 | a _{r2} | INT8 | 2 ⁻⁵⁹ | SV clock drift rate correction coefficient (seconds/seconds ²) |
| 39-40 | Δ _n | INT16 | 2 ⁻⁴³ | Mean motion difference from computed value (semi-circles/second) |
| 41-44 | M ₀ | INT32 | 2 ⁻³¹ | Mean anomaly at reference time (semi-circles) |
| 45-48 | e | UINT32 | 2 ⁻³³ | Eccentricity (dimensionless) |
| 49-52 | √A | UINT32 | 2 ⁻¹⁹ | Square root of the semi-major axis (meters ^{0.5}) |
| 53-56 | i ₀ | INT32 | 2 ⁻³¹ | Inclination angle at reference time (semi-circles) |
| 57-58 | C _{rs} | INT16 | 2 ⁻⁵ | Amplitude of the sine harmonic correction term to the orbit radius (meters) |

| Byte | Item | Type | Value | Description |
|-------|----------------|-------|-----------|--|
| 59-60 | C_{rc} | INT16 | 2^{-5} | Amplitude of the cosine harmonic correction term to the orbit radius (meters) |
| 61-62 | C_{us} | INT16 | 2^{-29} | Amplitude of the sine harmonic correction term to the argument of latitude (radians) |
| 63-64 | C_{uc} | INT16 | 2^{-29} | Amplitude of the cosine harmonic correction term to the argument of latitude (radians) |
| 65-66 | C_{is} | INT16 | 2^{-29} | Amplitude of the sine harmonic correction term to the angle of inclination (radians) |
| 67-68 | C_{ic} | INT16 | 2^{-29} | Amplitude of the cosine harmonic correction term to the angle of inclination (radians) |
| 69-72 | | INT32 | 2^{-31} | Argument of perigee (semi-circles) |
| 73-76 | Ω_0 | INT32 | 2^{-31} | Longitude of ascending node of orbit plane at weekly epoch (semi-circles) |
| 77-80 | $\dot{\alpha}$ | INT32 | 2^{-43} | Rate of right ascension (semi-circles/second) |
| 81-82 | IDOT | INT16 | 2^{-43} | Rate of inclination angle (semi-circles/second) |
| 83 | Checksum | UINT8 | Any | |
| 84 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 85 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

NavIC Response

| Byte | Item | Type | Value | Description |
|------|------------|-------|-------|-----------------|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-----------|---|
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x23 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 4 | 4: NavIC |
| 7 | SV PRN | UINT8 | 1-14 | Satellite number |
| 8 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 9-10 | WN | UINT16 | Any | Week number |
| 11 | L5 Flag | UINT8 | 0-1 | 0: all navigation data on L5 SPS signal are OK 1: some or all navigation data on L5 SPS signal are bad |
| 12 | S Flag | UINT8 | 0-1 | 0: all navigation data on S SPS signal are OK 1: some or all navigation data on S SPS signal are bad |
| 13 | URA | UINT8 | Any | User Range Accuracy Index |
| 14 | IODEC | UINT8 | Any | Issue of Data Ephemeris & Clock |
| 15-16 | t_{oc} | UINT16 | 16 | Time of clock (seconds) |
| 17-18 | t_{oe} | UINT16 | 16 | Ephemeris reference time (seconds) |
| 19 | T_{GD} | INT8 | 2^{-31} | Total group delay (seconds) |
| 20-23 | a_{f0} | INT32 | 2^{-31} | Clock bias (seconds) |
| 24-25 | a_{f1} | INT16 | 2^{-43} | Clock drift (seconds/second) |
| 26 | a_{f2} | INT8 | 2^{-55} | Clock drift rate (seconds/second ²) |
| 27-30 | Δ_n | INT32 | 2^{-41} | Mean motion difference (semi-circles/second) |

| Byte | Item | Type | Value | Description |
|-------|----------------|--------|-----------|--|
| 31-34 | M_0 | INT32 | 2^{-31} | Mean anomaly at reference time (semi-circles) |
| 35-38 | e | UINT32 | 2^{-33} | Eccentricity (dimensionless) |
| 39-42 | \sqrt{A} | UINT32 | 2^{-19} | Square root of the semi-major axis (meters ^{0.5}) |
| 43-46 | I_0 | INT32 | 2^{-31} | Inclination (semi-circles) |
| 47-48 | C_{rs} | INT16 | 2^{-4} | Amplitude of the sine harmonic correction term to the orbit radius (meters) |
| 49-50 | C_{rc} | INT16 | 2^{-4} | Amplitude of the cosine harmonic correction term to the orbit radius (meters) |
| 51-52 | C_{us} | INT16 | 2^{-28} | Amplitude of the sine harmonic correction term to the argument of latitude (radians) |
| 53-54 | C_{uc} | INT16 | 2^{-28} | Amplitude of the cosine harmonic correction term to the argument of latitude (radians) |
| 55-56 | C_{is} | INT16 | 2^{-28} | Amplitude of the sine harmonic correction term to the angle of inclination (radians) |
| 57-58 | C_{ic} | INT16 | 2^{-28} | Amplitude of the cosine harmonic correction term to the angle of inclination (radians) |
| 59-62 | | INT32 | 2^{-31} | Argument of perigee (semi-circles) |
| 63-66 | Ω_0 | INT32 | 2^{-31} | Longitude of ascending node of orbit plane at weekly epoch (semi-circles) |
| 67-70 | $\dot{\Omega}$ | INT32 | 2^{-43} | Rate of right ascension (semi-circles/second) |
| 71-72 | IDOT | INT16 | 2^{-43} | Rate of inclination angle (semi-circles/second) |

| Byte | Item | Type | Value | Description |
|------|-------------|-------|-------|-----------------|
| 73 | Checksum | UINT8 | Any | |
| 74 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 75 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Raw Ionosphere (0xA2-24)

Use TSIP packet 0xA2-24 to obtain the raw ionosphere data of each GNSS satellite.

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x24 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | SV Type | UINT8 | 0-3 | 0: GPS 1: GLO -- error, no model for GLO 2: BeiDou 3: Galileo 4: NavIC |
| 7 | SV PRN | UINT8 | Any | Satellite number |
| 8 | Checksum | UINT8 | Any | |
| 9 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 10 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

GPS, BeiDou, and NavIC Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-----------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x24 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 0, 1 or 3 | 0: GPS 1: BeiDou 3: NavIC |

| Byte | Item | Type | Value | Description |
|------|-------------|--------|-----------|---|
| 7 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 8 | α_0 | UINT8 | 2^{-30} | seconds |
| 9 | α_1 | UINT8 | 2^{-27} | GPS, NavIC: sec/semi-circle BeiDou: sec/pi |
| 10 | α_2 | UINT8 | 2^{-24} | GPS, NavIC: sec/semi-circle ² BeiDou: sec/pi ² |
| 11 | α_3 | UINT8 | 2^{-24} | GPS, NavIC: sec/semi-circle ³ BeiDou: sec/pi ³ |
| 12 | β_0 | UINT8 | 2^{11} | seconds |
| 13 | β_1 | UINT8 | 2^{14} | GPS, NavIC: sec/semi-circle BeiDou: sec/pi |
| 14 | β_2 | UINT16 | 2^{16} | GPS, NavIC: sec/semi-circle ² BeiDou: sec/pi ² |
| 15 | β_3 | UINT16 | 2^{16} | PS, NavIC: sec/semi-circle ² BeiDou: sec/pi ² |
| 16 | Checksum | UINT8 | Any | |
| 17 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 18 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Galileo Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA2 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x24 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | SV Type | UINT8 | 2 | 2: Galileo |

| Byte | Item | Type | Value | Description |
|------|-------------|--------|-----------|--|
| 7 | Valid | UINT8 | 0-1 | 0: Invalid data 1: Valid data |
| 8 | α_0 | UINT16 | 2^{-2} | sfu *1 sfu (solar flux unit) = $10^{-22}W/(m^2Hz)$ |
| 9 | α_1 | INT16 | 2^{-8} | sfu/degree |
| 10 | α_2 | INT16 | 2^{-15} | sfu/degree |
| 16 | Checksum | UINT8 | Any | |
| 17 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 18 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

System Alarms (0xA3-00)

Use TSIP packet 0xA3-00 to obtain the system alarm information.

This packet will generate once per second automatically if it is set to enable on [Receiver Configuration \(0x91-05\)](#).

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA3 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 A3 00 00 02 00 A1 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA3 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |

| Byte | Item | Type | Value | Description |
|-------|--------------|--------|-------|--|
| 6-9 | Minor Alarms | UINT32 | | Bit 0 - Antenna open Bit 1 - Antenna shorted Bit 2 - Leap second pending Bit 3 - Total almanac status: 1 - almanac incomplete 0 - almanac complete Bit 4 - Survey in progress Bit 5 - GPS almanac status Bit 6 - GLONASS almanac status Bit 7 - BeiDou almanac status Bit 8 - Galileo almanac status Bit 9 - Leap second insertion Bit 10 - Leap second deletion |
| 10-13 | Reserved | UINT32 | Any | |
| 14-17 | Major Alarms | UINT32 | Any | Bit 0 - Not tracking satellites Bit 1 - PPS bad Bit 2 - PPS not generated Bit 3 - Reserved Bit 4 - Reserved Bit 5 - Reserved Bit 6 - Reserved Bit 7 - Spoofing/multipath Bit 8 - Reserved |
| 18-21 | Reserved | UINT32 | Any | |
| 22 | Checksum | UINT8 | Any | |
| 23 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 24 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

```
10 A3 00 00 12 02 00 00 00 09 FF FF FF FF 00 00 00 00 FF FF FF FF BA 10 03
```

Receiver Status (0xA3-11)

Use TSIP packet 0xA3-11 to obtain the receiver status information for GNSS satellites tracking.

This packet will generate once per second automatically if it is set to enable on [Receiver Configuration \(0x91-05\)](#).

Query

| Byte | Item | Type | Value | Description |
|------|--------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA3 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x11 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0 | 0: Query |
| 6 | Checksum | UINT8 | Any | |
| 7 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 8 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Query example:

```
10 A3 11 00 02 00 B0 10 03
```

Response

| Byte | Item | Type | Value | Description |
|------|---------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA3 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x11 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Receiver Mode | UINT8 | 0-6 | 0 - 2D 1 - Full position (3D) Time only 3 - Automatic 6 - Over determined clock |

| Byte | Item | Type | Value | Description |
|-------|----------------------|--------|-------|--|
| 7 | Status | UINT8 | | 0 - Doing position fixes 1 - Do not have GPS time yet 2 - PDOP is too high 3 - No usable satellites 4 - Only 1 usable satellite 5 - Only 2 usable satellites 6 - Only 3 usable satellites 255 - Have GPS time fix (OD mode) |
| 8 | Self survey progress | UINT8 | 0-100 | Survey progress, in percentage of total fixes |
| 9-12 | PDOP | SINGLE | Any | PDOP |
| 13-16 | HDOP | SINGLE | Any | HDOP |
| 17-20 | VDOP | SINGLE | Any | VDOP |
| 21-24 | TDOP | SINGLE | Any | TDOP |
| 25-28 | Temperature | SINGLE | Any | In degree celsius |
| 29 | Signal Count | UINT8 | 0-78 | This is a count of the total number of signals in the receiver correlation channels. The satellites in this count can be in any state of acquisition. |
| 30 | Satellites Used | UINT8 | 0-78 | Number of satellites actually used in the Receiver Mode computation. If the unit is in OD mode, used count will be the satellites used in timing, else it will be the satellites used in positioning |
| 31-32 | Reserved | UINT32 | Any | |
| 33 | Checksum | UINT8 | Any | |
| 34 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 35 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

Response example:

```
10 A3 11 00 1D 02 06 FF 64 3F 81 47 AE 3F 02 8F 5C 3F 5E B8 52 3F 0A 3D 71 42 06 84 17 38
07 FF FF 93 10 03
```

If data is not available:

```
10 A3 11 00 02 02 B0 10 03
```

Error Codes (0xA3-21)

TSIP packet 0xA3-21 returns the error codes for TSIP query or set command.

The receiver automatically outputs this packet with an error code if received TSIP packets include undefined data.

Response

| Byte | Item | Type | Value | Description |
|------|------------------------|--------|---------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA3 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x21 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 2 | 2: Response |
| 6 | Reference packet ID | UINT8 | Any | |
| 7 | Reference subpacket ID | UINT8 | Any | |
| 8 | Error code | UINT8 | 1 - 255 | 1 - Parameter error 2 - Length error 3 - Invalid packet format 4 - Invalid checksum 5 - Incorrect TNL/User mode 6 - Invalid Packet ID 7 - Invalid subpacket ID 8 - Update in progress 9 - Internal error caused div by 0 10 - Internal error (failed queuing) 11 - Invalid setting for configuration |
| 9 | Checksum | UINT8 | Any | |
| 10 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 11 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

AGNSS (0xA4-00)

Use TSIP 0xA4-00 packet to set the assisted GNSS(AGNSS).

The Acutime 720 antenna supports Assisted GNSS, which allows the receiver to obtain a position fix even in very poor GNSS signal conditions using almanac, ephemeris, time and position data.

Set: Single Precision

| Byte | Item | Type | Value | Description |
|-------|---------------------------|--------|-------|--|
| 0 | Start Byte | UINT8 | 0x10 | Start of packet |
| 1 | Packet ID | UINT8 | 0xA4 | Packet ID |
| 2 | Subpacket ID | UINT8 | 0x00 | Subpacket ID |
| 3-4 | Length | UINT16 | Any | Total length of mode + data + checksum |
| 5 | Mode | UINT8 | 0-2 | 1: Set |
| 6 | Precision | UINT8 | 0 | Single Precision |
| 7 | Format | UINT8 | 0-1 | NOTE - Position must be entered in WGS-84 datum. 0: Latitude, longitude, altitude in degrees 1: Latitude, longitude, altitude in radians 2: ECEF X, Y, Z |
| 8-11 | Latitude / X | Single | Any | Latitude in radians, + for north, - for south X in meters |
| 12-15 | Longitude / Y | Single | Any | Longitude in radians, + for east, -for west Y in meters |
| 16-19 | Altitude / Z | Single | | Altitude in meters, -400 to 10000, HAE Z in Meters |
| 20-23 | Horizontal Uncertainty | Single | | |
| 24-27 | Vertical Uncertainty | Single | | |
| 28 | Checksum | UINT8 | Any | |
| 29 | Delimiter 1 | UINT8 | 0x10 | End of packet 1 |
| 30 | Delimiter 2 | UINT8 | 0x03 | End of packet 2 |

NMEA 0183 Protocol

This provides a brief overview of the NMEA 0183 protocol, and describes both the standard and optional messages offered by the Acutime 720 antenna.

- ▶ [Introduction](#)
- ▶ [NMEA 0183 communication interface](#)
- ▶ [NMEA 0183 message structure](#)
- ▶ [Field definitions](#)
- ▶ [NMEA 0183 message options](#)
- ▶ [NMEA 0183 message formats](#)
- ▶ [Exception behavior](#)

Introduction

The National Marine Electronics Association (NMEA) protocol is an industry standard data protocol which was developed for the marine industry.

NMEA 0183 is a simple, yet comprehensive ASCII protocol which defines both the communication interface and the data format. The NMEA 0183 protocol was originally established to allow marine navigation equipment to share information. Since it is a well-established industry standard, NMEA 0183 has also gained popularity for use in applications other than marine electronics.

NMEA 0183 communication interface

The NMEA 0183 protocol allows a single source (talker) to transmit serial data over a single twisted wire pair to one or more receivers (listeners). The table below lists the standard characteristics of the NMEA 0183 data transmissions.

| Signal | NMEA Standard |
|-----------|---------------|
| Baud rate | 115 kbps |
| Data bits | 8 |
| Parity | None |
| Stop bits | 1 |

NMEA 0183 message structure

The NMEA 0183 protocol covers a broad array of navigation data. This broad array of information is separated into discrete messages which convey a specific set of information. The entire protocol encompasses over 50 messages, but only a sub-set of these messages apply to a GPS receiver like the . The NMEA message structure is described below.

\$IDMSG, D1, D2, D3, D4, , Dn*CS [CR] [LF]

Where:

| | |
|----------|--|
| \$ | Signifies the start of a message |
| ID | The talker identification is a two letter mnemonic which describes the source of the navigation information. The GP identification signifies a GPS source while GL will signify a GLONASS source. In the event that the information in the sentence is agnostic the ID will be GP. |
| MSG | The message identification is a three letter mnemonic which describes the message content and the number and order of the data fields. |
| , | Commas serve as delimiters for the data fields. |
| Dn | Each message contains multiple data fields (Dn) which are delimited by commas. |
| * | The asterisk serves as a checksum delimiter. |
| CS | The checksum field contains two ASCII characters which indicate the hexadecimal value of the checksum. |
| [CR][LF] | The carriage return [CR] and line feed [LF] combination terminate the message. |

NMEA-0183 messages vary in length, but each message is limited to 79 characters or less. This length limitation excludes the "\$" and the [CR][LF]. The data field block, including delimiters, is limited to 74 characters or less.

Talker IDs

The message talker ID, which is the two characters immediately following the starting marker (\$) in a standard NMEA message, describes the source of data in a particular message. Specifically, it indicates the GNSS constellation to which the data is applicable. The following table lists talker IDs.

| Talker ID | Constellation | Description |
|-----------|---------------|---|
| GN | ALL | Data combines all supported and enabled constellations on a given device. |
| GP | GPS | Data from GPS |
| BD | BEIDOU | Data from BEIDOU |
| GA | GALILEO | Data from GALILEO |
| GL | GLONASS | Data from GLONASS |

Field definitions

Many of the NMEA data fields are of variable length, and the user should always use the comma delineators to parse the NMEA message data field. The following table specifies the definitions of all field types in the NMEA messages supported by Protempis:

| Type | Symbol | Definition |
|------------------------------|-----------|---|
| Status | A | Single character field: A=Yes, data valid, warning flag clear V=No, data invalid, warning flag set. |
| Special Format Fields | | |
| Latitude | lll.lll | Fixed/variable length field: Degreesminutes.decimal-2 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeroes always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal- fraction are optional if full resolution is not required. |
| Longitude | yyyyy.yyy | Fixed/Variable length field: Degreesminutes.decimal-3 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeroes always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal- fraction are optional if full resolution is not required. |
| Time | hhmmss.ss | Fixed/Variable length field: hoursminutesseconds.decimal-2 fixed digits of minutes, 2 fixed digits of seconds and a variable number of digits for decimal-fraction of seconds. Leading zeroes always included for hours, minutes, and seconds to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required. |
| Defined | | Some fields are specified to contain pre-defined constants, most often alpha characters. Such a field is indicated in this standard by the presence of one or more valid characters. Excluded from the list of allowable characters are the following, that are used to indicated field types within this standard: "A", "a", "c", "hh", "hhmmss.ss", "lll.lll", "x", "yyyyy.yy". |
| Numeric Value fields | | |

| Type | Symbol | Definition |
|---------------------------|--------|---|
| Variable | x.x | Variable length integer or floating numeric field. Optional leading and trailing zeros. The decimal point and associated decimal-fraction are optional if full resolution is not required (example: 73.10=73.1=073.1=73). |
| Fixed HEX | hh | Fixed length HEX numbers only, MSB on the left. |
| Information fields | | |
| Fixed Alpha | aa | Fixed length field of upper-case or lower-case alpha characters. |
| Fixed Number | xx | Fixed length field of numeric characters. |

NOTE -

- Spaces are only to be used in variable text fields.
- Units of measure fields are appropriate characters from the **Symbol** column, unless a specified unit of measure is indicated.
- Fixed length field definitions show the actual number of characters. For example, a field defined to have a fixed length of 5 HEX characters is represented as hhhhh between delimiters in a sentence definition.

NMEA 0183 message options

The Protempis[®] Acutime 720 Smart antenna can output any or all of the messages listed in the table below. In its default configuration (as shipped from the factory), the Acutime 720 Smart antenna outputs only TSIP messages. Typically, NMEA messages are output at a one second interval with the "GP" talker ID and checksums. These messages are output at all times during operation, with or without a fix. If a different set of messages has been selected (using Packet 0x91-13), and this setting has been stored in flash memory (using Packet 0x91-02), the default messages are permanently replaced until the receiver is returned to the factory default settings.

NOTE - You can configure a custom mix of the messages listed in the following table.

CAUTION - If too many messages are specified for output, you may need to increase the unit's baud rate.

| Message | Description |
|---------|---|
| GGA | GPS fix data |
| GLL | Geographic position Latitude/Longitude |
| GSA | GPS DOP and active satellites |
| GSV | GPS satellites in view |
| RMC | Recommended minimum specific GPS/Transit data |
| VTG | Track made good and ground speed |
| ZDA | Time and date |

Acutime 720 Smart antenna proprietary NMEA messages

| Message | Description |
|---------|--|
| CR | Query or set GPS receiver configuration information. |
| NM | Query or set NMEA automatic message output control. |
| PT | Query or set serial port configuration. |
| VR | Query and response to version information |

NMEA 0183 message formats

GGA - GPS Fix Data

The GGA message includes time, position and fix related data for the GNSS receiver.

This message is output automatically if selected in the NMEA message output mask. It can also be queried using the command `$GPGPQ,GGA*hh<CR><LF>`

`$aaGGA,hhmmss.s,lll.lllx,d,yyyy.yyyx,d,q,s,xh.hx,xaaaaa,M,xggg,M,xxx,xxxx*hh<CR><LF>`

| Field | Description |
|-----------|---|
| aa | Talker ID |
| hhmmss.s | Hours, minutes, seconds, sub-seconds of position in UTC. |
| lll.lllx | Latitude |
| d | N S |
| yyyy.yyyx | Longitude |
| d | E W |
| q | Quality indicator (see Section 3.1 for more info): 0 = fix not available 1 = autonomous GNSS mode, fix valid 2 = differential/SBAS-aided GNSS mode, fix valid 4 = RTK (fixed) or RTX 5 = RTK (float) 6 = estimated/dead reckoning mode (DR) |
| s | Number of satellites in use |
| xh.hx | HDOP |
| xaaaaa | Antenna altitude, meters MSL |
| xggg | Geoidal separation, meters. This is the difference between the earth ellipsoid and mean-sea-level (geoid) defined by the reference datum used in the position solution. A negative value indicates the mean-sea-level is below ellipsoid. |
| xxx | Age of differential corrections data |
| xxxx | Differential reference station ID |
| hh | checksum |

GLL - Geographic Position - Latitude/Longitude

The GLL message contains the latitude and longitude of the present vessel position, the time of the position fix and the status.

This message is output automatically if selected in the NMEA message output mask. It can also be queried using the command `$GPGPQ, GLL*hh<CR><LF>`

`$aaGLL, llll.lllx, d, yyyyy.yyyx, d, hhmmss.s, s, a*hh<CR><LF>`

| Field | Description |
|------------|---|
| aa | Talker ID |
| lll.lllx | Latitude |
| d | N S |
| yyyyy.yyyx | Longitude |
| d | E W |
| hhmmss.s | Hours, minutes, seconds, sub-seconds of position in UTC. |
| s | Status: A = data valid V = data invalid |
| a | Mode indicator: N = data not valid A = autonomous mode D = differential/SBAS-aided mode F = RTK (float) R = RTK (fixed) P = RTX or PPP E = estimated/DR M = manual mode |
| hh | checksum |

GSA - GPS DOP and Active Satellites

The GSA messages indicate the GNSS receiver's operating mode and lists the satellites used for navigation and the DOP values of the position solution.

This message is output automatically if selected in the NMEA message output mask. It can also be queried using the command `$GPGPQ,GSA*hh<CR><LF>`

`$aaGSA,m,s,n1,n2,n3,n4,n5,n6,n7,n8,n9,n10,n11,n12,xp.px,xh.h.x,xv.vx,h*hh<CR><LF>`

| Field | Description |
|------------|--|
| aa | Talker ID |
| m | Operating Mode: M = Manual, forced to either 2D or 3D A = Automatic, allowed to switch between 2D and 3D |
| s | Navigation mode: 1 = Fix not available 2 = 2D fix 3 = 3D fix D |
| n1 ... n12 | Satellite ID's used in solution (position fix), null if unused. Refer to GNSS identification table for NMEA v4.1 |
| x.x | Position dilution of precision (PDOP) |
| x.x | Horizontal dilution of precision (HDOP) |
| x.x | Vertical dilution of precision (VDOP) |
| h | GNSS System ID 1 - GPS (GP) 2 - GLONASS (GL) 3 - GALILEO (GA) 4 - BeiDou (GB) 5 - QZSS (GQ) |
| hh | Checksum |

GSV - GPS Satellites in View

The GSV message identifies the GNSS satellites in view, including their PRN number, elevation, azimuth and SNR value. Each message contains data for four satellites. Second and third messages are sent when more than 4 satellites are in view. Fields #1 and #2 indicate the total number of messages being sent and the number of each message respectively.

This message is output automatically if selected in the NMEA message output mask. It can also be queried using the command `$GPGPQ,GSV*hh<CR><LF>`

`$aaGSV,t,m,ts,n1,e1,aa1,s1,n2,e2,aa2,s2,n3,e3,aa3,s3,n4,e4,aa4,s4,h*hh<CR><LF>`

| Field | Description |
|---------------|--|
| aa | Talker ID |
| t | Total number of messages |
| m | Message number |
| ts | Total number of satellites in view |
| n1n4 | Satellite ID's. Refer to GNSS identification table for NMEA v4.1 |
| e1e4 | Elevation in degrees (90 degrees max) |
| aa1 aa4 | Azimuth in degrees true (000 - 359) |
| s1s4 | SNR (00 - 99 dB-Hz) |
| h | Signal ID. Refer to GNSS identification table for NMEA v4.1 |
| hh | Checksum |

RMC - Recommended Minimum Specific GPS/Transit Data

The RMC message contains the time, date, position, course, and speed data provided by the GNSS navigation receiver. A checksum is mandatory for this message and the transmission interval may not exceed 2 seconds. All data fields must be provided unless the data is temporarily unavailable. Null fields may be used when data is temporarily unavailable. This message is output automatically if selected in the NMEA message output mask.

`$aaRMC,hhmmss.s,s,lll.lllx,d,yyyy.yyyx,d,xs.sx,xc.cx,ddmmyy,xm.vx,d,a*hh<CR><LF>`

| Field | Description |
|-----------|---|
| aa | Talker ID |
| hhmmss.s | Hours, minutes, seconds, sub-seconds of position in UTC. |
| s | Status (see Section 3.1 for more info): A = data valid V = data invalid |
| lll.lllx | Latitude |
| d | N S |
| yyyy.yyyx | Longitude |
| d | E W |
| xs.sx | Speed Over Ground in Knots |
| xc.cx | Course Over Ground in Degrees True |
| ddmmyy | Day, month, year of date |
| xm.vx | Magnetic Variation in Degrees |
| d | E W |
| a | Mode indicator: N = data not valid A = autonomous mode D = differential/SBAS-aided mode F = RTK (float) R = RTK (fixed) P = RTX or PPP E = estimated/DR M = manual mode |
| hh | Checksum (mandatory for RMC) |

VTG - Track Made Good and Ground Speed

The VTG message conveys the actual track made good (COG) and the speed relative to the ground (SOG).

This message is output automatically if selected in the NMEA message output mask.

```
$aaVTG,xc.cx,T,xc.cx,M,xs.sx,N,xs.sx,K,a*hh<CR><LF>
```

| Field | Description |
|-------|---|
| aa | Talker ID |
| xc.cx | Course Over Ground in Degrees True |
| xc.cx | Course Over Ground in Degrees Magnetic |
| xs.sx | Speed Over Ground in knots |
| xs.sx | Speed Over Ground in km/hr |
| a | Mode indicator: N = data not valid A = autonomous mode D = differential/SBAS-aided mode F = RTK (float) R = RTK (fixed) P = RTX or PPP E = estimated/DR M = manual mode |
| hh | Checksum |

ZDA - Time & Date

The ZDA message contains UTC time, the day, the month, the year and the local time zone.

This message is output automatically if selected in the NMEA message output mask.

```
$aaZDA,hhmmss.s,dd,mm,yyyy,zh,zm*hh<CR><LF>
```

| Field | Description |
|----------|--|
| aa | Talker ID |
| hhmmss.s | Hours, minutes, seconds, sub-seconds of position in UTC. |
| dd | Day (01 to 31) |
| mm | Month (01 to 12) |
| yyyy | Year |
| zh | Local Zone Hour, offset from UTC to obtain Local time |
| zm | Local Zone Minute |
| hh | Checksum |

CAUTION - If UTC offset is not available, time output will be in GPS time until the UTC offset value is collected from the GPS satellites. When the offset becomes available, the time will update to UTC time.

NOTE - GPS time can be used as a time tag for the 1PPS. The ZDA message comes out 100-500 msec after the PPS.

CR - Configure Receiver

Use this sentence to query or set receiver configuration information.

The Query sentence format is:

\$PTNLQCR*hh<CR><LF>

The Response to query or Set sentence format is:

\$PTNLaCR,x.x,x.x,x.x,x.x,x.x,x.x,a,a,a,a,*hh<CR><LF>

| Field | Description |
|-------|--|
| a | Mode (S = set; R = response) |
| x.x | Signal Level Mask (default = 0.6 AMU) |
| x.x | Elevation mask in degrees (default = 5 degrees) |
| x.x | PDOP mask (default = 12) |
| x.x | PDOP switch (default = 6) (unused in Onix) |
| x.x | Max Oscillator Offset (unused in Onix) |
| a | Constellation Mode, default is 0 0 - AUTO |
| a | Dynamics, default is 0 1 - Land 2 - Sea 3 - Air |
| a | Reserved, set to 1. |
| a | SBAS mode, default is 0 |

| Field | Description |
|-------|--|
| a | Bitmap of Constellation track/use mask: Bit 0 - GPS L1C Bit 1 - GPS L2 (Not supported, for future use) Bit 2 - GPS L5 Bit 3 - Reserved Bit 4 - Glonass G1 Bit 5 - Glonass G2 (Not supported, for future use) Bit 6,7 - Reserved Bit 8 - SBAS Bit 9 - Reserved Bit 10 - Reserved Bit 11 - Reserved Bit 12 - Beidou B1 Bit 13 - Beidou B2i (Not supported, for future use) Bit 14 - Beidou B2a Bit 15 - Reserved Bit 16 - Galileo E1 Bit 17 - Galileo E5a Bit 18 - Galileo E5b (Not supported, for future use) Bit 19 - Galileo E6 (Not supported, for future use) Bit 20 - Reserved Bit 21 - QZSS L1C Bit 22 - QZSS L2C (Not supported, for future use) Bit 23 - QZSS L5 Bit 24 - Reserved Bit 25 - Reserved Bit 26 - Navic L5 Bit 27 - Reserved Bit 28 - Reserved Bits 29-31 - Reserved |
| a | Jamming enable/disable (1 default): 0 - disable 1 - enable In Acutime 720 Smart antenna, it is set to 1 and not configurable. |
| hh | Checksum |

The Response to set format is:

\$PTNLRCR,a*hh<CR><LF>

| Field | Description |
|-------|-----------------------------------|
| a | Status (A - success; V - failure) |
| hh | Checksum |

PT - Serial Port Configuration

Use this sentence to configure the current serial port. The Query sentence format is:

\$PTNLQPT*hh<CR><LF>

The Response sentence to query or Set sentence format is:

\$PTNLaPT,xxxxxx,a,a,a*hh<CR><LF>

In the case of Set, the Response message with new parameters is sent using the old parameters first, and then the switch to the new parameters is made.

If the switch fails for any reason, an NMEA error response is sent. If the switch succeeds, no additional response is sent.

| Field | Description |
|--------|---|
| a | Mode (S = set, R = response) |
| xxxxxx | Baud rate (9600, 19200, 38400, 57600, 115200, 230400, 460800, 926100), Default baud rate is 115200 |
| a | Number of data bits (7 or 8) |
| a | Parity (N = None, O = Odd, E = Even) |
| a | Number of stop bits (1 or 2) |
| h | Input protocol. This is a hex bit-map but only one protocol in use. This field may not be 0. Bit 0: NONE (TBD) Bit 1: TSIP Bit 2: NMEA |
| h | Output protocol. This is a hex bit-map (same as input). Bit 0: NONE (TBD) Bit 1: TSIP Bit 2: NMEA |
| hh | Checksum |

The Response sentence to set format is:

\$PTNLRPT,a*hh<CR><LF>

| Field | Description |
|-------|-----------------------------------|
| a | Status (A - success; V - failure) |
| hh | Checksum |

VR - Version

This sentence may be issued by the user to get application version information.

The Query sentence format is:

\$PTNLQVR,a*hh<CR><LF>

| Field | Description |
|-------|--|
| a | Component ID for which to query the version: S - system (application firmware) version H - hardware info |
| hh | Checksum |

The Response to query sentence format for all components versions except the hardware (H).

\$PTNLRVR,a,a..a,b...b,xx,xx,xxxx*hh<CR><LF>

Application firmware

| Field | Description |
|-------|--|
| a | Component ID (same as in Query format) |
| a..a | Component name (variable length character string) |
| b...b | Version number in the format xx.yy.zz where xx - major version number (2 digits, prepend 0 if the number is less than 10) yy - minor version number (2 digits, prepend 0 if the number is less than 10) zz - build version number (2 digits, prepend 0 if the number is less than 10) |
| | NOTE - There must be a period character separating the major/minor and minor/build numbers. |
| xx | Month (1-12) |
| xx | Day (1-31) |
| xxxx | Year |
| hh | Checksum |

The Response to query sentence format for the Hardware version (H) information is:

\$PTNLRVR,H,xxxx,a..a,xxxxxxxx,xx,xx,xxxx,xx*hh<CR><LF>

| Field | Description |
|----------|--|
| xxxx | Hardware code |
| a..a | Hardware ID (variable length character string) |
| xxxxxxxx | Serial number |
| xx | Build month (1-12) |
| xx | Build day (1-31) |
| xxxx | Build year |
| xx | Build hour (0-23) |
| hh | Checksum |

NM - NMEA Configuration

This sentence may be issued by the user to configure NMEA message output. The Query sentence format is:

\$PTNLQNM, x*hh<CR><LF>

| Field | Description |
|-------|--|
| x | Port, default is current port if field is left null. 0 - Port A 1 - Port B 255 - Current port |

The Response sentence to query or Set sentence format is:

\$PTNLanM, hhhhhhhh, x.x, x, x*hh<CR><LF>

| Field | Description |
|---------|---|
| a | Mode (S = set; R = response) |
| hhhhhhh | Message Flags (32 bits maximum), one bit for each message: Bit 0 - GGA Bit 1 - GLL Bit 2 - VTG Bit 3 - GSV Bit 4 - GSA Bit 5 - ZDA Bits 6,7 - Reserved Bit 8 - RMC Default is 0x3D |
| x.x | Automatic Report Interval (1 - 255 seconds), default is 1 if field is left null. Default is 1 second |
| x | Position fix data source. This field indicates the source of fix data in messages containing position fix information (GGA, RMC). 255 - position fix data source not supported (fix data always comes from DR for DR-capable products or from GNSS for non-DR products) This is output by default. Users can set any values or null. |

| Field | Description |
|-------|--|
| x | Port, default is current port if field is left null. 0 - Port A 1 - Port B 255 - Current port |
| hh | Checksum |

The Response sentence to set format is:

\$PTNLRNM, a*hh<CR><LF>

| Field | Description |
|-------|-----------------------------------|
| a | Status (A - success; V - failure) |
| hh | Checksum |

Exception behavior

When no position fix is available, some of the data fields in the NMEA messages will be blank. A blank field has no characters between the commas.

Interruption of GNSS signal

If the GNSS signal is interrupted temporarily, the NMEA will continue to be output according to the user-specified message list and output rate. Position and velocity fields will be blank until the next fix, but most other fields will be filled.

GNSS identification table for NMEA v4.1

| System | Satellite ID | Signal ID | Signal channel |
|---------|--------------------------|-----------|------------------|
| GPS | 1 - 32 for GPS | 0 | All signals |
| | | 1 | L1 (C/A) |
| | 33 - 64 for SBAS | 2 | L1 P(Y) |
| | | 3 | L1 M |
| | 65 - 99 undefined | 4 | L2 P(Y) |
| | | 5 | L2C-M |
| | | 6 | L2C-L |
| | | 7 | L5-I |
| | | 8 | L5-Q |
| | 9 - F | Reserved | |
| GLONASS | 33 - 64 for SBAS | 0 | All signals |
| | | 1 | G1 C/A |
| | 65 - 99 for GLONASS | 2 | G1 P |
| | | 3 | G2 C/A |
| | | 4 | GLONASS (M) G2 P |
| | 5 - F | Reserved | |
| GALILEO | 1 - 36 for Galileo | 0 | All signals |
| | | 1 | E5a |
| | 37 - 64 for Galileo SBAS | 2 | E5b |
| | | 3 | E5 a+b |
| | | 4 | E6-A |
| | | 5 | E6-BC |
| | | 6 | L1-A |
| | | 7 | L1-BC |
| | 8 - F | Reserved | |
| BeiDou | 1 - 64 for Beidou | 0 | All signals |
| | | 1 | B1I |
| | 65 - 99 undefined | 2 | B1Q |
| | | 3 | B1C |
| | | 4 | B1A |
| | | 5 | B2-a |
| | | 6 | B2-b |
| | | 7 | B2 a+b |
| | | 8 | B3I |
| | | 9 | B3Q |
| | | A | B3A |
| | | B | B2I |
| C | B2Q | | |
| | D - F | Reserved | |

| System | Satellite ID | Signal ID | Signal channel |
|--------|-----------------------|-----------|----------------|
| QZSS | 1 - 10 for QZSS | 0 | All signals |
| | 55 - 63 for QZSS SBAS | 1 | L1 C/A |
| | | 2 | L1C (D) |
| | 64 - 99 undefined | 3 | L1C (P) |
| | | 4 | LIS |
| | | 5 | L2C-M |
| | | 6 | L2C-L |
| | | 7 | L5-I |
| | | 8 | L5-Q |
| | | 9 | L6D |
| | | A | L6E |
| | | B - F | Reserved |

Setting up the Acutime Smart antenna

Protempis recommends that you install the Protempis VTS software before setting up the Acutime 720 smart antenna, as this will enable you to monitor the acquisition of satellites once you start up the multi-GNSS antenna.

A starter kit is available for testing, evaluation, and engineering purposes. This section describes the components of the starter kit, and how to set it up.

NOTE - The VTS software and the starter kit should **NOT** be considered for the commercial service grade product, but only for lab testing, lab evaluation, and engineering purposes.

NOTE - Protempis does not have any responsibility for any kind of abnormal behaviors during the commercial grade service with the VTS software and/or the starter kit.

The hardware integration is described in [Integration](#).

- ▶ [Smart Antenna Placement](#)
- ▶ [System requirements](#)
- ▶ [Installing and using the software](#)
- ▶ [Acutime 720 starter kit](#)
- ▶ [Setting up the starter kit](#)
- ▶ [Starter kit components](#)



Smart Antenna Placement

Sky-Visibility

GNSS signals can only be received on a direct line of sight between Smart antenna and satellite. The Smart antenna should see as much as possible of the total sky. Seen from the northern hemisphere of the earth, more satellites will be visible in the southern direction rather than in northern direction. The Smart antenna should therefore have open view to the southern sky. If there are obstacles at the installation site, the Smart antenna should be placed south of the obstacles, preferably, in order not to block sky-view to the south.

If the installation site is in the southern hemisphere of the earth, then the statements above are reversed - more satellites will be visible in the northern direction. Near to the equator, it doesn't matter.

Partial sky visibility causes often poor DOP values due to the geometry of the visible satellites in the sky. If the Smart antenna can only see a small area of the sky, the DOP has a high degree of uncertainty and will be worse compared to a condition with better geometric distribution. It may happen that a Smart antenna is seeing 6 satellites, all close together, and still get a much worse DOP than a Smart antenna which sees 4 satellites, but all in different corners of the sky. The Smart antenna's DOP filter rejects fixes with high DOP (high uncertainty), therefore it can take longer to get the first acceptable fix if sky visibility is partly obstructed.

Multipath-reflections

Multipath occurs when the GNSS signals are reflected by objects, such as metallic surfaces, walls and shielded glass for example. The Smart antenna should not be placed near a wall, window or other large vertical objects if it can be avoided.

Jamming

Jamming occurs when the Smart antenna function is disturbed by external RF sources that interfere with GNSS signals or saturate the antenna LNA or receiver front-end. A good indicator to detect jamming is switching off all other equipment except the GNSS. Watch the satellite signal levels in this condition. Then switch on other equipment and see if the signal levels go down. A drop of signal levels indicates interference to GNSS from the other equipment. This method cannot, however, detect all possible kinds of jamming. Spurious events are hard to catch. Low frequency fields, like 50 Hz, are unlikely to jam the Smart antenna. Broadband sparks are a potential source of spurious jamming. There's no general installation rule or specification though, because the effect of jamming highly depends on the nature of the jamming signal and there are uncountable many variations possible, so that it's not possible to standardize a test scenario.

Ground plane

A metal plate or surface under the antenna can block signal reflections from below. This is a good method to mitigate reflections, if the antenna is mounted on high masts or other elevated sites.

System requirements

Hardware

- For evaluation or engineering purposes:
 - The Protempis Acutime 720 Dual-band multi-GNSS smart antenna starter kit, see later in this chapter.
- For permanent installation:
 - Protempis Acutime 720 Dual-band multi-GNSS smart antenna
 - Interface cable with DB-25 connector
 - Universal Interface Module

Computer

An office computer powered by a version of the Microsoft® Windows® operating system (Windows XP or later).

System software

- Protempis VTS software. This is used to monitor the Acutime 720 antenna's performance and to assist system integrators in developing a software interface for the smart antenna. The software is compatible with the Windows operating systems. See [Protempis VTS software](#).
- Protempis Standard Interface Protocol (TSIP). This consists of command packets and report packets. See Appendix A Protempis Standard Interface Protocol, page 1.
- NMEA-0183. See Appendix B [NMEA 0183 Protocol](#).

Installing and using the software

All software programs for the Acutime 720 starter kit are available online from the Protempis website at <http://www.Protempis.com/Timing/Acutime-360.aspx>. These programs enable you to monitor the Acutime 720 antenna and change its settings.

TIP - Install and set up the monitor program before turning on the Acutime 720 antenna—this allows you to watch the timing process, from start up to fully functioning.

Protempis VTS software

CAUTION - Use only the Protempis VTS software with this product. Previous software versions may not be compatible.

To install the Protempis VTS software from the website:

1. Go to <http://www.Protempis.com/timing/acutime-360.aspx> and then select **Support for TGS / Installation Files**.

2. Select and then download Protempis VTS.exe to the computer's hard drive.
3. To run the application, double-click the file. The **Protempis VTS** screen appears.
4. To specify the communications port and protocol for your office computer, right-click in the bottom right of the Protempis VTS screen and then select the required COM port and settings.
5. Connect the Acutime 720 antenna to the Universal Interface Module (UIM) using the provided antenna interface cable. Connect the 12-pin connector to the antenna, and the DB-25 connector to the UIM.
6. Connect one end of the USB cable to the USB port of the UIM.
7. Connect the other end of the cable to the USB port of your computer.
8. Turn on the DC power source or plug in the AC/DC converter and then turn on the power.
The Tx and Rx in the lower left of the status bar indicate the following:
 - If the Tx blinks, the computer is transmitting commands to the receiver.
 - If the Rx blinks, the computer is receiving reports from the receiver.
9. The Acutime 720 antenna automatically begins its self-survey. When this is complete and the receiver achieves a position fix, the following information appears:
 - position
 - time
 - satellites tracked
 - GPS receiver status

NOTE - The receiver sends a health report every few seconds, even if satellites are not being tracked.

Data fields

If the Protempis VTS software displays a question mark (?) in a data field, the receiver has not reported a status for this field. If the question mark stays in place, the Acutime 720 antenna may not be communicating with the computer. Check the interface cable connections and verify the serial port selection and settings.

If the communication fails, contact the Protempis Technical Assistance Center or local reseller..

TSIP

The Protempis Standard Interface Protocol (TSIP) consists of command packets and report packets, see Appendix A Protempis Standard Interface Protocol.

The TSIP is installed by factory default.

NMEA-0813

To convert to the NMEA protocol, refer to and use the Protempis VTS software for serial port protocol, Input/Output, message type output, and baud rate configuration.

Acutime 720 starter kit



Acutime 720 Smart
Antenna



Universal Interface Module (RS-422 to USB converter)



Power converter
(AC to 24 VDC)



Power pin adapters

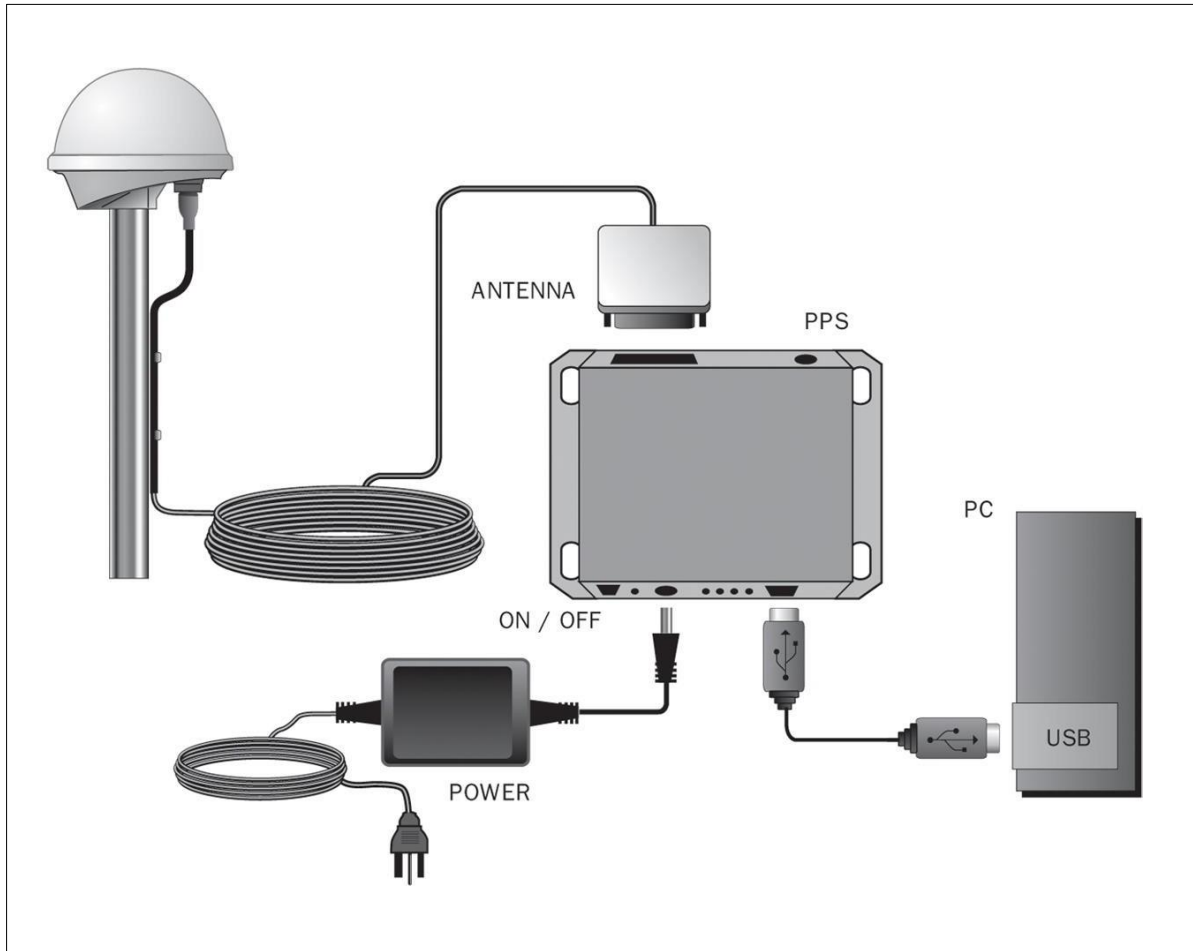


USB cable



30 m (100 feet) of interface
cable
with DB-25 connector

Setting up the starter kit



1. Mount the Acutime 720 antenna on a 1" OD marine pipe or 3/4" ID pipe, with 14 threads per inch.
2. Connect the antenna cable to the Acutime 720 antenna. Allow for the cable to maintain a "drip-loop" to prevent water intrusion and to allow for flex on the antenna to cable connector.
3. Place the Acutime 720 antenna so that it has the fullest possible view of the sky to ensure that the maximum number of satellites is available.
4. Use the DB-25 connector to connect the antenna cable to the rear of the UIM.

CAUTION - Be careful not to damage the cable. Take care to avoid sharp bends or kinks in the cable, hot surfaces (for example, exhaust manifolds or stacks), rotating or reciprocating equipment, sharp or abrasive surfaces, door and window jambs, routing near high EMI / EMF (Electro-Magnetic Induction / Field) transformers or equipment, and corrosive fluids or gases.

5. When using the TSIP protocol, connect one end of the USB interface cable to the USB port of the interface unit. Connect the other end of the cable to the USB port on a computer.

NOTE - The antenna supports the TSIP or NMEA protocols. Dual ports support either the input/output of TSIP messages or the output of NMEA messages.

6. To connect the power connector to the UIM, do one of the following:
 - Use the DC power cable. Connect the terminated end of the power cable to the power connector on the UIM. Connect the red lead to DC positive voltage (+12 VDC to +24 VDC) and the black power lead to DC ground. The yellow wire is not used.
 - Use the AC/DC power converter. Connect the output cable of the converter to the power connector on the UIM. Use the appropriate 3-pin power adapters to connect the converter to mains power (110 VAC or 220 VAC).
7. Switch on the DC power source or turn on the mains power.

To integrate the multi-GNSS smart antenna, into your system, see [Integration](#).

Starter kit components

The Protempis® Acutime 720 antenna is available as part of the starter kit, or as an individual item. The starter kit includes all the components necessary to quickly test and integrate the receiver.

| Product | Part Number |
|--|---------------------------------|
| Acutime 720 dual-band multi-GNSS Smart antenna | 121224-00 |
| 100' Acutime cable | 60155 (included in Starter kit) |
| Acutime 720 Universal Interface Module | Available with SK only |
| AC/DC power supply module | Available with SK only |
| Interface cable (USB/USB) | Available with SK only |

NOTE - Part numbers are subject to change. Confirm part numbers with your Protempis representative when placing your order.

Integration

The setup procedures for the Protempis® the Acutime 720 dual-band multi-GNSS Smart antenna are described in [Setting up the Acutime Smart antenna](#).

This chapter describes the hardware components, to assist you when you integrate the Acutime 720 antenna into a system.

To integrate the Acutime 720 dual-band multi-GNSS Smart antenna into your system you must:

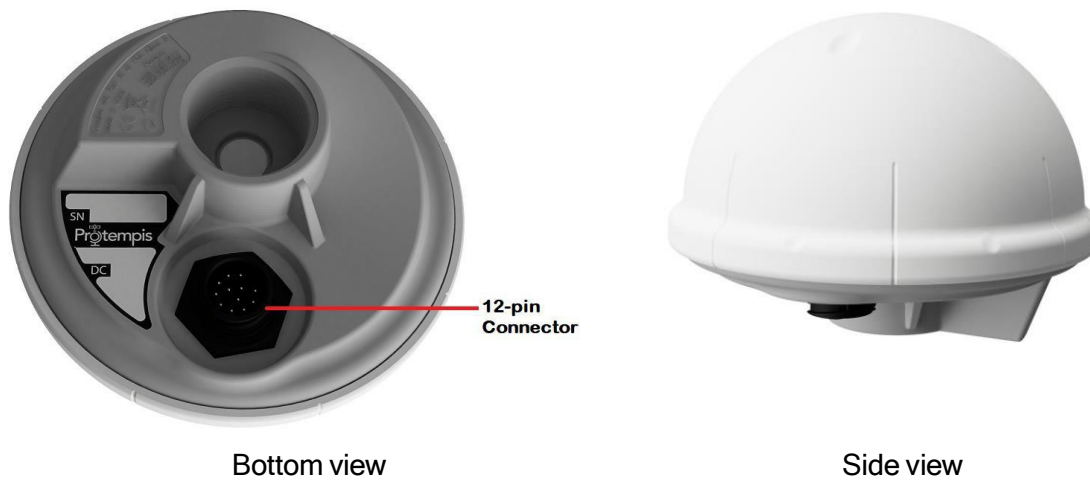
- Connect to a standard serial interface port on the host system
- Design a circuit to read the electrical 1PPS
- Develop a software interface

The setup procedures for the Acutime 720 dual-band multi-GNSS Smart antenna starter kit are described in [Setting up the Acutime Smart antenna](#).

GNSS Error Correction: ITU-T technical paper GSTR-GNSS suggested different error correction mechanisms for various physical and environmental condition that may impede signal reception and processing. Protempis recommends that the those guideline are followed for the implementation of error correction mechanisms.

- ▶ [Acutime Smart antenna](#)
- ▶ [Interface cables](#)
- ▶ [Power requirements](#)

Acutime Smart antenna



Interface cables

The Acutime 720 smart antenna's interface cable is twisted-pair technology, 22 American Wire Gauge (AWG), 6 pair/12 conductors, shielded, and protected with a PVC-U/V outer sheath.

The interface cables are available in the following standard lengths:

- 15 m (50 feet)
- 30 m (100 feet)
- 60 m (200 feet)
- 120 m (400 feet)

By following the RS-422 standard, also known as TIA/EIA-422, the maximum cable length can be up to 1000 m (3280 feet) with a data rate of 115,200 Kbit/s.

For custom-length cables of up to 550 m (1800 feet), contact Protempis.

All cables are terminated on the antenna end.

Power requirements

The Protempis® Acutime 720 is designed for static timing applications and requires a nominal +12 VDC to +24 VDC input (a range of +7 VDC to +36 VDC is possible). You can apply power to the Universal Interface Monitor using one of two options: the DC power cable, or the AC/DC power converter.

TIP - Some voltage drop will occur over the cable run. If feed voltage is limited to +7 VDC, the cable length is limited to 9 m (30 feet). When the cable is 30 m (100 feet) or longer, the feed voltage must be at least +12 VDC. Protempis recommends +24 VDC for most runs.

The red wire (Acutime 720 pin 1) and the black wire (Acutime 720 pin 9) on the interface cable support power and ground connections, respectively. The Acutime 720 smart antenna features a linear power supply, which supports +7 to +36 VDC. The antenna is protected against reverse polarity and brief over voltage conditions, however, extended over-voltage conditions may cause permanent damage.

Power consumption of the Acutime 720 smart antenna is less than 80 mA at 12 VDC.

Pulse-Per-Second (PPS)

The Acutime 720 smart antenna provides a 10 ms wide, RS-422, Pulse-Per-Second (PPS) on antenna connector pins 11 and 12. The pulse is sent once per second and the leading edge of the pulse is synchronized to UTC, GPS, or GNSS time.

The pulse shape is affected by the distributed capacitance of the attached cabling and input circuit. The pulse's trailing edge should not be used for timing applications. An accurate timing pulse is available only when the Acutime 720 smart antenna is operating in the static.

Over-determined Clock Mode with a timing accuracy of 5 nanoseconds (one sigma) to UTC, GPS, or GNSS time under the 360 degree open sky view.

The PPS output can be programmed to provide an even-second output using TSIP packet 0x91-03.

Timing pulse connections

The Acutime 720 smart antenna outputs a timing pulse for timing and synchronization applications. The timing pulse is generated using an RS-422 line driver circuit (connector pins 11 and 12). The leading edge of the PPS output pulse is synchronized to UTC. The width of the pulse's leading edge is 20 nanoseconds or less. The exact width and shape of the pulse depends upon the distributed capacitance of the interface cable.

Serial ports

The Acutime 720 smart antenna has two RS-422 communication ports. The functions of these ports (B and A) are described below.

Port B

Port B is the primary serial port for the Acutime 720 smart antenna. Using this port, you can:

- Send commands and receive command responses.
- Query for and receive satellite data (for example, ephemeris, tracking information, and signal levels).
- Receive timing packets that are synchronized with the PPS output.
- Enable TSIP timing packets 0xA1-00(which output automatically after the self-survey has been completed) using command packet 0x91-05.
- Configure Port B to transmit NMEA packets.

The Acutime 720 smart antenna automatically sends a range of satellite data packets on Port B. You may not need these data packets—to disable them, use command packet 0x91-05. This

ensures that only the timing packets are sent. You can also choose to receive the timing packets on Port A, and use Port B to only send commands and receive satellite data.

Port A

Port A serves as a dedicated transmit port for timing packets and is also used by default to receive external event inputs.

You can select NMEA output on port A, with TSIP in / TSIP out on port B.

Event input

The Acutime 720 smart antenna accepts an external event input in the shape of an RS-422 pulse. The external event pulse input is supported on Port A (pins 6 and 7). The Acutime 720 transmits a TSIP time packet in response to the event input. The TSIP packet increments the event count field for each event received. The event time stamp is generated within 500 ns of its arrival at the Acutime 720 interface connector.

NOTE - The event capture feature is design for low frequency events of 1 PPS or longer.

NOTE - When the event input on Port A is enabled the serial receive function on Port A is disabled.