PROTEMPIS ICM 720 AND RES 720
DUAL-BAND TIMING MODULE

USER GUIDE

For use with:

- ICM 720™ dual-band timing module (P/N 121228-xx)
- RES 720™ dual-band timing module (P/N 121238-xx)
- ICM 720™ dual-band timing module on carrier board (P/N 123555-xx)
- RES 720™ dual-band timing module on carrier board (P/N 122970-xx)
- ICM 720™ dual-band timing module starter kit (P/N 128334-xx)
- RES 720™ dual-band timing module starter kit (P/N 123881-05)

Firmware version 1.00 and later

Precision Time. Perfected.

Protempis

Legal Notices

Corporate Office

Protempis
USA

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Release Notice

This is the September 2022 release (Revision C) of the RES/ICM 720 documentation.

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To obtain warranty service for the Product, please contact your local Protempis authorized dealer. Alternatively, you may contact Protempis to request warranty service by sending an email to support@protempis.com. Please prepare to provide:

- 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

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Official Language

THE OFFICIAL LANGUAGE OF THESE TERMS AND CONDITIONS IS ENGLISH. IN THE EVENT OF A CONFLICT BETWEEN ENGLISH AND OTHER LANGUAGE VERSIONS, THE ENGLISH LANGUAGE SHALL CONTROL.

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.

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Notice to Our European Union Customers

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: RES/ICM 720 timing receiver 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
V2.01.00 Rev C	September 2022	CV	Link fixes, Antenna chapter added
V2.01.00 Rev B	June 2022	CV	Protempis update
V2.00.00 Rev A	March 2022	FAE	For firmware v1.01 - Updated TSIP information - Updated NMEA information - Updated Carrier board information - Updated Starter kit information
V1.00.00 Rev A	July 2021	FAE	Initial version for firmware v1.00

List of Abbreviations

A-GPS	Assisted GPS
C/N0	Carrier-to-Noise power ratio
DC	Direct Current
DOP	Dilution of Precision
EGNOS	European Geostationary Navigation Overlay Service
ESD	Electrostatic Discharge
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema
GND	Ground
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
I/O	Input / Output
MSL	Mean Sea Level
LNA	Low Noise Amplifier
NMEA	National Marine Electronics Association
NVS	Non-Volatile storage
NTP	Network Time Protocol. Common time distribution over networks.
OCXO	Oven Controlled Crystal Oscillator
OD mode	Overdetermined clock mode
PoE	Power over Ethernet
PCB	Printed Circuit Board
PDOP	Position Dilution of Precision
PPS	Pulse per Second
PTP	Precision Time Protocol (IEEE-1588)
QZSS	Quasi-Zenith Satellite System
RF	Radio Frequency
RMS	Root Mean Square
Sync E	Synchronous Ethernet
TCXO	Temperature Controlled Crystal Oscillator

TTFF	Time to First Fix
ToD	Time of Day
T-RAIM	Timing Receiver Autonomous Integrity Monitoring
TSIP	Timing Receiver Standard Interface Protocol
UTC	Universal Time Coordinated
VCC	Voltage at the Common Collector; positive supply voltage
VSWR	Voltage Standing Wave Ratio
VTS	Protempis Visual Timing Studio
WNRO	Week Number Roll-Over

Contents

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.

This product can become extremely hot and cause burns. To reduce the risk of injury from a hot system, allow the surface to cool before touching it.

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

Operation and storage

WARNING – Operating or storing the RES/ICM 720 timing module 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.

1

Introduction

The Protempis® RES 720™ and ICM 720™ dual-band GNSS timing modules offer 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 RES 720 and the ICM 720 dual-band timing modules (referred to in this document as a *timing module*) offer 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.

An important distinction between the RES 720 and ICM 720 is that the ICM 720's main purpose is to supply a stable and low phase noise 10MHz frequency and PPS output based on this 10MHz frequency while the RES 720 is to supply a stable PPS output only.

To summarize:

RES 720: Primary Output is PPS (accurate) and no frequency(10MHz) output

ICM 720: Primary Output is 10MHz clock (stable, low phase noise) and PPS drift allowed to restrict abrupt disturbance to output clock

Key features

- 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 (no quantization error in ICM 720 only), can be configured as an even-second output, 3.3 V CMOS compatible

- Disciplined 10 MHz frequency output, 2.8 V CMOS Square wave(ICM 720 only)

- 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 phase-aligned, or adjusted, antenna, 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

Dual-band multi-constellation capability

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

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

Additionally, the RES/ICM 720 timing module 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 RES/ICM 720 timing module 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 RES/ICM 720 timing module has a single RF input for all the GNSS bands to simplify host circuitry. 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 RES/ICM 720 timing module offers precision time synchronization with 5 nanosecond accuracy in normal mode of operation. The RES/ICM 720 timing module 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 phase-aligned, or adjusted, antenna, 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 RES/ICM 720 timing module provides secure boot and anti-tampering features by default. Additionally, the RES/ICM 720 timing module offers T-RAIM to provide the highest level timing integrity.

Protocols and configuration

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

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Detailed Data Sheet

▶ Data sheet

▶ Recommended operating conditions

▶ Absolute maximum ratings

▶ 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 Hot start	30 s 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	
RES 720 Accuracy (Standard Deviation)	<5 ns (1-sigma, clear sky, absolute mode) NOTE – Requires a constant temperature, a phase-aligned or adjusted antenna, 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.
ICM 720 Accuracy (Standard Deviation)	<10 ns (1-sigma, clear sky, absolute mode) @ room temperature NOTE – Requires a constant temperature, a phase-aligned or adjusted antenna, 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/PP2S	3.3 VDC, CMOS compatible
1 PPS pulse width	1 ms(default) to 500 ms
1 PPS offset	-0.25 to 0.25 seconds
programmable output (ICM 720 only)	1 PPS (±5 ns) / PP2S / ... / 5MHz / ... / 10 MHz

Features	Specifications
Holdover (ICM 720 only)	±7 µs for 5 minutes(temperature variation of less than 5 °C per hour)
Frequency output(ICM 720 only)	
10MHz	2.8VDC, CMOS, Square wave [Duty 50±10%]
Phase noise	Typical: -124dBc/Hz @ 100Hz -140dBc/Hz @ 1kHz -145dBc/Hz @ 10kHz -150dBc/Hz @ 100kHz -150dBc/Hz @ 1MHz
Environmental data, quality and reliability	
Humidity	5% to 95% (non-condensing)
RoHS compliant (lead-free)	
Green (halogen-free)	
ETSI-RED compliant	
Manufactured and fully tested in ISO/TS 16949 certified production sites	
High vibration and shock resistance	
Electrical data	
Supply voltage	3.0 V to 3.6 V
Power consumption	30 mA @ 3.3 V (continuous), maximum 50 mA @ 3.3V
Interfaces	
UART	2
Protocols	TSIP v1.0, NMEA v4.11
Miscellaneous	
Supported antennas	Active only. Minimum gain : 15 dB; Nominal gain: 20 dB;

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)	2.7		3.6	V
I_{CC}	DC supply current		30	50 mA	mA
V_{IL}	Low-level input voltage			0.8	V
V_{IH}	High-level input voltage	2.0			V
V_{IL}	Low-level input voltage (RESET)			0.8	V
V_{IH}	High-level input voltage (RESET)		2.0		V
V_{OL}	Low-level output voltage			0.4	V
V_{OH}	High-level output voltage	Vcc-0.4			V
I_{IO}	Input/Output current			±8	mA
$tw_{(RESET)}$	RESET low pulse width	300			ns
R_{PU}	Pull-up resistor (RESET input). 10K ohm to 1.8 V through a Schottky diode		10		KΩ

Absolute maximum ratings

Pin	Signal	Description	Value	Unit
27	V_{CC}	Receiver power supply input	-0.3 to +3.6	Volt
2	V_I	Input voltage	-0.3 to V_{CC}+0.3	Volt
1, 4	V_O	Output voltage	-0.3 to V_{CC}+0.3	Volt
1, 2, 4	I_{IO}	Input /Output current	25	mA

CAUTION – Absolute maximum ratings indicate conditions beyond which permanent damage to the device may occur. Electrical specifications do not apply when you are operating the device outside its rated operating conditions.

Physical specifications

Dimensions	19 mm x 19 mm x 2.54 mm
Weight	1.7 g including metal shield

Environmental specifications

Parameter	Condition
Operating temperature	-40 °C to + 85 °C
Storage temperature	-55 °C to + 105 °C
Vibration	1.5 g sine sweep from 10 Hz to 1200 Hz random vibration 3.06 GRMS
Vibration, non-operating	1.5 g from 10 Hz to 500 Hz
Mechanical shock	±40 g operational, ±75 g non-operational
Operating humidity	5% to 95% R.H., non-condensing at +60 °C
Operating altitude	-400 m to 10000 m Mean Sea Level

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).

The RF IN pin is protected up to 1 kV contact discharge. If a higher level of compliance is required, you must add additional electrostatic and surge protection.

The PCB and component areas of the RES/ICM 720 timing module were not tested for ESD sensitivity. The open board assembly is an electrostatic sensitive device. 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 RF input of the RES/ICM 720 timing module is ESD protected, but not surge protected against external, larger overvoltage peaks. To arrest higher energy from lightning, a coax surge arrestor is required, and it has to be placed at the point where the antenna cable enters the building, according to local installation regulations for rooftop antennas in the country where the antenna is installed.

EMI

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

3

GNSS Antenna

A good GNSS antenna, together with a good installation site, is the key for getting the best performance from a GNSS receiver.

This chapter explains the requirements for the antenna and provides recommendations for a good installation.

3

GNSS antenna overview

The antenna receives the GNSS satellite signals and passes them to the receiver. The GNSS signals are spread spectrum signals in the 1551 MHz to 1614 MHz range for L1 frequency band and 1176 MHz for L5 frequency band and do not penetrate conductive or opaque surfaces. Therefore, the antenna must be located outdoors with a clear view of the sky. Protempis timing module requires an active antenna with integrated LNA. The received GNSS signals are very low power, approximately -130 dBm, at the surface of the earth. Protempis's active antenna includes a preamplifier that filters and amplifies the GNSS signals before delivery to the receiver.

The onboard circuit of the RES/ICM 720 carrier board provides DC supply voltage on the SMB coax connector for the external, active GNSS antenna. The antenna supply voltage is fully protected against short circuit by the onboard Open/Short detection with integrated current limiter. The RES/ICM 720 carrier board has a full antenna monitoring circuit on board.

Antenna requirements

The RES/ICM720 requires an active GNSS antenna with built-in Low-Noise Amplifier (LNA) for optimal performance. The antenna LNA amplifies the received satellite signals for two purposes:

a. Compensation of losses on the cable

b. Lifting the signal amplitude in the suitable range for the receiver frontend.

Task b) requires an amplification of at least 15 dB, while 20 dB is the sweet spot for the RES/ICM720 module. This would be the required LNA gain if the antenna was directly attached to the receiver without cable in between.

The cable and connector between the antenna and the receiver cause signal loss.

The overhead over the minimum required 15 dB and the actual LNA gain of the antenna is available for task a). So in case of a 30 dB LNA gain in the antenna, 15 dB are available for compensating losses.

Or in other words, the attenuation of all elements (cables and connectors) between the antenna and the receiver can be up to a total of 15 dB with a 30 dB LNA.

With a different antenna type, take the difference between 15 dB and the antenna's LNA gain as the available compensation capability. Subtract the insertion losses of all connectors from the 15 dB (or whatever the number is) and the remainder is the maximum loss, which your cable must not exceed.

As the GNSS signals are hidden in the thermal noise floor, it is very important that the antenna LNA doesn't add more noise than necessary to the system; therefore a low noise figure is even more important than the absolute amplification.

Protempis does not recommend having more than 35 dB remaining gain (LNA gain minus all cable and connector losses) at the antenna input of the receiver module. The recommended range of remaining LNA gain at the connector of the receiver module is 20 dB to 30 dB with a minimum of 15 dB and a maximum of 35 dB.

Antenna OPEN/SHORT detection

The RES/ICM720 module does not have an integrated antenna feed circuit. In order to provide the required operating power to the active GNSS antenna, an external feed circuit has to be designed-in by the system integrator. The antenna feed circuit might be very basic, simply applying a DC overlay voltage to the RF line. However, it may also contain more advanced circuitry for monitoring the antenna supply status, providing current limiting in case of short circuit conditions of the antenna cable and protecting the receiver against surges on the RF-input, all of which are optional functions. Recommendations for suitable circuits are provided in the chapter Application Circuits in this User Guide.

The RES/ICM720 carrier board has an onboard antenna feed circuit, which is described in detail in the chapter about the carrier board in this User Guide.

Antenna placement

Sky-Visibility

GNSS signals can only be received on a direct line of sight between antenna and satellite. The 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 antenna should therefore have open view to the southern sky. If there are obstacles at the installation site, the 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 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 an antenna is seeing 6 satellites, all close together, and still get a much worse DOP than an antenna which sees 4 satellites, but all in different corners of the sky. The receiver connected to an 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 antenna should not be placed near a wall, window or other large vertical objects if it can be avoided.

Jamming

Jamming occurs when the receiver connected to an 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 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.

4

Hardware

The Protempis® timing module 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.

At the RF input, there is a TVS diode for transient voltage protection and a SAW diplexor for the L1 and L5 frequency bands.

The IF frequency is 4.092 MHz.

Communication with the customer host can be achieved via the two 3.3 V UARTS.

RES 720 Block diagram

RES 720 Pin assignment

RES 720 Pin Description

Pin	Name	Description	Function	Note
1	GND	Ground	Ground	Signal ground. Connect to common ground.
2	GND	Ground	Ground	Connect to common ground.
3	RFIN	GNSS RF input	Input	50 Ω unbalanced RF input.
4	GND	Ground	Ground	Connect to common ground.

Pin	Name	Description	Function	Note
5	OPEN	Antenna OPEN	Input	Logic level from external antenna detection circuit. See Detailed pin description.
6	SHORT	Antenna SHORT	Input / Output	Logic level from external antenna detection circuit. See Detailed pin description.
7	Reserved	Reserved		Do not connect.
8	EVENT_IN	Ext reference	Input	
9	Reserved	Reserved		Do not connect.
10	Reserved	Reserved		Do not connect.
11	Reserved	Reserved		Do not connect.
12	Reserved	Reserved		Do not connect.
13	Reserved	Reserved		Do not connect.
14	GND	Ground	Ground	Signal ground. Connect to common ground.
15	GND	Ground	Ground	Signal ground. Connect to common ground.
16	RXDA	UART A Receive	Input	Logic level serial port A receive.
17	TXDA	UART A Transmit	Output	Logic level serial port A transmit.
18	Reserved	Reserved		Do not connect.
19	PPS	Pulse per second	Output	Logic level timing signal at 1 Hz. Do not connect if not used.
20	Reserved	Reserved		Do not connect.
21	RXDB	UART B Receive	Input	Logic level serial port B receive.
22	TXDB	UART B Transmit	Output	Logic level serial port B transmit.
23	Reserved	Reserved		Do not connect.
24	Reserved	Reserved		Do not connect.
25	RESET	External Reset	Input	Active low logic level reset. If not used, do not connect.

Pin	Name	Description	Function	Note
26	Reserved	Reserved		Do not connect.
27	VCC	Supply voltage	Power	Module power supply, 3.0 – 3.6 V DC.
28	GND	Ground	Ground	Signal ground. Connect to common ground.

ICM 720 Block diagram

ICM 720 Pin assignment

ICM 720 Pin description

Pin	Name	Description	Function	Note
1	GND	Ground	Ground	Signal ground. Connect to common ground.
2	GND	Ground	Ground	Connect to common ground.
3	RF IN	GNSS RF input	Input	50 Ω unbalanced RF input.
4	GND	Ground	Ground	Connect to common ground.
5	ANTOPEN	Antenna OPEN	Input	Logic level from external antenna detection circuit. See Detailed pin description.
6	ANTSHORT	Antenna SHORT	Input / Output	Logic level from external antenna detection circuit. See Detailed pin description.
7	Reserved	Reserved		Do not connect.
8	EVENT_IN	Ext reference	Input	Secondary reference - ICM 720 only
9	Reserved	Reserved		Do not connect.
10	Reserved	Reserved		Do not connect.
11	Reserved	Reserved		Do not connect.
12	Reserved	Reserved		Do not connect.
13	Reserved	Reserved		Do not connect.
14	GND	Ground	Ground	Signal ground. Connect to common ground.
15	GND	Ground	Ground	Signal ground. Connect to common ground.
16	RXDA	UART A Receive	Input	Logic level serial port A receive.
17	TXDA	UART A Transmit	Output	Logic level serial port A transmit.
18	Reserved	Reserved		Do not connect.
19	PPS	Pulse-per-second	Output	Logic level timing signal at 1 Hz (default) ˜ 10MHz (see the 0x91-03, bytes 9-12 settings) Do not connect if not used.

Pin	Name	Description	Function	Note
20	Reserved	Reserved		Do not connect.
21	RXDB	UART B Receive	Input	Logic level serial port B receive.
22	TXDB	UART B Transmit	Output	Logic level serial port B transmit.
23	SYSCLK	System Clock	Output	Frequency (10 MHz) - ICM 720 only
24	Reserved	Reserved		Do not connect.
25	RESET	External Reset	Input	Active low logic level reset. If not used, do not connect.
26	Reserved	Reserved		Do not connect.
27	VCC	Supply voltage	Power	Module power supply, 3.0 – 3.6 V DC.
28	GND	Ground	Ground	Signal ground. Connect to common ground.

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

Detailed pin description

EVENT_in pin

3.3 V must be driven by active output.

The EVENT_in pin provides a method for the unit to time-tag an event. A rising edge pulse is assigned a time-tag and that data is available as an event packet over the user interface. In the timing module this can be used as a secondary reference and is used if there is a loss of GNSS signal.

RFIN

The RF input pin is a 50 Ω unbalanced GNSS RF input, and can be used only with an active antenna. The VSWR of the RF input is equal or less than 2.0. Refer to the application designs for examples of antenna power circuits.

OPEN/SHORT pins

Protempis recommends that you use an antenna detection circuit that has short-circuit protection. Two pins are provided for reporting the antenna status: OPEN and SHORT. The SHORT pin usually functions as an input to monitor for short circuits. After power-up and following a short-circuit condition, it is driven high for approximately four microseconds in every second to turn the antenna power circuit back on.

The antenna status in the respective TSIP and NMEA packets will be reported according to the following truth table, depending on the logic levels from an external detection circuit.

Antenna detect truth table

Antenna reports	SHORT pin	OPEN pin
Antenna Open reported	1	1
Antenna Normal reported	1 [1]	0 [2]

[1] If the SHORT pin is not used it should be pulled to Vcc through a 10 kΩ resistor.

[2] If the OPEN pin is not used it should be pulled to GND.

Antenna reports	SHORT pin	OPEN pin
Antenna Shorted reported	0	0
Undefined	0	1

A typical active antenna draws between 10 mA to 20 mA.

RESET pin

The RESET pin is an open drain input/output pin that allows the module to be forced into a reset state. This pin is normally held high by an internal pull-up resistor. It is pulled low to force the unit into a reset state.

To reset the module, drive this pin to logic level 0 or "Low" for at least 300 nanoseconds, and then release this signal. Do not continue to actively drive this pin high after reset as it might prevent software resets from working. Be aware that if a software reset is issued, then this pin will be driven low internally and drive anything connected to this line low.

This pin has an internal pull-up resistor—if this pin is not used, leave it disconnected.

VCC pin

This is the primary voltage supply pin for the module.

PPS pin

Pulse-per-second. This logic level output provides a 1 Hz timing signal to external devices. The PPS pin can be configured to provide an even second output.

The pulse width of this signal is variable from 1 ms to 500 ms for PPS output.

- The cable delay compensation, enable state, and polarity can be controlled by TSIP packet 0x91-03 (see page 101).
- The PPS output options are set by TSIP packet 0x91-03.

> NOTE – For ICM 720, this pin can be configurable for the programmable frequency output from an even second pulse(PP2S) up to 10MHz with only integer values of 10MHz divisors. For more details, please check the TSIP packet 0x91-03, bytes 9-12 settings.

RXDA, RXDB pins

This logic level input is the serial port receive line (data input to the module). The baud rate for the port is user configurable. If any of these pins are not used, they should be left disconnected.

TXDA, TXDB pins

This logic level output is the serial port transmit line (data output from the module). The baud rate for the port is user configurable.

Reserved pins

There are several reserved pins on the timing module.

> **CAUTION –** Connecting any of the reserved pins to supply voltage or GND or any logic level may bring the timing module into an undefined condition that may impact the function and performance of the receiver or may cause damage to the module.

RF layout considerations

General recommendations

The design of the RF transmission line that connects the GNSS antenna to the RES/ICM 720 timing module multi-GNSS timing module is critical to system performance. If the overall RF system is not implemented correctly, the RES/ICM 720 timing module multi-GNSS timing module performance may be degraded.

The radio frequency (RF) input on the RES/ICM 720 timing module is 50 Ω, unbalanced. There are ground castellations (pins 2 and 4) on both sides of the RF input castellation (pin 3). This RF input should be connected to the output of an LNA which has a GNSS antenna as its input.

If the GNSS antenna must be located a significant distance from the RES/ICM 720 timing module multi-GNSS timing module, the use of an LNA at the antenna location is necessary to overcome the transmission losses from the antenna to the RES/ICM 720 timing module multi-GNSS timing module.

Determine the specifications for the external LNA as follows:

- The noise figure for the external LNA should be as low as possible with a recommended typical of 3 dB. Protempis recommends that the gain of the LNA exceeds the loss that is measured from the LNA output to the module input by 15 dB. For example, if the loss from the external LNA output is 10 dB, the recommended minimum gain for the LNA is 25 dB. In order to keep losses at the LNA input to a minimum, Protempis recommends that you connect the antenna directly to the LNA input, to ensure the minimum loss.

- To connect to the LNA output, use a 50 Ω, unbalanced transmission system. This transmission system may take any form, such as microstrip, coaxial, stripline, or any other 50 Ω characteristic impedance unbalanced, low-loss system.

You must keep noise sources with frequencies at or near the range from 1150 MHz to 1260 MHz and 1540 MHz to 1620 MHz away from the RF input. You can use a shielded transmission line system (stripline, coaxial) to route the signal if noise ingress is a concern.

To power an active antenna from the RF transmission line, you will need a bias-tee connector at the RES/ICM 720 timing module multi-GNSS timing module end. A simple series inductor, and shunt capacitor to which the bias voltage is supplied is sufficient. Alternatively, you can use an open/short detection and over current protection circuit. See chapter Application Circuits in this User Guide.

For the printed circuit board (PCB) layout, Protempis recommends that you keep the copper layer on which the RES/ICM 720 timing module multi-GNSS timing module is mounted clear of solder mask and copper (vias or traces) under the module. This is to insure mating of the castellations between the RES/ICM 720 timing module GPS module and the board to which it is mounted, and that there is no interference with features beneath the RES/ICM 720 timing module multi-GNSS timing module that will cause it to lift during the re-flow solder process.

For a microstrip RF transmission line topology, Protempis recommends that the layer immediately below the one to which the RES/ICM 720 timing module multi-GNSS timing module is mounted is ground plane:

- Pins 2 and 4 should be directly connected to the ground plane with low inductance connections.
- Pin 3, the RF input, can be routed on the top layer using the proper geometry for a 50 Ω system.

Design considerations for RF track topologies

You must take the following into consideration when designing the RF layout for the RES/ICM 720 timing module multi-GNSS timing module:

- The PCB track connection to the RF antenna input must:
  - Have a 50 Ω impedance
  - Be as short as possible
  - Be routed away from potential noise sources such as oscillators, transmitters, digital circuits, switching power supplies, and other sources of noise
  - Transition from the circuit board to the external antenna cable, which is typically a RF connector, if an external antenna is used
- The PCB track connection to the RF antenna input must not have:
  - Sharp bends
  - Components overlaying the track
  - Routing between components (to avoid undesirable coupling)
- RF and bypass grounding must be direct to the ground plane through its own low inductance via.

As a general guideline to prevent radiation and coupling, it helps to think of voltages and currents as electrical and magnetic fields. The electric field forms between a positive and negative charge. The magnetic field forms around a trace with current flow. You can minimize the radiation by keeping the fields under control, which means minimizing the area in which the fields form out and by separating areas with stronger fields.

- Keep the path of supply currents and their GND return currents together as close as possible. The same applies for signal currents and their GND return currents.
- Keep signal traces, which are likely to interfere with each other, apart and separate them with GND areas.
- Route supply traces and their corresponding GND return paths to separate functional blocks with separate traces and connect them only at the feed point.
- Have at least one uninterrupted GND plane on or in your PCB. The GND plane should be separated by functional blocks, but within a functional block, do not route signals across the GND plane. Route signals on another layer.

- Signal traces on a GND plane can block the way for GND return currents, thereby opening up current loops and increasing radiation. Even worse, slots in a GND plane can act as a slot-antenna structure and radiate or receive radiation on the resonating frequency.

- Surround the PCB edges with GND on top and bottom and stitch them together with multiple vias. This reduces edge radiation from traces nearby the PCB edge. On a PCB with separated GND planes, do the same on every GND area to prevent radiation from one area into another.

- Do not route signal traces across the borders of GND areas. Route them first to the GND star point and from there back to another GND area. In this way you will reduce GND coupling between the functional groups and reduce the size of the current loop, thereby reducing radiation.

- In digital circuits, lower the rising time of edges if possible. Fast rising edges (sharp square wave signals) generate many harmonics at higher frequencies. Lowering the rising time of digital outputs at the source, for example by inserting series resistors near digital output pads of ICs, will reduce the generated harmonics and therefore reduce the radiation of high frequencies.

- Always aim to minimize the sources of radiation. It is much easier and less costly to not generate radiation than to try to get rid of radiation by shielding.

PCB considerations

The minimum implementation is a two-layer PCB substrate with all the RF signals on one side and a solid ground plane on the other. You may also use multilayer boards. Two possible RF transmission line topologies include microstrip and stripline.

Microstrip transmission lines
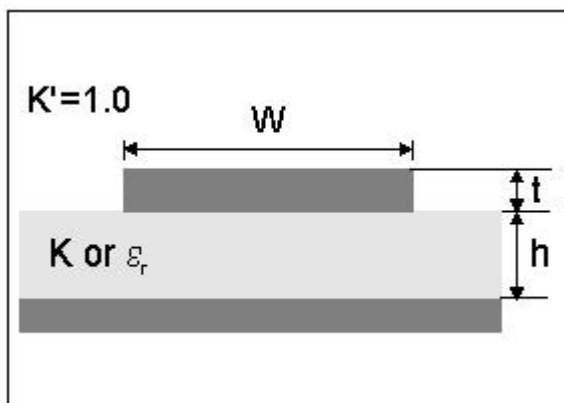
Ground plane design recommendation

Use a complete ground plane immediately under the PCB layer on which the RES/ICM 720 timing module timing module is mounted. On the same layer as the module, flood or "copper pour" around the signal tracks and then connect to the ground plane using low inductance vias. A single ground plane is adequate for both analog and digital signals.

Designing a microstrip transmission line

Use a 50 Ω unbalanced transmission system for connections to the LNA output. The following PCB parameters affect impedance:

- Track width (W)
- PCB substrate thickness (H)
- PCB substrate permittivity (εr)
- PCB copper thickness (T) and proximity of same layer ground plane (to a lesser extent)
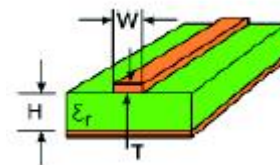
The following table shows typical track widths for an FR4 material PCB substrate (permittivity εr of 4.6 at 1.5 GHz) and different PCB thickness. The thickness of the top layer is assumed as being one ounce copper. If using a multi-layer PCB, the thickness is the distance from the signal track to the nearest ground plane.

Substrate	Permittivity	Substrate thickness H	Track width W (mm)
		1.6	2.91
		1.2	2.12
		1.0	1.81
FR4	4.6	0.8	1.44
		0.6	1.07
		0.4	0.71
		0.2	0.34

Microstrip design recommendation

Protempis recommends that the antenna connection PCB track is routed around the outside of the module outline, kept on a single layer, and that it has no bends greater than 45 degrees. For production reasons, Protempis recommends that you do not route the track under the module

Stripline transmission lines
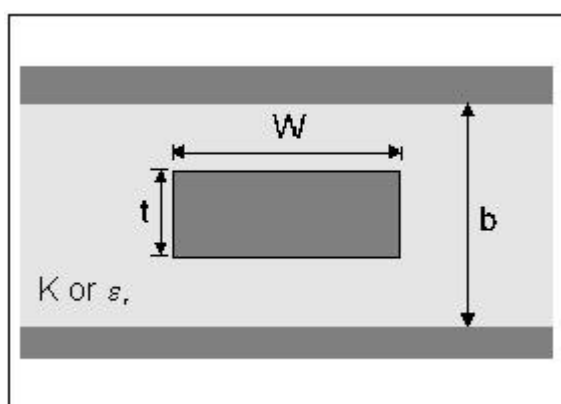
Ground plane design recommendation

The stripline topology requires three PCB layers: two for ground planes and one for signal. One of the ground plane layers may be the layer to which the RES/ICM 720 timing module multi-GNSS timing module is mounted. If this is the case:

- The top layer must be flooded with ground plane and connected to all ground castellations on the RES/ICM 720 timing module multi-GNSS timing module.
- The RF input should be connected to the signal layer below using a via.
- The layer below the signal layer is the second ground plane.
- Connect the two ground planes with vias, typically adjacent to the signal trace.
- Other signals of the RES/ICM 720 timing module multi-GNSS timing module may be routed to additional layer using vias.

For the symmetric stripline topology where the signal trace is an equal distance from each ground plane, the following applies:

Substrate	Permittivity	Substrate thickness H	Track width W (mm)
FR4	4.6	1.6	0.631
		1.2	0.438
		1.0	0.372
		0.8	0.286
		0.6	0.2
		0.4	0.111
		0.2	N/A

Soldering information

Solder pad pattern

To ensure good mechanical bonding with sufficient solder to form a castellation solder joint, use a solder mask ratio of 1:1 with the solder pad. When using a 5 ±1Mil stencil to deposit the solder paste, Protempis recommends a 4 Mil toe extension on the stencil.

> **NOTE –** All units shown are in millimeters.

The required user pad pattern is shown below.
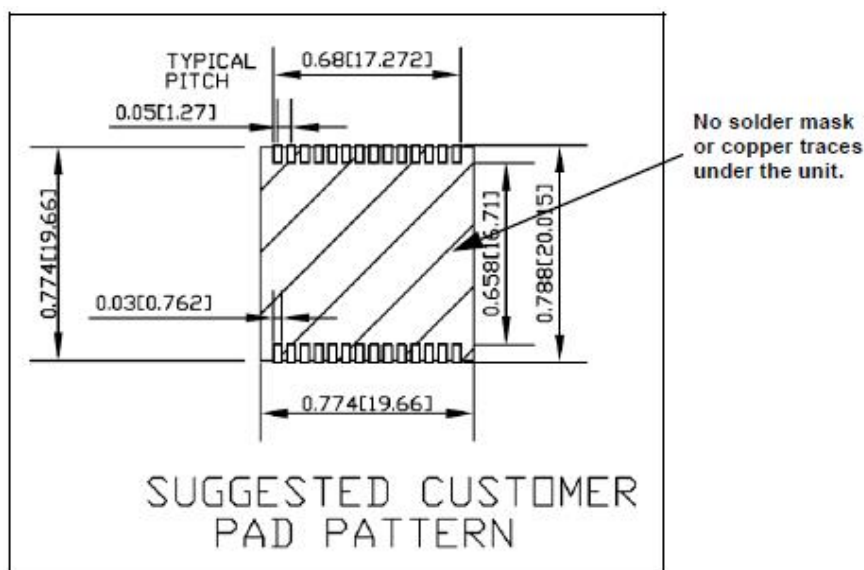
Solder mask

When soldering the RES/ICM 720 timing module multi-GNSS timing module to a PCB, keep an open cavity underneath the RES/ICM 720 timing module module (that is, do not place copper traces or solder mask underneath the module). The diagram below illustrates the required solder mask.
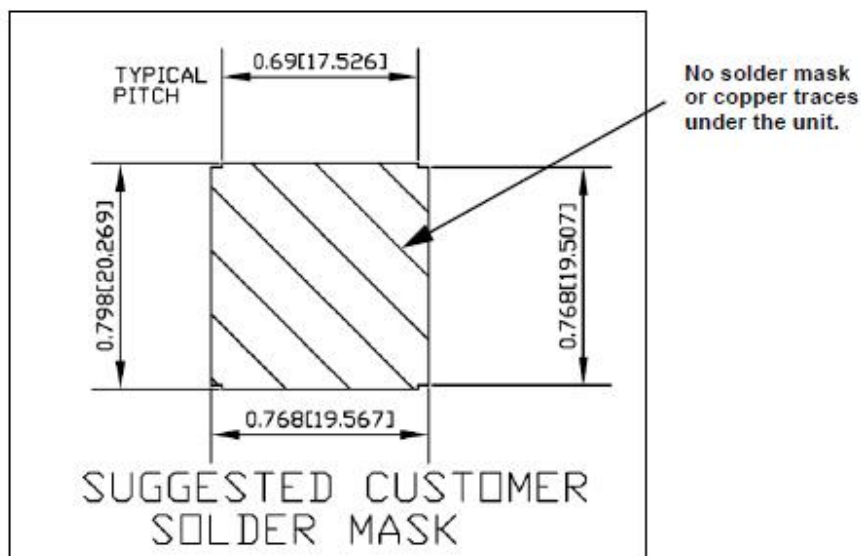
Soldering paste

The RES/ICM 720 timing module multi-GNSS timing module itself is not hermetically sealed. Protempis strongly recommends using the "No Clean" soldering paste and process. The castellation solder pad on this module is plated with gold plating. Use Type 3 or above soldering paste to maximize the solder volume.

Solder reflow

A hot air convection oven is strongly recommended for solder reflow. For the lead-free solder reflow, we recommend using a nitrogen-purged oven to increase the solder wetting. Reference IPC-610D for the lead-free solder surface appearance.

CAUTION – Follow the thermal reflow guidelines from the IPC-JEDEC J-STD-020C.

The size of this module is 916.9 mm^3. According to J-STD-020C, the peak component temperature during reflow is 245 +0 °C.

Recommended soldering profile
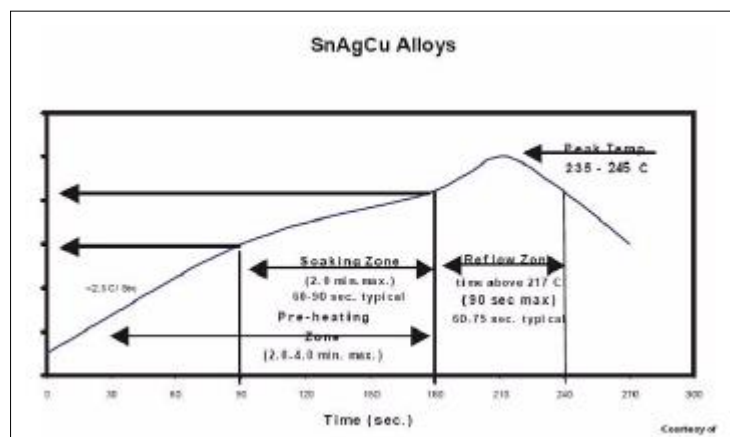
Select the final soldering thermal profile very carefully. The thermal profile depends on the choice of the solder paste, thickness and color of the carrier board, heat transfer, and the size of the panel.

> **CAUTION -** For a double-sided surface-mount carrier board, the unit must be placed on the top side to prevent falling off during reflow.

Optical inspection

After soldering the RES/ICM 720 timing module timing module to the carrier board, follow the IPC-610 specification and use a 3x magnification lens to verify the following:

- Each pad is properly aligned with the mount pad
- The pads are properly soldered
- No solder is bridged to the adjacent pads. X-ray the bottom pad if necessary

Cleaning

When the RES/ICM 720 timing module multi-GNSS timing module is attached to the user board, a cleaning process voids the warranty. Please use a "no-clean" process to eliminate the cleaning process. The gold-platedRES/ICM 720 timing module timing module may discolor with cleaning agent or chlorinated faucet water. Any other form of cleaning solder residual may cause permanent damage and will void the warranty.

Orientation for reflow soldering

The liquidus temperature of the solder paste on the RES/ICM 720 timing module module is 220 °C, which means the solder will reflow during the assembly process on the host PCB, even with the Protempis recommended temperature profile. To prevent the module falling off the host PCB during soldering, and to prevent the shield falling off the RES/ICM 720 timing module module, it must only be placed on the top side of the host PCB for the reflow process.

Repeated reflow soldering

The RES/ICM 720 timing module lead-free gold plated module can withstand two reflow solder processes. If the unit must mount on the first side for surface-mount reflow, add glue on the bottom of the module to prevent it falling off when processing the second side.

Wave soldering

The RES/ICM 720 timing module timing module cannot soak in the solder pot. If the carrier board is mixed with through-hole components and surface mount devices, it can be processed with one single lead-free wave process. The temperature of the unit will depend on the size and the thickness of the board. Measure the temperature on the module to ensure that it remains under 180 °C. Add glue on the bottom of the module to prevent it falling off during wave soldering.

Hand soldering

For the lead-free RES/ICM 720 timing module timing module, use a lead-free solder core, such as Kester 275 Sn96.5/Ag3/Cu0.5. When soldering the module by hand, keep the temperature of the soldering iron below 260 °C.

Rework

The RES/ICM 720 timing module timing module can withstand one rework cycle. The module can heat up to the reflow temperature to precede the rework. Never remove the metal shield and rework on the module itself.

Conformal coating

Conformal coating on the RES/ICM 720 timing module multi-GNSS timing module is not allowed and will void the warranty.

Mechanical Outline Drawing

Below is the RES 720 and ICM 720 timing module footprint. All dimensions are in mm.
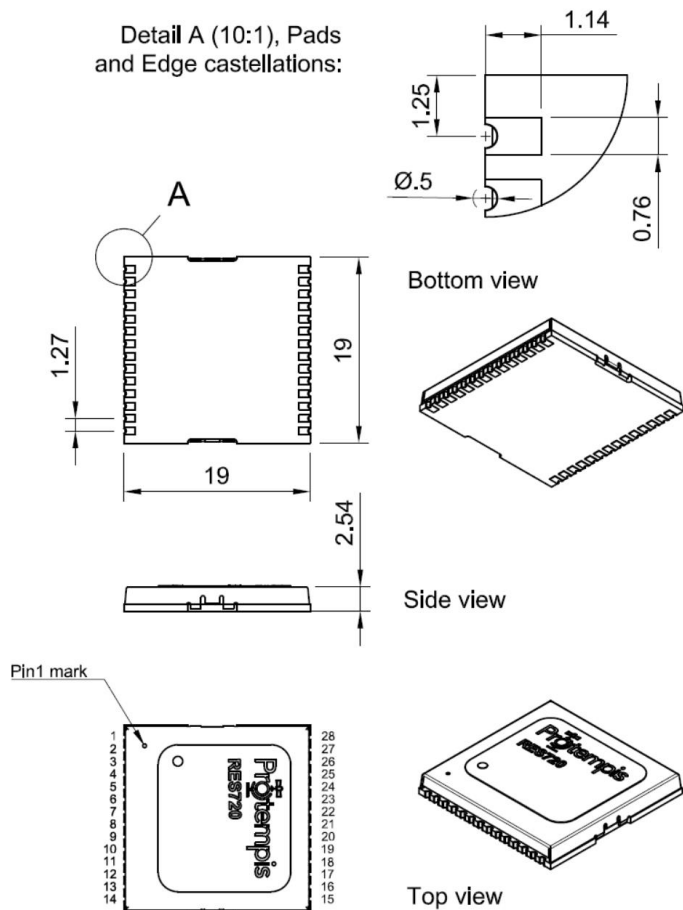
Below is the RES 720 and ICM 720 timing module visual appearance (conceptual image - see chapter Label for the label design and content).

Start-up checklist

Antenna placement for Timing receivers

Select an antenna location

- The GNSS 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 GNSS 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 GNSS 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 GPS receiver to the antenna location should not degrade the supply voltage below the minimum requirement of the antenna.

The Timing GNSS operation

Start-up

- When the timing module 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 timing module outputs periodic TSIP status messages.
- These status messages confirm that the receiver is working.

Automatic operation

- When the timing module 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 timing module automatically switches to overdetermined (OD) mode.

Satellite masks

- The timing module 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 timing module. 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 timing module 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 timing module can produce a reliable PPS by:

- making sure the received signal strength is adequate(> 35 dBm).
- determining that the timing module completes the self-survey.
- confirming the position has been stored.
- determining that the timing module stays in overdetermined (OD) mode.
- testing that the system is stable and available for a 24-hour period.

1. Connect the GNSS antenna to the receiver.
2. Apply power to the timing module.
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 1 for Short Alarm if using external antenna power. Also 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: Antenna open = 0			Check antenna connection if = 1.
Bit 1: Antenna shorted = 0			Check for short (maybe "1" if using external power).
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.

Checklist from the start-up	Yes	No	Comment
Bit 1: PPS bad			If not zero, then investigate presence of other alarms and RF signal quality.
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.

5

RES/ICM 720 on a Carrier Board

The RES 720 and ICM 720 timing modules are available on a carrier board with connectors for the RF antenna, power supply, and I/O signals.

▶ RES 720 and ICM 720 carrier board visual appearance

▶ Physical specifications

▶ Mechanical specifications

▶ Mounting

▶ Circuit diagram

▶ Interface connectors

▶ Power requirements

▶ Serial interface

▶ Pulse-per-second (PPS)

▶ 10 MHz frequency output (SYSCLK) – ICM 720 only

▶ Antenna OPEN/SHORT detection

▶ Surge protection

▶ GNSS antenna

RES 720 and ICM 720 carrier board visual appearance

The following photos show the visual appearance of the RES 720 and ICM 720 carrier board from the top-side (component side) and the bottom-side (non-component side). The carrier board is an open PCB assembly that comes without enclosure. It is designed to be integrated in a host system to provide appropriate connections, interfaces and protection to environmental influences to the device.

Carrier board top side:
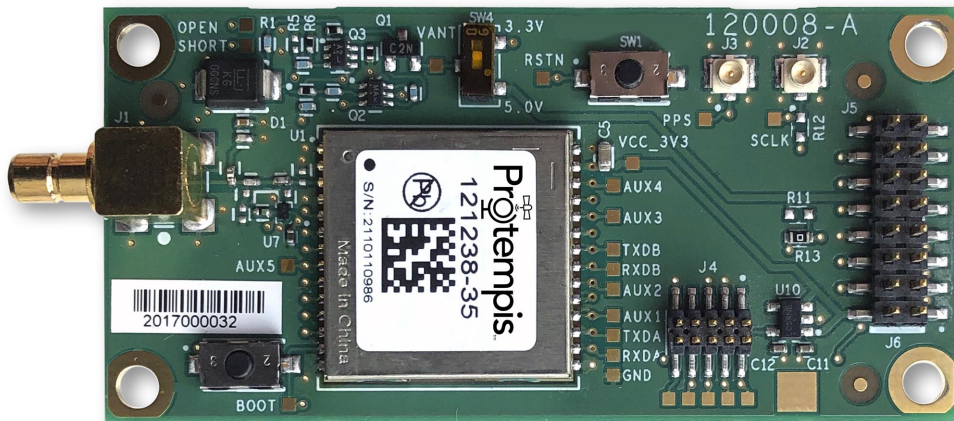
Carrier board bottom side:
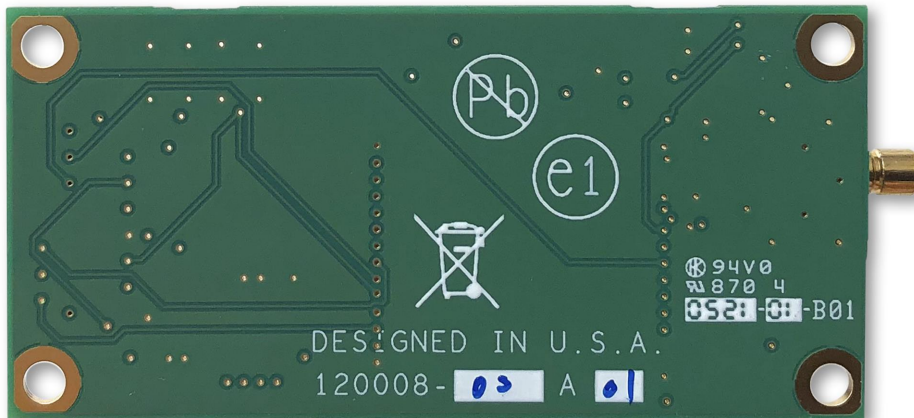
Mechanical specifications

The drawing below shows the mechanical dimensions of the RES/ICM 720 carrier board. All dimensions are shown in mm:

Physical specifications

Dimensions	66.04 mm × 31.75 mm × 8.9 mm (PCB size, excl. SMB connector)
Weight	11 g

Interface connectors

RF antenna connector

The RF antenna connector mounted on the PCB is an SMB right angle receptacle. The contact area of this connector is gold-plated.

Digital IO/Power connector

The RES/ICM 720 carrier board uses a single 16-pin (2×8) male header connector for both power and data I/O. The power and I/O connector, J5, is a surface-mount micro terminal strip. This connector uses 3.2 mm (0.126 inch) high pins on 2 mm (0.079 inch) spacing. The manufacturer of this connector is Samtec, part number TMM108-01-S-D-SM.

Mating connectors

A surface mount mating connector from those specified by Samtec as compatible to Samtec TMM-108-01-S-D-SM is recommended.

Digital IO/Power connector pin-out

The digital IO/Power connector pin-out information is provided in the following table:

Pin	Function	Description
1	TXDB	Port B transmit, CMOS 3.3 V
2	Prime power input	+3.3 V DC ±0.3 V DC
3	TXDA	Port A transmit, CMOS 3.3 V
4	Sysclk (ICM 720 only)	10MHz Frequency Output
5	RXDA	Port A receive, CMOS 3.3 V
6	1PPS	One pulse-per-second, CMOS 3.3 V
7	RXDB	Port B receive, CMOS 3.3 V
8	GND	Ground, Power and Signal
9	Antenna power input	5 V DC, 55 mA max
10	Reset input	Reset
11	Reserved, do not connect	Reserved
12	Reserved, do not connect	Reserved

Pin	Function	Description
13	Reserved, do not connect	Reserved
14	Reserved, do not connect	Reserved
15	Reserved, do not connect	Reserved
16	Reserved, do not connect	Reserved

Power requirements

The RES/ICM 720 timing module requires +3.3 V DC ±0.3 V DC at 110 mA, typical, excluding the antenna. The on-board capacitance is approximately 22 μF.

The receiver does not require any special power up or down sequencing. The receiver power is supplied through pin 2 of the I/O connector. See the following table for the power specifications.

> **CAUTION –** The RES/ICM 720 timing module is ready to accept TSIP commands approximately ten seconds after power-up. If a command is sent to the receiver within this ten second window, the receiver will ignore the command. The RES/ICM 720 timing module will not respond to commands sent within the ten second window and will discard any associated command data.

The digital IO/Power connector pinout information is provided in the following table:

Signal	Voltage	Current	J2 Pin
VCC	3.0 - 3.6	110 mA	2
Ground	0		8

Supply voltage control

If you want to be able to power-cycle the module, you should use tri-state gates at all signal and PPS lines during power-down. No I/O pin should be actively driven or being pulled-high during power-down. The board may not start up as expected if pins are driven before supply voltage is switched-on.

Protempis recommends that the Off-time in case of a power-cycle is not shorter than 1 s to allow all capacitors on the board to discharge sufficiently before the next power-on. Supply voltage dips below 3.0 V or short V_{CC} outages may bring the RES/ICM 720 into a lock-up state, which can only be resolved with a complete power-cycle.

Power-sequencing

Ideally, V_{ANT} and V_{CC} are both switched On and Off at the same time. In most designs, they are just tied together. Special sequencing is not required.

Removing V_{ANT} while V_{CC} is ON doesn't pose a problem; it just un-powers an active antenna and will raise the SHORT indicator in the TSIP and NMEA messages, but that doesn't affect the receiver's operation, except that no more satellites are being tracked with an unpowered

antenna. As soon as V_{ANT} is applied again, the receiver will resume normal operation and tracking and the SHORT alarm will be removed.

V_{ANT} without V_{CC} will not back-power the RES/ICM 720 timing module, because the Open and Short signals have both a 10 k in-line resistor to the I/O-pins. However, that is an undefined condition and Protempis does not recommend powering V_{ANT} without V_{CC} to avoid any latch-up condition or other unexpected effects.

Mounting

There are four mounting holes at the corners of the PCB that accept 3/16" / SW6 hex or ø6mm round standoffs, and #2-2-56 or M3 mounting screws. Space constrained environments may require a different standoff. All four mounting holes are non-isolated vias, which are connected to common GND.

Use conductive metal standoffs for providing a good chassis ground connection from the GND vias to the chassis ground of the host system for surge protection.

Circuit diagram

The following picture shows the main circuit diagram of the RES/ICM 720 carrier board.

> Note: The PCB has pads for more components but not all of them will be populated on production units. Some components are load-options and others are only used for Protempis-internal purposes.

The bold connections at the RF input are showing the current path of the surge protection, explained in a separate chapter.

Antenna OPEN/SHORT detection

The circuit diagram shows the short circuit protection and OPEN/SHORT detection circuit of the RES/ICM 720 carrier board. This circuit generates the ANTOPEN and ANTSHORT hardware signals for the GNSS processor, which generates the antenna status reports in the TSIP protocol from these hardware signals.

The antenna monitoring circuit is a current monitor with current limiting. The current limiting of the timing module may begin above 120 mA up to approximately 190 mA in a full short-circuit condition, but it is not a sharp cut-off. You will see an increasing drop of the supply voltage that goes up with the supply current. The values in the table below depend on component tolerances and operating temperature and are therefore only approximate numbers and not very precise.

Antenna Voltage Feed Conditions:

V$_{ANT}$	Condition
+3.3 V	Open: Below the 4 mA to 2 mA range
	Short Alarm: approx. 80 mA
	Current Limiting: Above 120 mA
+5.0 V	Open: Below the 8 mA to 4 mA range
	Short: Above 150 mA
	Current Limiting: Above 190 mA

The antenna power input is only specified up to 5.5 V (55 mA). The reason for the 55 mA upper limit is the voltage drop. Exceeding 55 mA will not damage the receiver, but the antenna supply might be insufficient. The 5.5 V limit shall, however, not be exceeded, because the ANTOPEN/ANTSHORT signals are routed directly to the processor, and higher voltage at those points may cause damage to the receiver due to electrical overstress.

> NOTE – The current-sensing circuit is causing a voltage drop between the supply voltage input and antenna feed output. Voltage drops occur on transistor Q1 (current limiter to protect against short circuit condition), on the current sensing resistor R15 and on the inductor L2.
>
> If you are using antennas with high current consumption, the voltage drop across the sensing resistor will increase and the supply voltage at the RF-connector may drop too low to provide sufficient power to the antenna LNA. In that case, Protempis recommends using either antennas with lower operating current (preferred), or antennas with wider supply voltage range.

Surge protection

The RF-input of the RES/ICM 720 carrier board is surge-protected with a TVS diode, as shown on the circuit diagram. D1 is a 6.0 V TVS diode with a peak pulse power dissipation of 600 W (10/1000 µs waveform). The bold connections indicate the current path of a surge on the antenna center wire. A surge on the antenna shield will directly go to common GND at the coax connector of the carrier board.

This circuit provides second-level surge protection, but it does not provide primary surge protection against lightning strikes. To arrest higher energy from lightning, a coax surge arrestor is required that must be placed at the point where the antenna cable enters the building, according to local installation regulations for rooftop antennas in the country where the antenna is installed. Protempis recommends using a fast first-level lightning protector that has 15 or 20 V clamping voltage.

Pulse-per-second (PPS)

The RES/ICM 720 timing module provides a 3.3 V CMOS compatible Pulse-Per-Second (PPS). The PPS is a positive pulse available on pin 6 of the power and I/O connector J3.

The PPS output can drive a load up to 15 mA without damaging the receiver.

> **NOTE –** No voltage shall be applied to the PPS pin while V_{CC} is off, as this can back-power the device and cause a lock-up.

Pin	Signal	Description	Condition	Min	Typ	Max
6	PPS (Pulse per Second)					
	V_{OH}	Output high voltage	I_{OH}=-15 mA, V_{CC}=3.0 V	2.4 V		
	V_{OL}	Output low voltage	I_{OL} = 15 mA, V_{CC} = 3.3 V			0.4 V
	I_{OH}	Output high-current sink capability	V_{CC}=3.0 V			-15 mA
	I_{OL}	Output low-current source capability	V_{CC}=3.0 V			15 mA

10 MHz frequency output (SYSCLK) – ICM 720 only

The ICM 720 provides a low-voltage (3.3 V) CMOS-compatible 10 MHz frequency output (SYSCLK). The SYSCLK is available on pin 4 of the power and I/O connector J2. The 10 MHz oscillator of the ICM 720 is disciplined by using the GNSS signals as reference. The frequency output is phase-locked with the PPS pulse.

The 10 MHz output is not available on the RES 720 version of the carrier board.

The 10 MHz output can drive a load up to 15 mA without damaging the receiver.

> **NOTE –** No voltage shall be applied to the 10 MHz pin while V_{CC} is off, as this can back-power the device and cause a lock-up.

Pin	Signal	Description	Condition	Min	Typ	Max
4	*SYSCLK 10 MHz frequency output*					
	V_{OH}	Output high voltage	I_{OH}=-15 mA, V_{CC}=3.0 V	2.4 V		
	V_{OL}	Output low voltage	I_{OL} = 15 mA, V_{CC} = 3.3 V			0.4 V
	I_{OH}	Output high-current sink capability	V_{CC}=3.0 V			-15 mA
	I_{OL}	Output low-current source capability	V_{CC}=3.0 V			15 mA

Serial interface

The RES/ICM 720 timing module provides a direct 3.3 V CMOS compatible serial I/O commincation interface. The RX and TX signals on the J2/J5 I/O connector are driven directly by the UART Ports A and B on the timing module.

GNSS antenna

The antenna receives the GNSS satellite signals and passes them to the receiver. The GNSS signals are spread spectrum signals in the 1.5 GHz range and do not penetrate conductive materials. Therefore, the antenna must be located outdoors with a clear view of the sky.

The RES/ICM 720 timing module requires an active antenna for L1+L5 band reception.

> NOTE – The RES/ICM 720 timing module can work at reduced performance with L1-only antennas but the full, specified performance is only achievable with an L1+L5 antenna. Protempis recommends that you do not operate the timing module with L1-only antennas; the performance with L1-only antennas is not specified.

The received GNSS signals are very low power, approximately -130 dBm, at the surface of the earth. The Protempis active antenna includes a preamplifier that filters and amplifies the GNSS signals before delivery to the receiver.

Protempis recommends the Bullet™ 720 GPS antenna to use with the RES/ICM 720 timing module:

6

RES/ICM 720 Starter Kit

This chapter provides a detailed description of the Starter Kit components and usage.

- ▶ RES/ICM 720 starter kit content
- ▶ Universal Interface Module
- ▶ Powering the UIM
- ▶ AC/DC power converter
- ▶ Pulse-per-second (PPS)
- ▶ 10 MHz frequency output (ICM 720 only)
- ▶ System requirements
- ▶ Using the RES/ICM 720 starter kit with VTS
- ▶ Removing the RES/ICM 720 Carrier Board from the UIM

RES/ICM 720 starter kit content

The RES/ICM 720 multi-GNSS starter kit includes all the components necessary to quickly test and integrate the receiver:

Power pin adapter set (international)

Power converter (AC to 24 VDC)

Universal Interface Module (Serial port to USB converter)

SMB-N Adapter

Bullet 720
GNSS antenna

Antenna cable 15m

USB cable

The starter kit includes the RES/ICM 720 Carrier Board, mounted on an interface motherboard in a durable metal enclosure. The kit also contains:

- Interface cable, USB
- AC/DC power supply adapter:
  - Input: 100 – 240 VAC
  - Output: 24 VDC
- SMB to N adapter cable

- 15m Antenna cable N-to-N
- Bullet 720 GNSS antenna

Universal Interface Module

The Universal Interface Module (UIM) consists of a USB interface which is compatible with most PC communication ports. Power (24 VDC) is supplied through the power connector on the front of the interface unit. The motherboard features a switching power supply which converts this voltage input to the 3.3 V required by the receiver and the antenna. The USB connector allows for an easy connection to an office computer using the USB interface cable provided in the starter kit. The metal enclosure protects the receiver and the motherboard for testing outside of the laboratory environment.

The RES/ICM 720 Carrier Board, installed in the UIM, is a dual-port receiver and both ports are available as virtual serial COM ports over USB. A straight-in, panel-mount RF SMB connector supports the GNSS antenna connection.

The following pictures show the starter kit UIM:
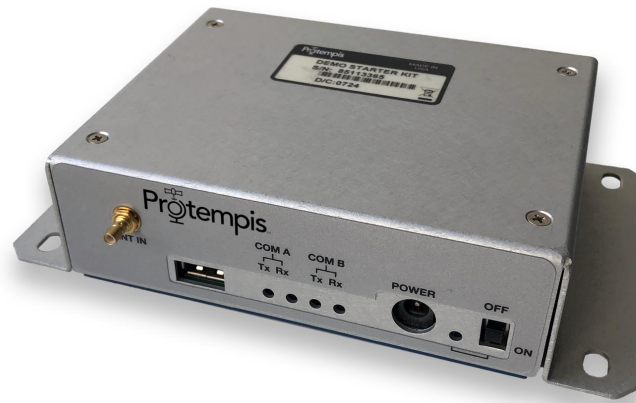
Front panel view:
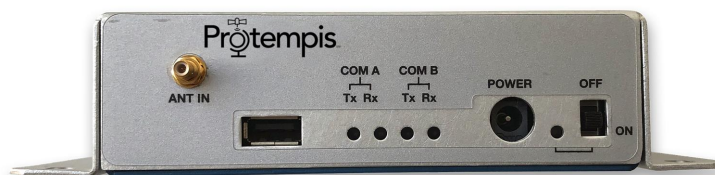
Backside view:

This following picture shows the receiver in the metal enclosure:

Powering the UIM

The UIM can be powered in two alternative ways:

- From the host PC through a powered USB port
- From the AC/DC converter that it included in the Starter Kit

The RES/ICM 720 multi-GNSS timing module is designed for embedded applications and requires a regulated +3.3 VDC input (+3.0 to +3.6 VDC). The receiver provided in the starter kit is installed on a motherboard, which provides a DC power regulator which converts a 24 VDC input from the power connector or a 5 VDC input from the USB connector to the regulated 3.3 VDC required by the receiver and the antenna.

The following picture shows a fully connected Starter Kit UIM box with antenna cable, USB cable and power supply cable connected at the front panel and a BNC cable for PPS output on the back side.

The On/Off switch on the front panel switches the power to the RES/ICM 720 module on or off. The USB interface is, however, powered from the PC to which it is connected. The serial COM

ports will therefore be available as long as the USB port is powered, regardless of the switch position.

The green LED on the front panel indicates whether the RES/ICM 720 module is powered or not.
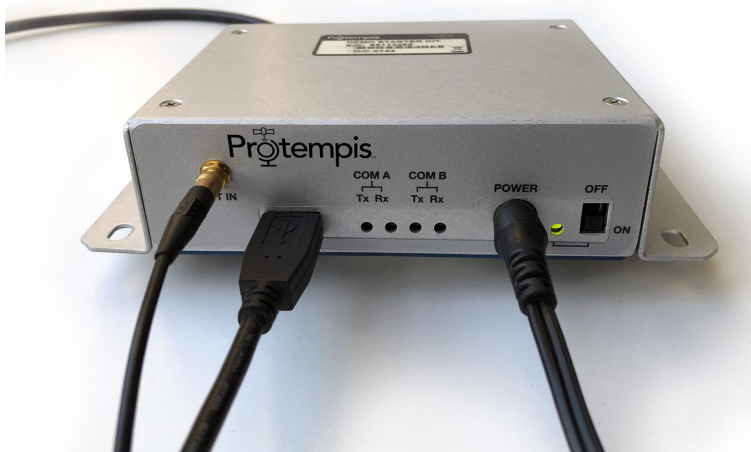
AC/DC power converter

The AC/DC power converter may be used as an alternate power source for the interface unit if no sufficient 5 VDC is available from the USB host. The AC/DC power converter converts 110 or 240 VAC to a regulated 24 VDC compatible with the UIM. The AC/DC power converter output cable is terminated with a connector compatible with the power connector on the metal enclosure. The AC supply comes with a range of clip-on adapters for international use.

Pulse-per-second (PPS)

The Pulse-per- second (PPS) is available on the BNC connector of the UIM.

10 MHz frequency output (ICM 720 only)

The 10 MHz frequency output is available on the SMA connector " SYSCLK" of the rear side ICM 720 starter kit.

> **NOTE –** The ICM 720 on carrier board product will also provide 10MHz output on the SYSCLK pin #4.

System requirements

Hardware

- The Protempis RES/ICM 720 Starter Kit
- User-provided equipment to analyze the PPS accuracy and a BNC cable to connect it to the RES/ICM 720 Starter Kit.
- A PC with Microsoft Windows 10.

Software

- Protempis's Visual Timing Studio (VTS) version 3.01.00 or higher.

Using the RES/ICM 720 starter kit with VTS

Refer to the *VTS User Guide* for more information about the functions of VTS, which is Protempis's universal monitor and configuration tool for the Timing products, including the

RES/ICM 720 module. VTS and the User Guide are available for download on Protempis's website: https://timing.Protempis.com/products/.

Removing the RES/ICM 720 Carrier Board from the UIM

> **WARNING –** Before opening the interface unit, disconnect the unit from any external power source and confirm that both you and your work surface are properly grounded for ESD protection.

The RES/ICM 720 Carrier Board is attached to the motherboard standoffs with Phillips head screws, allowing for removal and integration with the user's application. Follow these steps to remove the receiver from the UIM motherboard:

1. Disconnect power and USB from the enclosure.
2. Remove the base plate and unplug the RF cable from the receiver.
3. Use a small Phillips screwdriver to remove the securing hardware which holds the RES/ICM 720 Carrier Board to the motherboard.
4. Gently slip the board loose from the motherboard I/O connector.

7

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 timing module including start-up, satellite acquisition, operating modes, serial data communication, the timing pulse and the frequency output.

▶ GNSS timing

▶ Time references

▶ GNSS constellation configuration

▶ PPS and 10 MHz availabilityPPS and 10 MHz availabilityPPS and 10 MHz availability

▶ Automatic operation

▶ Operating modes

▶ Integrity monitoring

▶ Cable delay compensation

▶ Timing module performanceTiming module performance

▶ Acquiring the correct time

▶ Holdover stability (ICM 720)

▶ Customizing operations

GNSS timing

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 RES/ICM 720 timing module 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 –** RES/ICM 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 and 10 MHz availability

Protempis cannot guarantee that the PPS is 100% available or a pulse is generated each and every second and that the frequency is continuously disciplined. The receiver's ability to generate the PPS and to discipline the 10 MHz oscillator 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 and a valid 10MHz frequency may not be available at all times.

Startup

The first time the RES/ICM 720 module is powered-up, it is searching for satellites from a cold start (no almanac, time, ephemeris, or stored position). During the satellite acquisition process,

the RES/ICM 720 module 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 a complete almanac. The almanac contains, amongst others, the UTC leap second value. RES/ICM 720 module 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 RES/ICM 720 module 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 RES/ICM 720 module may not respond to commands sent within the 10 second window and may discard any associated command data.

Automatic operation

Automatic operation

When the RES/ICM 720 timing module 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 RES/ICM 720 timing module automatically switches to a time-only mode (overdetermined clock mode).

Satellite masks

The following table lists the default satellite masks used by the RES/ICM 720 timing module. 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 Protempis Standard Interface Protocol(TSIP).

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 timing module automatically switches to overdetermined (OD) clock mode.

Self-survey mode

At power-on, the timing module 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 timing module 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 timing module 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.

In this mode, the timing module does not update the self-survey information, but maintains the PPS output, solving only for the receiver clock error (bias) and error rate (bias rate).

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 timing module 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 RES/ICM 720 timing module 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 RES/ICM 720 timing module 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 RES/ICM 720 timing module 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 RES/ICM 720 timing module 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 timing module 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. To compensate for the cable delay, use a negative offset to advance the PPS output.

> 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).

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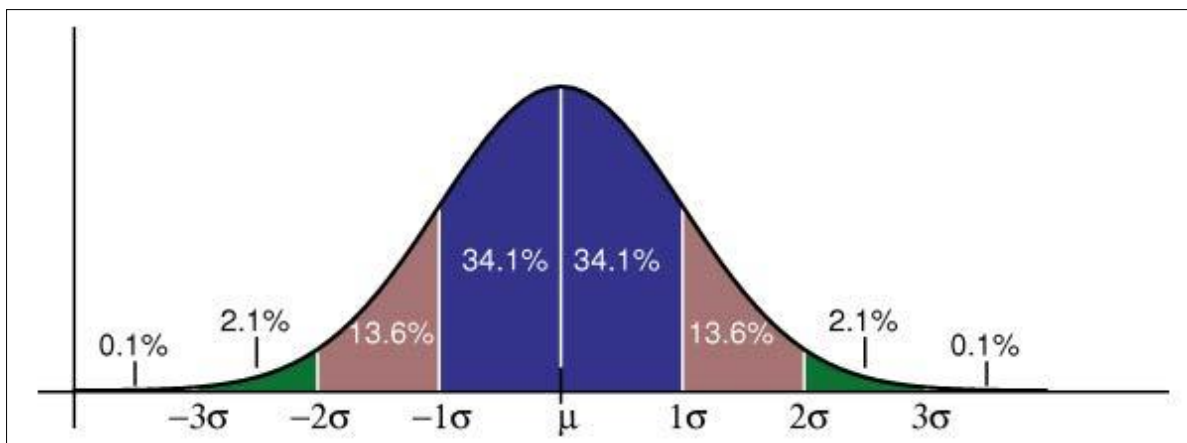
A definition of a parameter with 1 sigma (1σ) means that 68.2% of all samples are within the specified range, but 31.8% of all samples are outside. A definition with statistical notation also implies that there's no specified minimum or maximum. This applies also to Protempis's accuracy specifications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

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 134) 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 101) or the falling edge.

- If using TSIP, capture the time from TSIP packet 0xA1-00 (see page 134). If using NMEA, capture the time from NMEA packet ZDA (see page 202).

- 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 RES/ICM 720 timing module 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 124). 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 timing module 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 timing module to save the current parameter values to the flash. To save or delete the stored position, use command packet 0x91-04 (see page 106). 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 timing module 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® RES/ICM 720 timing module 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 0x91-02 (see).

Protocols

The following protocols are available:

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

[1]Requires use of Protempis-proprietary NMEA messages.

Serial port default settings

The timing module supports two serial ports. The default settings are:

Port	Port Directions	Pin #	Protocol	Characteristic				
				Baud rate	Data bits	Parity	Stop bits	Flow control
A	TXDA	17	TSIP out	115 kbps	8	None	1	None
	RXDA	16	TSIP in	115 kbps	8	None	1	None
B	TXDB	22	Not set[1]	115 kbps	8	None	1	None
	RXDB	21	Not set[1]	115 kbps	8	None	1	None

[1]Use the TSIP 0x91-00 command (see page 90) on Port A to configure protocol for Port B, and then use the TSIP 0x91-02 command (see page 99) 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 RES 720 and ICM 720 timing module.

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**:
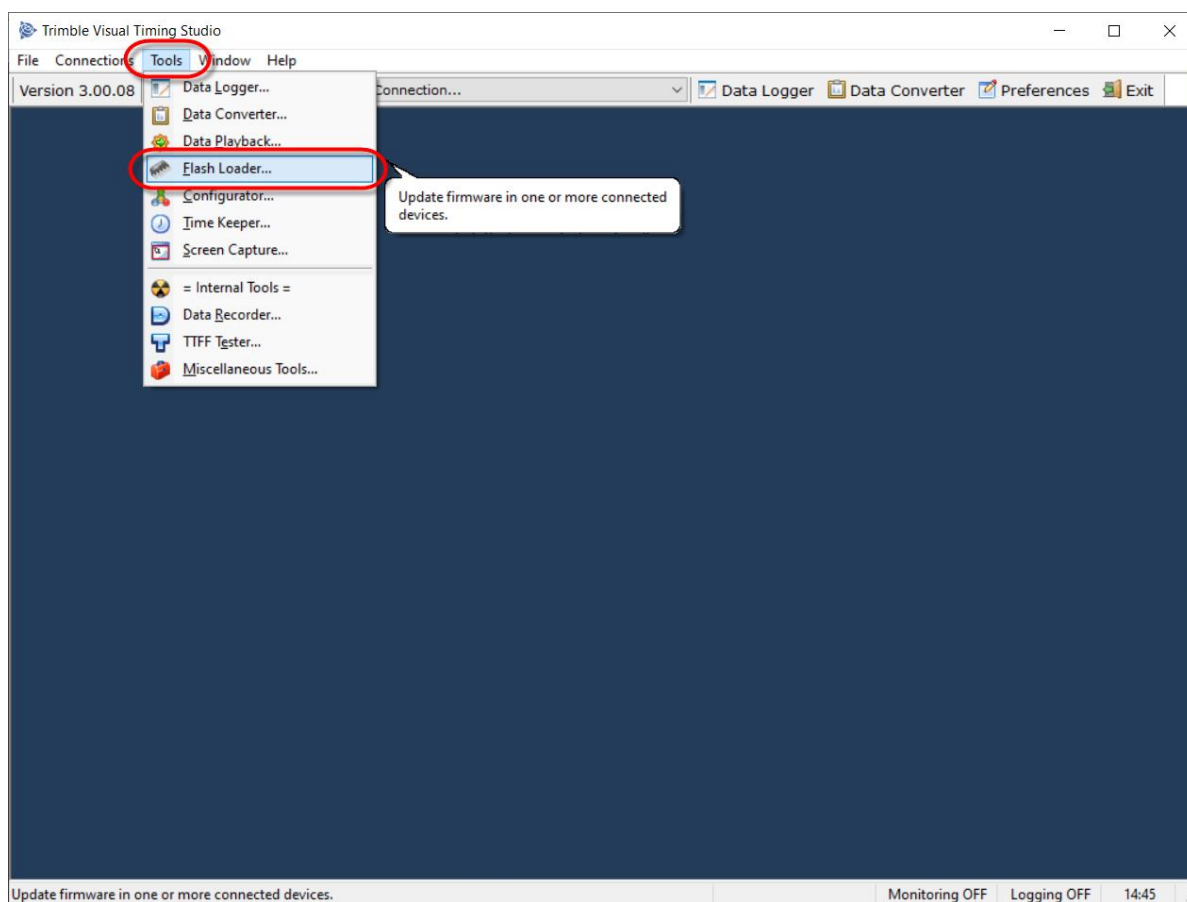
The following dialog appears:
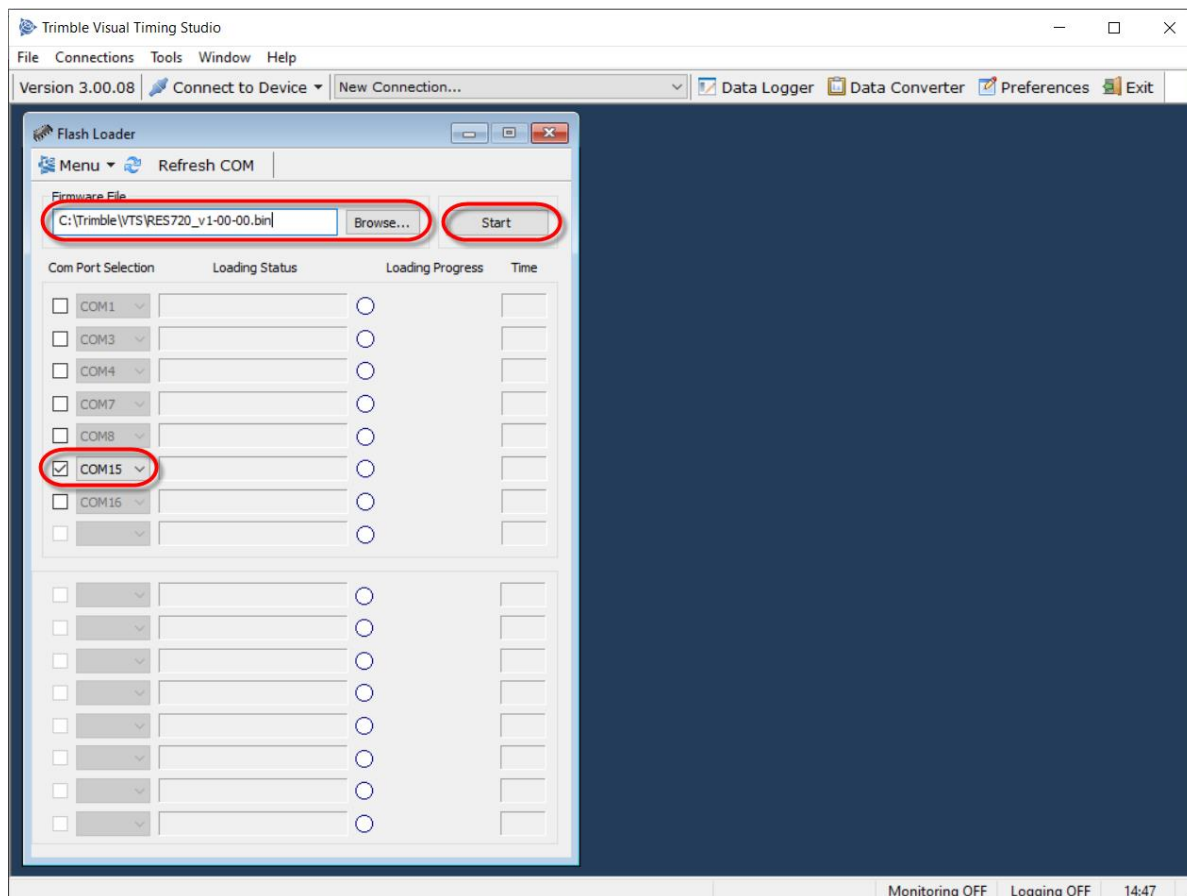
3. Select the check box of the COM port that is connected to port A of the timing module. Selecting a COM port in the Flash Loader software that is currently connected to a Monitor window automatically makes the Monitor window idle.

4. Click **Browse** and locate a valid firmware file for the timing module. 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:
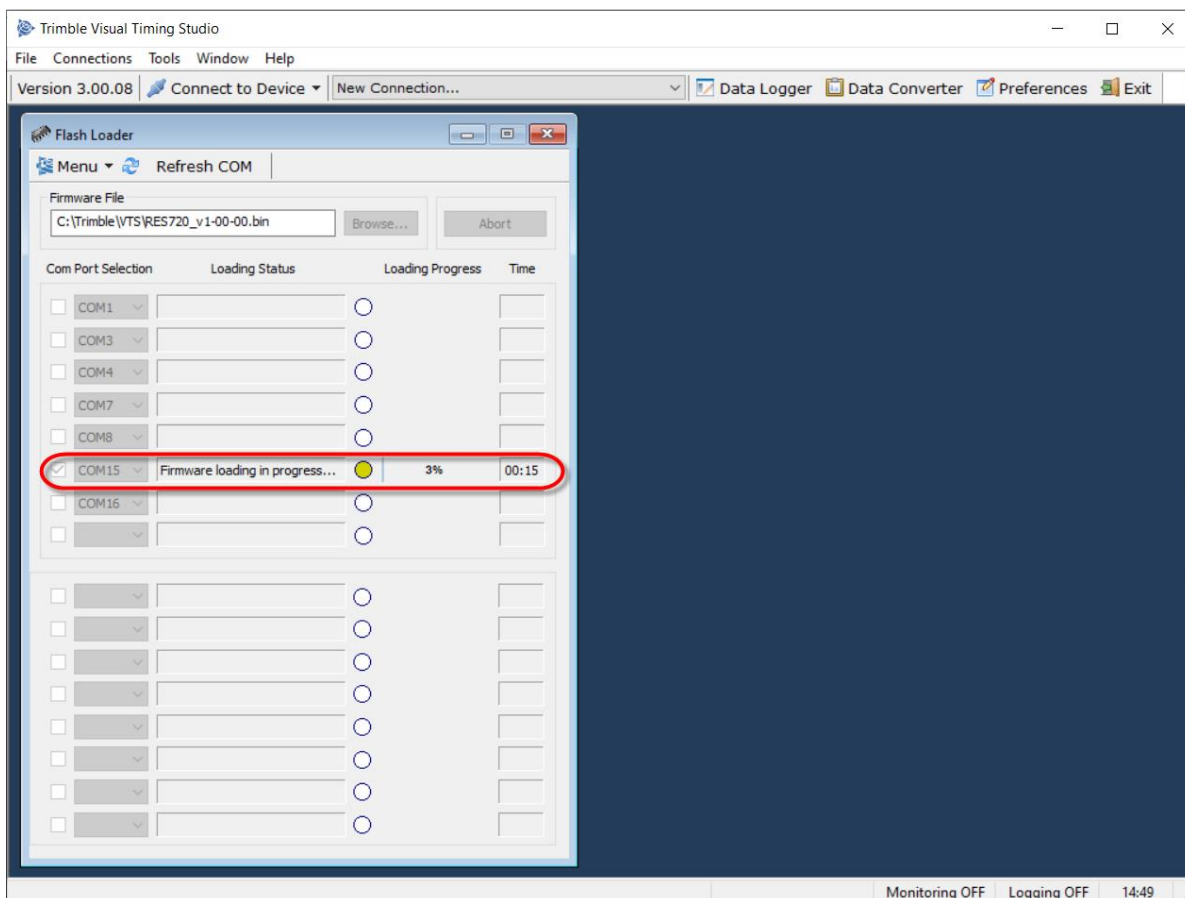
You will see the loading status, the loading progress and the time elapsed in the respective fields.

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*.
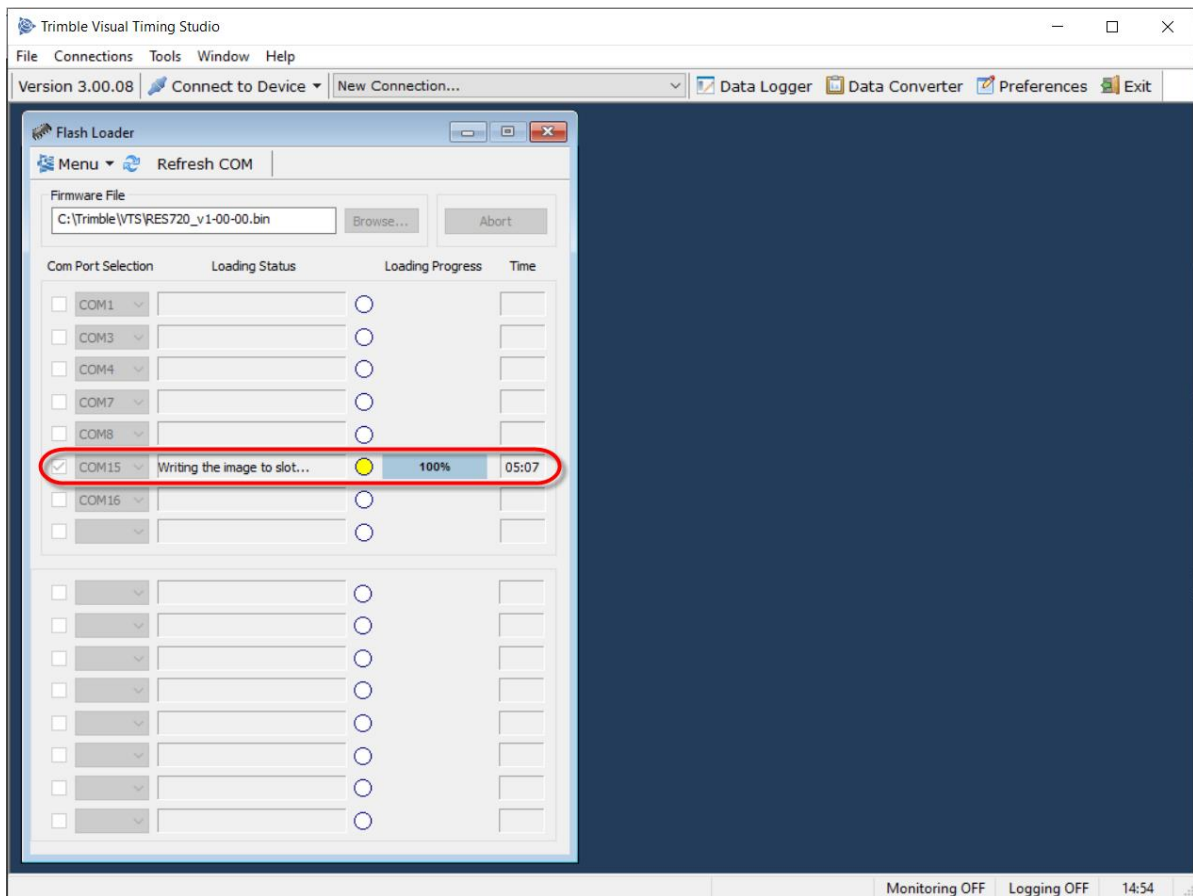
When the transfer to the firmware slot is finished, the *Loading Status* will show that the firmware loading was successful and the receiver will restart from the new firmware slot.
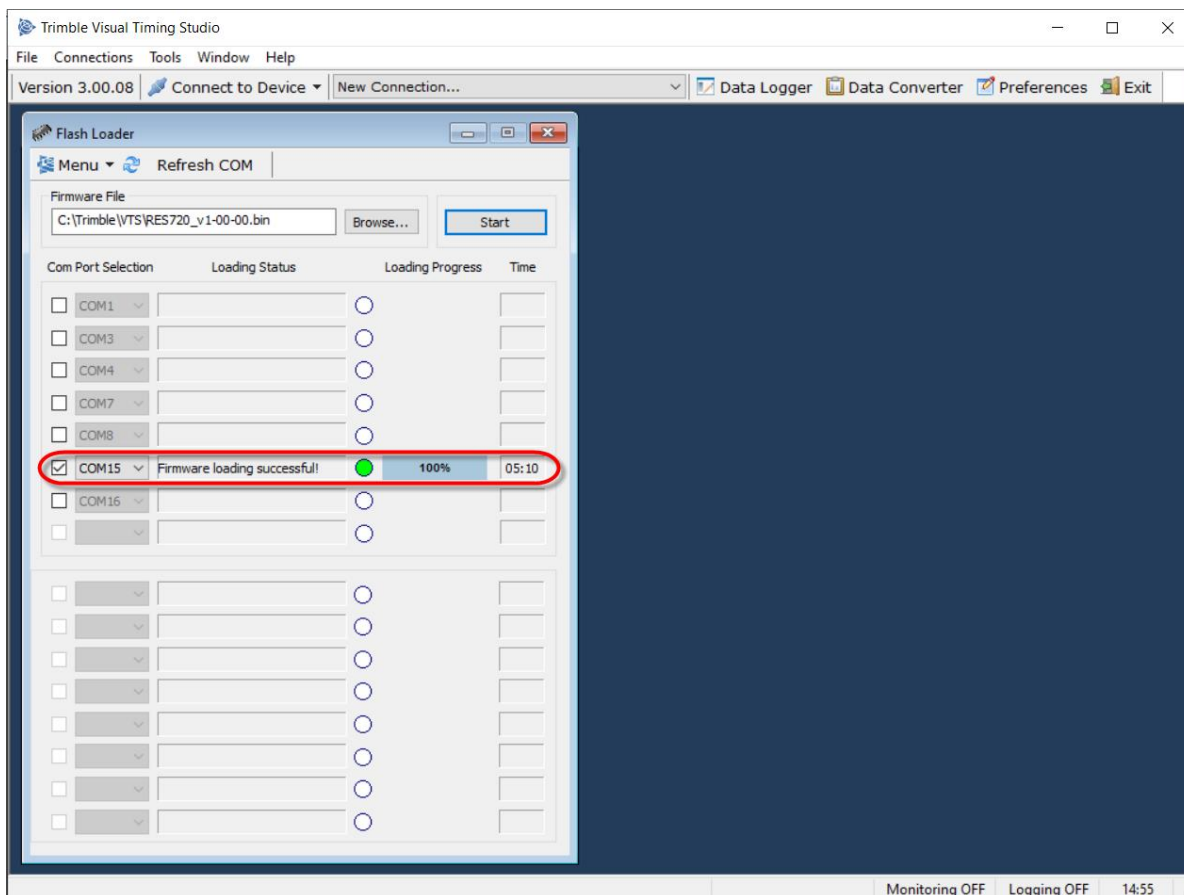
The time for the image upload takes several minutes, depending on the COM port speed. The time needed for writing the firmware to the firmware slot is very short, though. The actual service outage due to the firmware loading is basically just the normal TTFF time for the restart plus a few seconds for 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 RES/ICM 720 timing module. 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® RES 720 and ICM 720 timing modules 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.

```
<DLE> <ID> <SID> <LEN> <MODE> <DATA> <CHECKSUM>   <DLE>  <ETX>
                                                        0x10 03 (End Packet)
                                          Checksum
                                  Data Bytes
                          Mode
                  Packet Length
          Subpacket ID
      Packet ID
  0x10  (Packet Start)
```
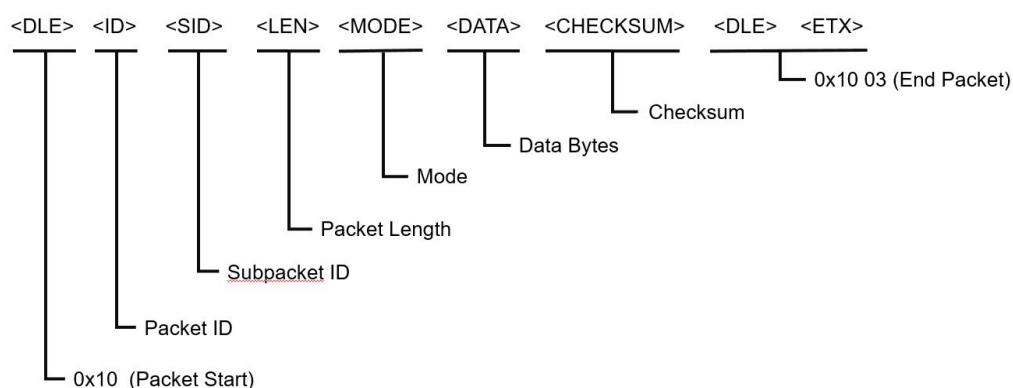
A typical v1.0 packet will look like the following format:

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
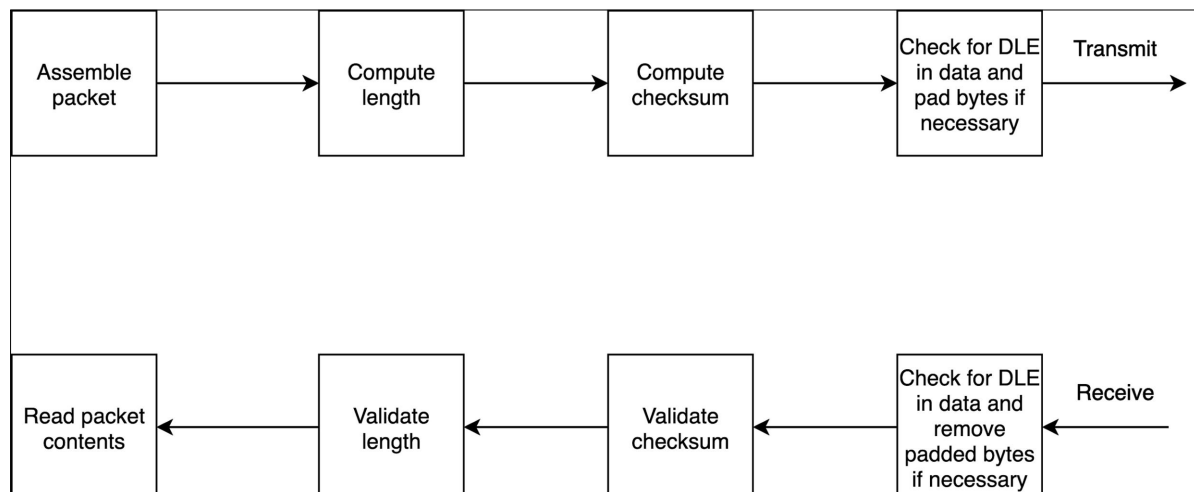
Packet groups

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
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 RES 720 or ICM 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 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	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 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	11-14	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/CN0 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: (ICM 720 only) 0: Pulse out better frequency response (possible higher phase error over temperature) 1: Pulse out, better phase response (possible higher frequency error)

Byte	Item	Type	Value	Description
9-12	Pulses/second	UNIT32	Any	Pulse frequency, Hz (ICM 720 TXCO pulse output only, ignored for any other device/setting)
				Number of pulses per second.
				0, 1 : 1 PPS
				2 : 2 PPS
				…
				5000000 : 5MHz
				10000000 : 10MHz
				NOTE – Only integer values of 10MHz divisors are allowed. If the remainder of 10E6/Pulses != 0 then the value is an error
				NOTE – Pulse frequency also affects the width allowed. If the pulse frequency is anything but 1 PPS then the pulse width is forced to 50/50 (i.e. 50% high, 50% low, or as close as the integer division allows).
13-14	Width	UINT16	Any	In milliseconds, 1< width <= 500, value must be value, but will be ignored for ICM 720 if pulses/second is not 1)
15-22	Offset	DOUBLE	Any	In seconds, -0.25 <= offset <= +0.25 (set to 0 if offset >= 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

Byte	Item	Type	Value	Description
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)
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: (ICM 720 only) 0: Pulse out better frequency response 1: Pulse out better phase response
9-12	Pulses/second	UINT32	Any	Pulse frequency, Hz (ICM 720 pulse output only, 0xFFFFFFFF for any other device) Number of pulses per second

Byte	Item	Type	Value	Description
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: 0xA1-03 Frequency information (**ICM 720 only**) 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

Byte	Item	Type	Value	Description
5	Mode	UINT8	2	2: Response
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: 0xA1-03 Frequency information (ICM 720 only) 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	UNIT8	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

Frequency Control Mode (0x91-09), **ICM 720 only**

Use TSIP 0x91-09 packet to set the frequency control mode.

This packet allows configuring the event input, reference input, frequency control mode for ICM 720.

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	0x09	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 09 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	0x09	Subpacket ID
3–4	Length	UINT16	Any	Total length of mode + data + checksum
5	Mode	UINT8	1	1: Set
6	Event In Function	UINT8	0, 1 or 0xFF	Selects the Event input pin to be either an event capture pin or usable as an input for the **ICM 720**. 0: Input used for event capture (default) 1: Input used for frequency control 0xFF: No change

Byte	Item	Type	Value	Description
7	Desired input	UINT8	0, 1 or 0xFF	Select desired input for ICM 720 : 0: GNSS signal 1: PPS in/Event In 0xFF: no change
8	Frequency Control Mode	UINT8	0-4 or 0xFF	This is a command only and the setting is not stored. A query returns the current operating mode. 0 : Command frequency control lock 1: Command user halt 2: Command user hold 3: Command Frequency control enable (alias for "lock") -- for completeness only 4: Command frequency control disable (alias for "halt") -- for completeness only 0xFF: no change
9	Checksum	UINT8	Any	
10	Delimiter 1	UINT8	0x10	End of packet 1
11	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	0x09	Subpacket ID
3-4	Length	UINT16	Any	Total length of mode + data + checksum
5	Mode	UINT8	2	2: Response
6	Event In Function	UINT8	0, 1	Event input pin functionality: 0: Input used for event capture 1: Input used for frequency control
7	Desired input	UINT8	0, 1	Desired input setting for ICM 720: 0: GNSS signal 1: PPS in/Event In 0x80: No reference currently selected (start-up or transition only)

Byte	Item	Type	Value	Description
8	Frequency Control Mode	UINT8	0-4	Commanded mode in set response
				Current loop status in query response (see 0xA1-03 packet)
9	Checksum	UINT8	Any	
10	Delimiter 2	UINT8	0x10	End of packet 1
11	Delimiter 2	UNIT8	0x03	End of packet 2

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 (RES 720 is filled with 0xFF).
78-81	Osc offset	FLT	0.001-8.000	Default oscillator offset in PPM (RES 720 is filled with 0xFF).
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 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. Always zero in **ICM 720**
28-31	Bias	SINGLE	Any	In seconds

Byte	Item	Type	Value	Description
32-35	Bias rate	SINGLE	Any	In seconds/second
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

Frequency Information (0xA1-03), ICM 720 only

Use TSIP packet 0xA1-03 to obtain the frequency information for ICM 720.

This packet provides information for the operational state such as Lock, HALT, Holdover, Acquire, Recover and etc. and frequency control of the receiver.

Also, Selected input(Byte 52) will provide the current configured reference input 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	0xA1	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

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	0x03	Subpacket ID
3-4	Length	UINT16	Any	Total length of mode + data + checksum
5	Mode	UINT8	2	2: Response
6-9	Freq Offet	SINGLE	Any	Current oscillator frequency offset in ns/s. This information is only meaningful in acquisition, locking or recovery mode

Byte	Item	Type	Value	Description
10	DAC size	UINT8	0-32	Number of bits in the DAC.
				If 0 then this system does not use a DAC and instead utilized DDS control and the Freq Offset is the output
11-14	DAC Voltage	SINGLE	Any	DAC voltage applied to the oscillator, if the oscillator is DAC controlled.
				If DAC size is 0 then this is always 0.0
15-18	DAC Value	UINT32	Any	DAC value, if applicable. If DAC size is 0 then this is always 0
19	Loop status	UINT8	Any	0 : Initialization,initial control state, system not started yet, or system failed 1: Freerun, No signal present to attempt acquisition. This is also a starting point for the loop 2: Jam sync. The output pulse is being aligned to the input source. In this state there may be discontinuities in the phase output. 3: Acquire, system is attempt lock to reference 4: Recover, system is attempting to re-achieve lock after a halt or hold mode 5: Lock, system is locked to reference 6: Halt, reference has been lost but not enough data for hold. Frequency control frozen at last update 7: Hold, reference has been lost and unit in holdover 8: User halt, user has commanded a halt 9: User hold, user has commanded a hold
20-23	Non-control Time	UINT32	Any	Length of non-control (freerun, halt, hold) period, in seconds.
				When in control mode this gives historical information about the length of the last non-control event.
24-27	Temperature	SINGLE	Any	In degree Celsius
28-31	Voltage Estimate	SINGLE	Any	Initial hold/halt voltage estimate if in holdover.
				Current voltage if not in holdover

Byte	Item	Type	Value	Description
32-35	Voltage StdDev	SINGLE	Any	The voltage estimate standard deviation value, ns.
				Lower values mean better certainty of the initial voltage estimate.
36-39	Learn time	UINT32	Any	Amount of learning time used in the computation for holdover.
				Precision holdover is only possible if there is at least 12 hours of learning time
40-43	Temp delta	SINGLE	Any	Average temperature delta seen during learning.
				This gives idea of how much information for temperature compensation was observed before going into holdover
44-47	Holdover Estimate	UINT32	Any	Estimation of the length of time before the unit will exceed holdover, in seconds
48-51	Temp Coeff R value	SINGLE	Any	Temperature coefficient R value for computation of frequency vs temperature.
				1.0 is perfect fit, lower values are lower correlation
52	Selected Input	UINT8	0 or 1	Current selected input.
				0: GNSS 1: PPS input (pin 11) 128: None (startup or selection transition only)
53-60	Unused	BYTE	Any	Reserved for expansion. May not be present, length determines the packet information
61	Checksum	UINT8	Any	
62	Delimiter 1	UINT8	0x10	End of packet 1
63	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

Satellite Information (0xA2-00)

Use TSIP 0xA2-00 packet to obtain the satellite tracking information for GPS L1, GPS L5, GLONASS, Beidou B1, Bedou 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 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	$\sqrt{A}$	UINT32	2^-11	Square root of semi-major axis ($\sqrt{m}$)
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	$\dot{\Omega}$	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_{f0}	INT16	2^-20	Satellite clock bias (seconds)
36-37	a_{f1}	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_λ	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	$\dot{\Omega}$	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 $i_0 = 56°$ (semi-circles)
19-20	$\dot{\Omega}$	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$_{f0}$	INT16	2^{-19}	Satellite clock bias "truncated" (seconds)
29-30	a$_{f1}$	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	$\dot{\Omega}$	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_{f0}	INT16	2^-20	Satellite clock bias (seconds)
39-40	a_{f1}	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 Ephermeris (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_{f0}	INT32	2^{-31}	Time polynomial coefficient 0 (seconds)
26-27	a_{f1}	INT16	2^{-43}	Time polynomial coefficient 1 (seconds/second)
28	a_{f2}	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 indicates satellite operation mode with respect to time parameters.
				P1 indicates a time interval between two adjacent values of tb parameter (in minutes)
				P2 is a flag of oddness ("1") or evenness ("0") of the value of tb (for intervals 30 or 60 minutes)
				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.
				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 Bit mapping: 0,1: P 2,3: P1 4: P2 5: P3 6: P4

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 Tb (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} ±1	Mean anomaly at reference time (pi)
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} ±1	Inclination angle at reference time (pi)
59-62	C_{rs}	INT32	2^{-6} ±2048	Amplitude of the sine harmonic correction term to the orbit radius (meters)
63-66	C_{rc}	INT32	2^{-6} ±2048	Amplitude of the cosine harmonic correction term to the orbit radius (meters)
67-70	C_{us}	INT32	2^{-31} ±6.10x10-5	Amplitude of the sine harmonic correction term to the argument of latitude (radians)
71-74	C_{uc}	INT32	2^{-31} ±6.10x10-5	Amplitude of the cosine harmonic correction term to the argument of latitude (radians)
75-78	C_{is}	INT32	2^{-31} ±6.10x10-5	Amplitude of the sine harmonic correction term to the angle of inclination (radians)
79-82	C_{ic}	INT32	2^{-31} ±6.10x10-5	Amplitude of the cosine harmonic correction term to the angle of inclination (radians)
83-86		INT32	2^{-31} ±1	Argument of perigee (pi)
87-90	Ω_0	INT32	2^{-31} ±1	Longitude of ascending node of orbit plane at weekly epoch (pi)

Byte	Item	Type	Value	Description
91-94	$\dot{\Omega}$	INT32	2^-43 ±9.54x10-7	Rate of right ascension (pi/second)
95-96	IDOT	INT16	2^-43 ±9.31x10-10	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_{f0}	INT32	2^{-34}	SV clock bias correction coefficient (seconds)
34-37	a_{f1}	INT32	2^{-46}	SV clock drift correction coefficient (seconds/seconds)
38	a_{f2}	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	$\sqrt{A}$	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	$\dot{\Omega}$	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	√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_{i0}	UINT16	2^-2	sfu *1 sfu (solar flux unit) = 10^-22W/(m^2Hz)
9	α_{i1}	INT16	2^-8	sfu/degree
10	α_{i2}	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 - DAC at rail (max or min) (ICM 720 only) Bit 4 - Ref Osc or hardware PLL failure (ICM 720 only) Bit 5 - Control loop not locked (ICM 720 only) 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 RES/ICM 720 timing module 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 section provides a brief overview of the NMEA 0183 protocol, and describes both the standard and optional messages offered by the RES/ICM 720 timing module.

▶ 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 date fields are of variable length, and the user should always use the comma delineators to parse the NMEA message date 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	llll.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", "llll.ll", "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® RES 720 and ICM 720 timing module can output any or all of the messages listed in the table below. In its default configuration (as shipped from the factory), the RES 720 and ICM 720 timing module 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

RES 720 and ICM 720 timing module 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>

$aa**GGA**,hhmmss.s,llll.lllx,d,yyyyy.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.
llll.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>

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

Field	Description
aa	Talker ID
llll.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 queried using the command $GPGPQ,GSA*hh<CR><LF>

$aa**GSA**,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>

$aa**GSV**,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
n1 .... n4	Satellite ID's. Refer to GNSS identification table for NMEA v4.1
e1 .... e4	Elevation in degrees (90 degrees max)
aa1 .... aa4	Azimuth in degrees true (000 - 359)
s1 .... s4	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,llll.lllx,d,yyyyy.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
llll.lllx	Latitude
d	N | S
yyyyy,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.

$aa**ZDA**,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,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 RES/ICM 720 module, 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 (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:

$PTNLa**NM,**hhhhhhhh,x.x,x,x*hh<CR><LF>

Field	Description
a	Mode (S = set; R = response)
hhhhhhhh	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 33 - 64 for SBAS 65 - 99 undefined	0 1 2 3 4 5 6 7 8 9 - F	All signals L1 (C/A) L1 P(Y) L1 M L2 P(Y) L2C-M L2C-L L5-I L5-Q Reserved
GLONASS	33 - 64 for SBAS 65 - 99 for GLONASS	0 1 2 3 4 5 - F	All signals G1 C/A G1 P G2 C/A GLONASS (M) G2 P Reserved
GALILEO	1 - 36 for Galileo 37 - 64 for Galileo SBAS	0 1 2 3 4 5 6 7 8 - F	All signals E5a E5b E5 a+b E6-A E6-BC L1-A L1-BC Reserved
BeiDou	1 - 64 for Beidou 65 - 99 undefined	0 1 2 3 4 5 6 7 8 9 A B C D - F	All signals B1I B1Q B1C B1A B2-a B2-b B2 a+b B3I B3Q B3A B2I B2Q Reserved

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

8

TSIPv1 Client API Library

Introduction

The Client API Library has been developed as a tool to simplify the process migrating to the TSIPv1 protocol syntax.

The code is provided free of charge and users are free to use it as they deem appropriate. They are also free to make any changes to the code as per their needs.

Protempis does not assume any liability or provide any warranty, whatsoever, for the use of this code in the user's codebase.

Users can use this code either as an example and replicate its behavior or use it as a reference for their own development.

Users can also use this code directly in their development as it is designed to run on any Unix based environment. The code is structured in a way to allow easy adaptability to be modified to run on any RTOS based environment.

> Refer to the full license terms in the project folder, file LICENSE.txt.

The code is written in C, assuming at least C99 extensions. In addition libm, libc and pthread operations are assumed to be available.

Principles of Usage

The basic principles for the utilization of the TSIPv1 Client API library are to provide software API functions to interact with a RES/ICM 720 timing module over a serial port using TSIPv1 with notification of responses from the RES/ICM 720 receiver handled asynchronously through callback functions. The users of the TSIPv1 Client API library do not need to generate and parse the messages specified in the "TSIP Design and Packets" document because all of that will be handled internally by the TSIPv1 Client API library. Users do not need to concern themselves with the endianness of their host processor or the exact byte ordering and bit/byte packing needed for generating the proper TSIPv1 commands to communicate with the RES/ICM 720 timing module. They will also be largely unaffected by any changes in the exact formatting needed due to future modifications of the TSIPv1 protocol.

Client API Library Usage Scenario
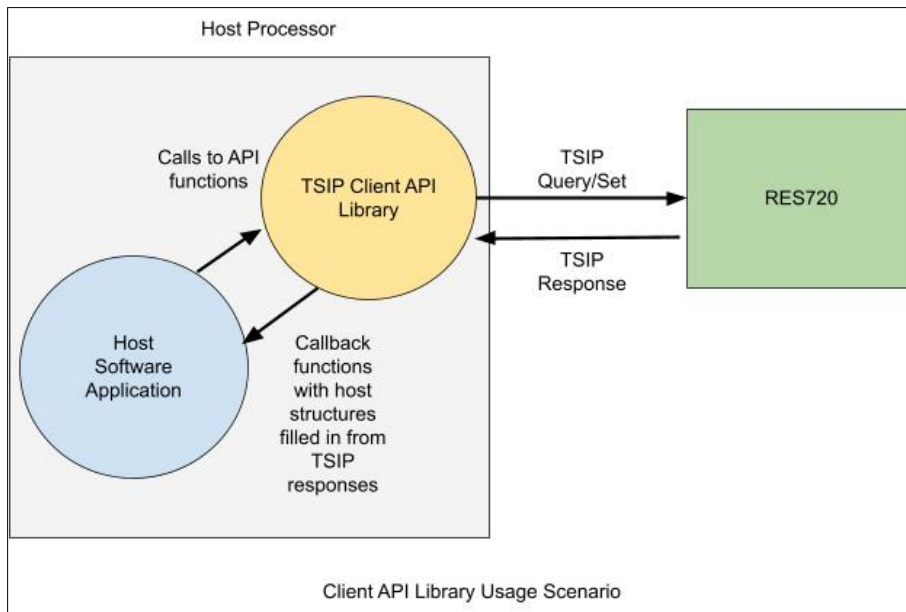
The following sequence diagram depicts a more detailed sequence of operations for the case of a GNSS Configuration 0x91-01 Query/Response:

The equivalent sequence diagram for the case of a GNSS Configuration 0x91-01 Set/Response is given by the following:
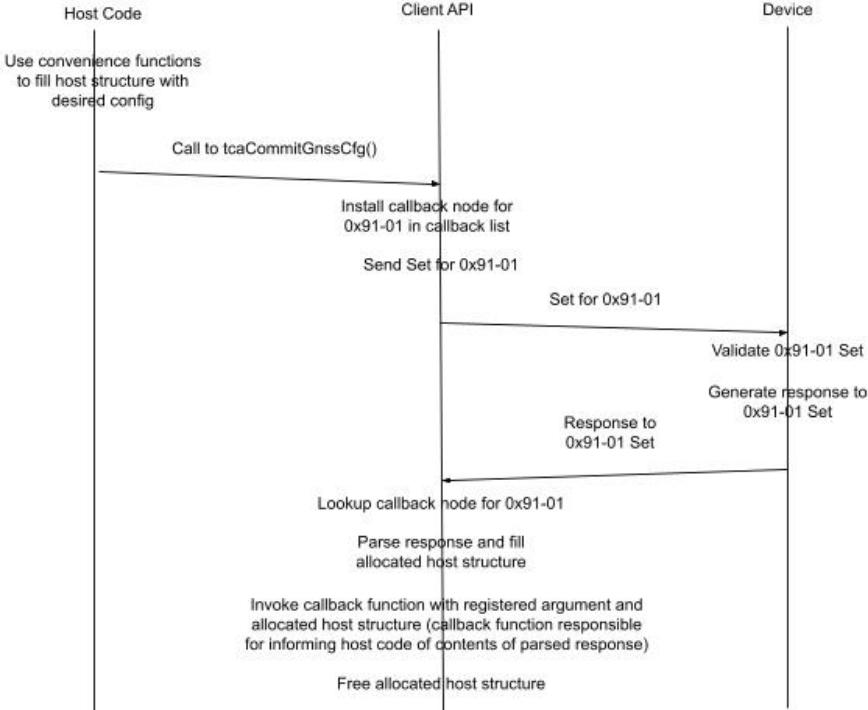
Installation

Users can download the TSIPv1 Client API as a ZIP archive from Protempis's file repository at Box.com. Contact your sales representative or tsgsupport@Protempis.com for requesting information on how to access the file repository.

The TSIPv1 Client API code can be installed by issuing the following command to uncompress the software archive along with supporting utility functions and example programs to demonstrate usage of some of the TSIPv1 Client API functions:

unzip TsipClientApiPkg-v1-01-00.zip

After unzipping the package, you should have a directory TsipClientApiPkg. The directory structure of TsipClientApiPkg is summarized in the following diagram:

```
                        TsipClientApiPkg
                               |
          +--------------------+--------------------+
          |                                         |
       Common                                  TsipClientApi
                                                    |
                                                 examples
                                                    |
                                    +---------------+---------------+
                                    |                               |
                           fwUploadTsipClientApi              asyncExample
```
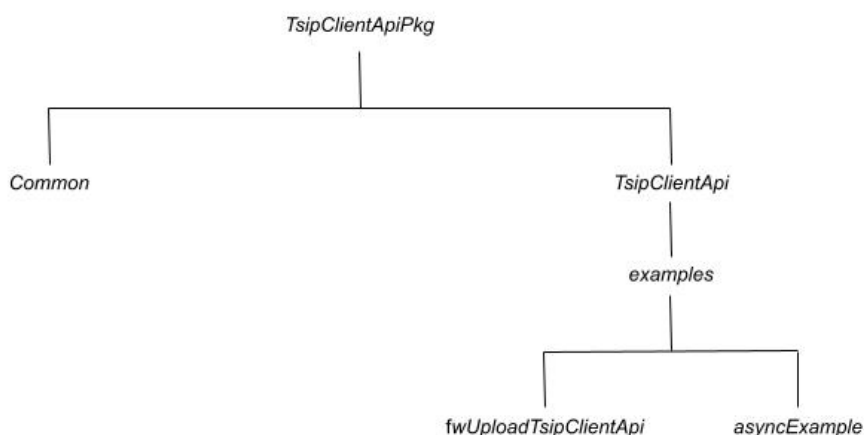
The TSIPv1 Client API software is in the TsipClientApi subdirectory. The supporting utilities are in the Common subdirectory. The example code applications are in the examples subdirectory under the TsipClientApi directory. There is an example application in the fwUploadTsipClientApi subdirectory for performing a Firmware Upload to the RES/ICM 720 module.

This example code utilizes the asynchronous TSIPv1 Client API functions in a "synchronous" manner to perform the Firmware Upload. The other example is provided in the asyncExample subdirectory. This example code just performs a series of calls to a subset of the TSIPv1 Client API functions to demonstrate their usage in an asynchronous manner.

Building

To build the Firmware Upload application, perform the following commands:

   cd TsipClientApiPkg/TsipClientApi/examples/fwUploadTsipClientApi

   make

On a Linux system, this will produce an executable fwUploadClientLibLinux in the linux subdirectory within the fwUploadTsipClientApi example subdirectory.

To build the asynchronous example program, perform the following commands:

   cd TsipClientApiPkg/TsipClientApi/examples/asyncExample

make

This will produce an executable asyncExampleLinux in the linux subdirectory within the asyncExample subdirectory.

Both the fwUploadClientLibLinux and the asyncExampleLinux utilize command line arguments to specify parameters to the executables. The following are example invocations of each executable from the command line:

./linux/fwUploadClientLibLinux -i 115200 -b 115200 -s 1024 -v 2 -p /dev/ttyUSB0 -f /home/fullpath/CombinedFile_abra_mainApp.bin

./linux/asyncExampleLinux -p ttyUSB0@115200@8N1 -vv

Use the following to display command line help for each of the example programs:

./linux/fwUploadClientLibLinux

./linux/asyncExampleLinux -h

Usage of TSIPv1 Client API functions

Please refer to the aforementioned example code for the following discussion. From a usage standpoint, the first step is to initialize the TSIPv1 Client API code with the information needed to connect to the serial port used to communicate with the RES/ICM 720 with TSIPv1. This is done using the following TSIPv1 Client API function:

> *int tcaInitClientApi(const char *pcPortName, int iBaudRate, const char *pcConnOptions)*

> *pcPortName = name of the serial port connected to the RES/ICM 720 (such as "ttyUSB0")*

> *iBaudRate = current baud rate of the serial port (e.g. 115200)*

> *pcConnOptions = string representing the number of data bits, parity, and stop bits (e.g. "8N1" for 8 data bits, no parity, and 1 stop bit)*

Once the TSIPv1 Client API has been successfully initialized with a call to *tcaInitClientApi()*, the remaining TSIPv1 Client API functions can be utilized to interact with the RES/ICM 720 to achieve either Query/Response, Set/Response, or Monitor for Response functionality using TSIPv1 without needing to directly generate any code to manipulate the bits/bytes of the TSIPv1 protocol over the serial port.

The host application code will interact with the RES/ICM 720 using host data structures through the TSIPv1 Client API. As a simple example of the usage of the various types of TSIPv1 Client API functions, refer to the example code implemented in the *asyncExample.c* file. This example program utilizes the various types of TSIPv1 Client API functions and convenience functions to interact with the RES/ICM 720 to alter its configuration for Periodic Message Configuration (0x91-05). Refer to the "TSIPv1 Design and Packets" document for details on the types of parameters that can be queried and set for this configuration. As already mentioned, the host software will access these configuration parameters through a host structure defined in the *tsipHostStructs.h* file in the Common subdirectory. The relevant host structure for the Periodic Configuration is the *typedef host_periodic_cfg_t*.

Example 1: Asynchronous Interaction

The example code given in the *asyncExample.c* file demonstrates the usage of the various types of TSIPv1 Client API functions in Query/Response, Set/Response, and Monitor Response type situations when interacting with the RES/ICM 720 using the TSIPv1 Client API. As you can see from the example code, the first interaction with the RES/ICM 720 (after successfully initializing the TSIPv1 Client API) is to query for the current Periodic Message Configuration (0x91-05) that exists on the RES/ICM 720 . Refer to the "TSIPv1 Design and Packets" document for the details of the Periodic Message Configuration.

From the example code, you can see that in order to query for the current Periodic Message Configuration, you need to specify which port you are requesting for the Periodic Message Configuration. Not all Query/Response interactions require additional parameters in order to Query for the current configuration. For this specific example, the Periodic Message Configuration requires that a port be specified. The TSIPv1 Client API function for performing the Query/Response for the Periodic Message Configuration is the following:

> *int tcaGetPeriodicCfg(host_periodic_cfg_t *ptPeriodicCfg, host_callback_v vCallback, void *pCbArg)*

where *ptPeriodicCfg* is a host structure that will allow any qualifying parameters to the query (in this case it would be the port), specified as PERIODIC_CFG_CURPORT and set into the structure using the convenience function *tcaSetPeriodicCfgPort()* as seen in the example code.

The second argument to *tcaGetPeriodicCfg()* is the user specified callback function *getPeriodicCfgCallback()* that will be invoked asynchronously after the response from the RES/ICM 720 module has been successfully parsed and filled into the appropriate allocated host structure. The third argument to *tcaGetPeriodicCfg()* is a user specified void pointer argument which will be passed as the first argument to the callback function to allow the callback function to access any information from the caller or to pass back any information needed by the caller, because the callback function will be executed in its own thread and will only be able to exchange information with the caller through this callback argument or through global variables.

The second and third arguments to the callback function are used to pass the response data to the callback function. The second argument is an error status that must be zero before the third argument can be used as a pointer to the expected host structure containing the response to the TSIPv1 Client API Query/Set command.

Note that the third argument to the callback function consists of allocated memory to contain the host structure for the response message. This allocated memory will be automatically freed by the TSIPv1 Client API code upon completion of the callback function. Therefore, it is the responsibility of the callback function provided by the caller to extract whatever information it might need from the allocated host response structure before the completion of the callback function. In the example code, we are copying the initial Periodic Message Configuration structure to a global structure *gtPeriodicPortCfg* along with setting the global flag *gbInitPerSaved* to indicate that we have successfully stored the initial Periodic Message Configuration from the RES/ICM 720 for later use in restoring the Periodic Message Configuration to its original set of values at the completion of the example code.

After storing the original Periodic Message Configuration into the global structure, the *getPeriodicCfgCallback()* function makes a copy of the original Periodic Message Configuration structure and modifies it so that the Timing Information (0xA1-00) will be changed to PERIODIC_CFG_QUERY_MODE from its default value of PERIODIC_CFG_PERIODIC_MODE. This is done by calling the convenience function *tcaSetPeriodicCfgTimingInfo()* to set the *ucTimingInfo* field of the *host_periodic_cfg_t* structure as seen in the example code.

This change to the Periodic Message Configuration is committed to the RES/ICM 720 using the Set/Response TSIPv1 Client API function *tcaCommitPeriodicCfg()* as seen in the example code in the callback function *getPeriodicCfgCallback()*. The call to *tcaCommitPeriodicCfg()* is attempting to alter the Periodic Message Configuration of the RES/ICM 720 so that the default periodic unsolicited sending of the Timing Information (0xA1-00) will be altered such that it needs to be queried by the host.

This change in configuration of the Periodic Message Configuration of the RES/ICM 720 is confirmed by the callback function specified in the call to *tcaCommitPeriodicCfg()*. The callback function *changeTimingInfoToQueryCb()* will be invoked after the receive thread has parsed the response and filled a corresponding allocated host structure indicating the current state of the

Periodic Message Configuration on the RES/ICM 720 . In the example code, the *changeTimingInfoToQueryCb()* function initiates a call to *tcaGetTimingInfo()* to poll for the Timing Information (0xA1-00). Notice that this Query/Response function only has two input parameters because there is no additional qualifier needed to request the Timing Information.

The *polledTimingInfoCb()* function is invoked after the response to the call to *tcaGetTimingInfo ()* has been processed (parsed and filled into the proper allocated host structure) by the receive thread. This callback function should only be invoked once because the Periodic Message Configuration was modified such that the Timing Information is no longer generated periodically by the RES/ICM 720 . The *polledTimingInfoCb()* function also performs a TSIPv1 Client API function call to Monitor the serial port for the receipt of unsolicited Timing Information messages using the TSIPv1 Client API function *tcaRegisterTimingInfoHandler().* This API function installs the callback function *periodicTimingInfoCb()* which will be invoked to notify the host if any unsolicited Timing Information message response is received and processed by the receive thread. This callback function should not be invoked until the Periodic Message Configuration is restored such that the Timing Information is configured to generate unsolicited Timing Information responses periodically.

Note that all of the prior description will happen asynchronously through the receive thread and the callback functions in response to the original call to *tcaGetPeriodicCfg()* from the host main program thread. The host main program thread continues to run after the intial call to *tcaGetPeriodicCfg()* and performs a Query/Response for Position Information (0xA1-11) using the API function call *tcaGetPosInfo().* Note that this particular Query/Response API function utilizes multiple qualifying fields to specify the format of the Position Information Response. This can be seen in the example code through the calls to the convenience functions *tcaSetPosMaskPositionMode()*, *tcaSetPosMaskCoordType()*, *tcaSetPosMaskHaeMslSelect ()*, and *tcaSetPosMaskVelocityMode()* to set fields in the structure used to qualify the Query for the Position Information through the call to *tcaGetPosInfo().* The callback function *getPosInfoCallback()* will be invoked after the Response to the Query for Position Information is processed by the receive thread.

Because the TSIPv1 Client API supports asynchronous operation, the main thread will also call the *tcaGetSatInfo()* TSIPv1 Client API function after calling the *tcaGetPosInfo()* function as seen in the example code. As in some of the previous TSIPv1 Client API function calls, there are also qualifying parameters for the Query/Response for Satellite Information (0xA2-00) with calls to the convenience functions *tcaSetSatInfoSvType()* and *tcaSetSatInfoSvPrn()* to set the appropriate fields in the structure for qualifying the Query/Response.

Note that the callback function and callback argument for *tcaGetSatInfo()* may need to behave differently than prior examples because of the possibility that there may be multiple Response messages with Satellite Information for a single call to *tcaGetSatInfo().* Therefore the caller must ensure that the callback function and callback argument can correctly handle the case of multiple callbacks with the same user supplied callback argument with different allocated host structures corresponding to the multiple response messages processed by the receive thread for a single query.

The example program then has the main thread enter a loop waiting for a certain amount of time to elapse to allow the prior API function calls to complete asynchronously through their callback functions. At that point, the example program calls the *tcaRegisterSatInfoHandler()* API function to receive callbacks for any periodically generated Satellite Info responses and calls

API functions to modify the Periodic Message Configuration to enable periodic Satellite Information messages. The *periodicSatInfoCb()* function will eventually be invoked due to the Periodic Message Configuration being modified to start sending Satellite Information periodically. After a certain amount of time has elapsed, the Periodic Message Configuration is restored to its original configuration of sending periodic Timing Information only. At this point, only the *periodicTimingInfoCb()* function should be invoked to notify the host of any periodic Timing Information responses being periodically generated by the RES/ICM 720 . Finally the code terminates the example program.

Example 2: Synchronous Firmware Upload

The other example program in the *fwUploadTsipClientApi* subdirectory demonstrates the usage of the TSIPv1 Client API code in a "synchronous" manner for the Firmware Upload application. Please refer to the example code and how it is used to to perform a Firmware Upload to the RES/ICM 720 .

As can be seen by these two example applications, the TSIPv1 Client API allows a host application to interact with the RES/ICM 720 to implement TSIP Query/Response, Set/Response, and Monitor for Response functions asynchronously through callback functions and host structures without needing to deal with any issues of exact TSIPv1 formatting and explicitly accessing the serial port for these purposes. This should allow the host application to be written more cleanly, without needing to intersperse function calls to explicitly handle serial port interactions, which is the purpose behind implementing the TSIPv1 Client API.

Additional Notes

It is the responsibility of the caller to ensure that the memory associated with the callback argument provided when the TSIPv1 Client API function was invoked remains within scope for use by the callback function.

For the TSIPv1 Client API functions that are expecting a response from the RES/ICM 720 , the occurrence of a timeout waiting for the expected response message causes the callback function to be invoked with an appropriate error status code in the second argument of the callback function. The callback function will also be automatically removed from the callback list for that particular Packet and Sub-packet ID key pair when the timeout occurs. This is required because the TSIPv1 Client API code does not know what type of memory is being utilized by the caller for the first argument of the callback function which could involve reading or writing of the memory associated with the first callback argument.

Because the TSIPv1 Client API code does not know whether the memory associated with the first argument of the callback function may potentially be from the stack, the callback function is removed automatically to prevent the receipt of a late arriving response message invoking the callback function with stack memory that is no longer in scope. This could lead to random stack corruption issues that would potentially be difficult to diagnose. Therefore, it is the responsibility of the caller to ensure that the callback function takes appropriate action to handle the timeout case in order to ensure that an appropriate callback function and callback argument are available for that Packet and Sub-packet ID key pair if needed. If no action is taken, the receipt of any late arriving response message will end up discarding the response message because there is no callback available to invoke for that response message.

The caller is also responsible for providing appropriate memory for the callback argument for any cases that involve multiple response messages for a single query or when utilizing a "Register" API function to handle periodically generated response messages, as the receipt of a response message for these key pairs will cause the specified callback function to be invoked with the specified callback argument.

There are no convenience API functions for reading the fields of the response host structures, even though convenience API functions are provided for writing the fields of the host structures when querying the RES/ICM 720 with additional qualifiers or when setting the fields of the host structure to be committed to the RES/ICM 720 . This is not an oversight and was done purposefully because the host structures for the responses are in the units specified by the "TSIP Design and Packets" document which may or may not match the units desired by the host software interacting with the user. Therefore, it is the responsibility of the user of the library to translate the values returned in the host structures for the responses into appropriate units desired by the host software.

Finally, not all Packet and Sub-Packet ID key pairs have a Query and Set command. There should eventually be a TSIPv1 Client API function available to allow the caller to interact with the RES/ICM 720 using the messages identified in the "TSIP Design and Packets" document. The document is periodically enhanced and updated to include additional functionality. It is expected that TSIPv1 Client API functions be provided for all necessary functionality in the document. It is still to be determined when full functionality will be available; however, a significant portion of the most important messages will be available with the first release.

9

Integration Examples

The timing module has many potential applications for both indoor and outdoor applications. The following shows typical small cell circuit diagram and deployment diagram of DCSG (Disaggregated Cell Site Gateway) or CSR (Cell Site Routers) with the timing module. The DCSG or CSR are widely deployed in 5G/LTE-A environment providing cell site aggregation and T-BC (Boundary Clock) services. The timing module can be used in such environment to provide GNSS reference input to the small cell device and T-BC device implemented in DCSG.

In the small cell application, below is a typical 5G/LTE small cell circuit diagram with a GNSS receiver.
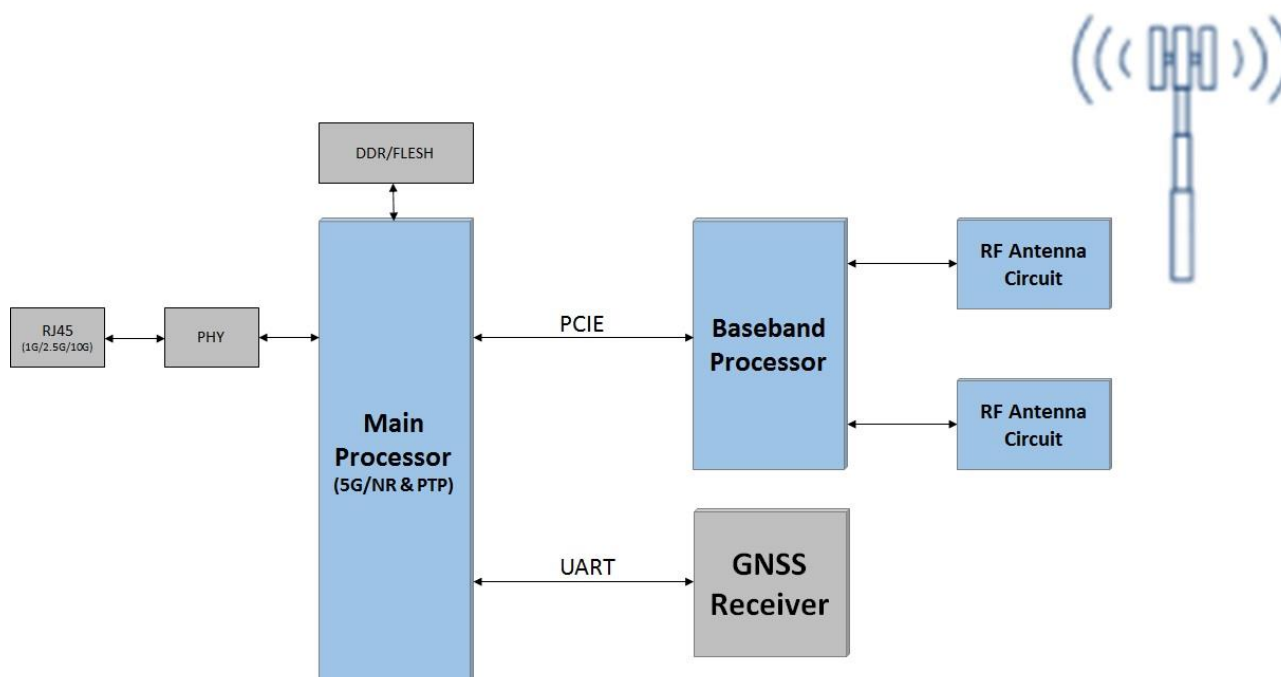
The RES/ICM 720 timing module can be applied for the small cell application depending on whether the PLL logic block is used and 10 MHz system frequency output is required or not.

This example is for a small cell application with RES 720 timing module, which does not output the 10 MHz system frequency.

Typical use case for RES720
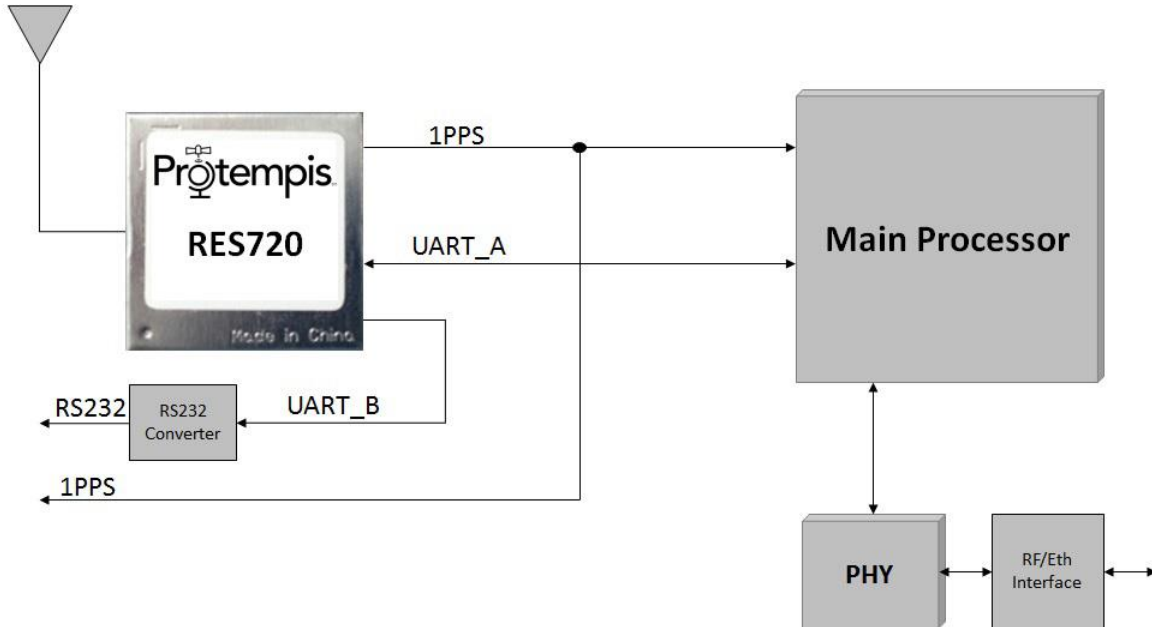
This example is for a small cell application with ICM 720 which does output 10 MHz system frequency.

Typical use case for ICM720
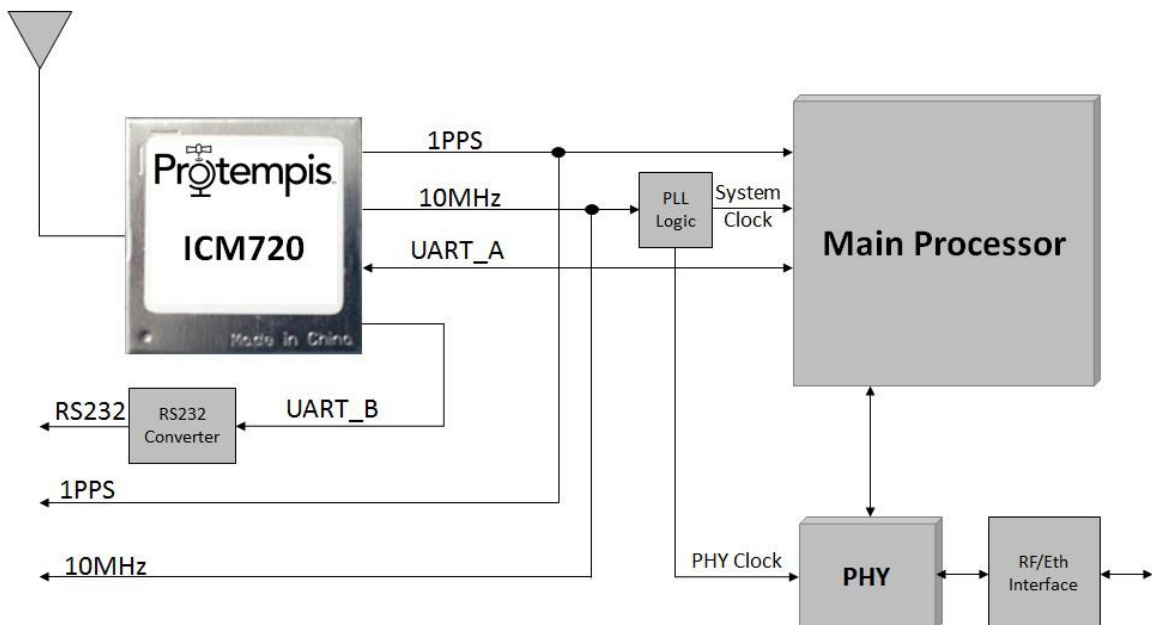
In the CSR (Cell Site Routers) application, below is a typical circuit diagram with a GNSS receiver.
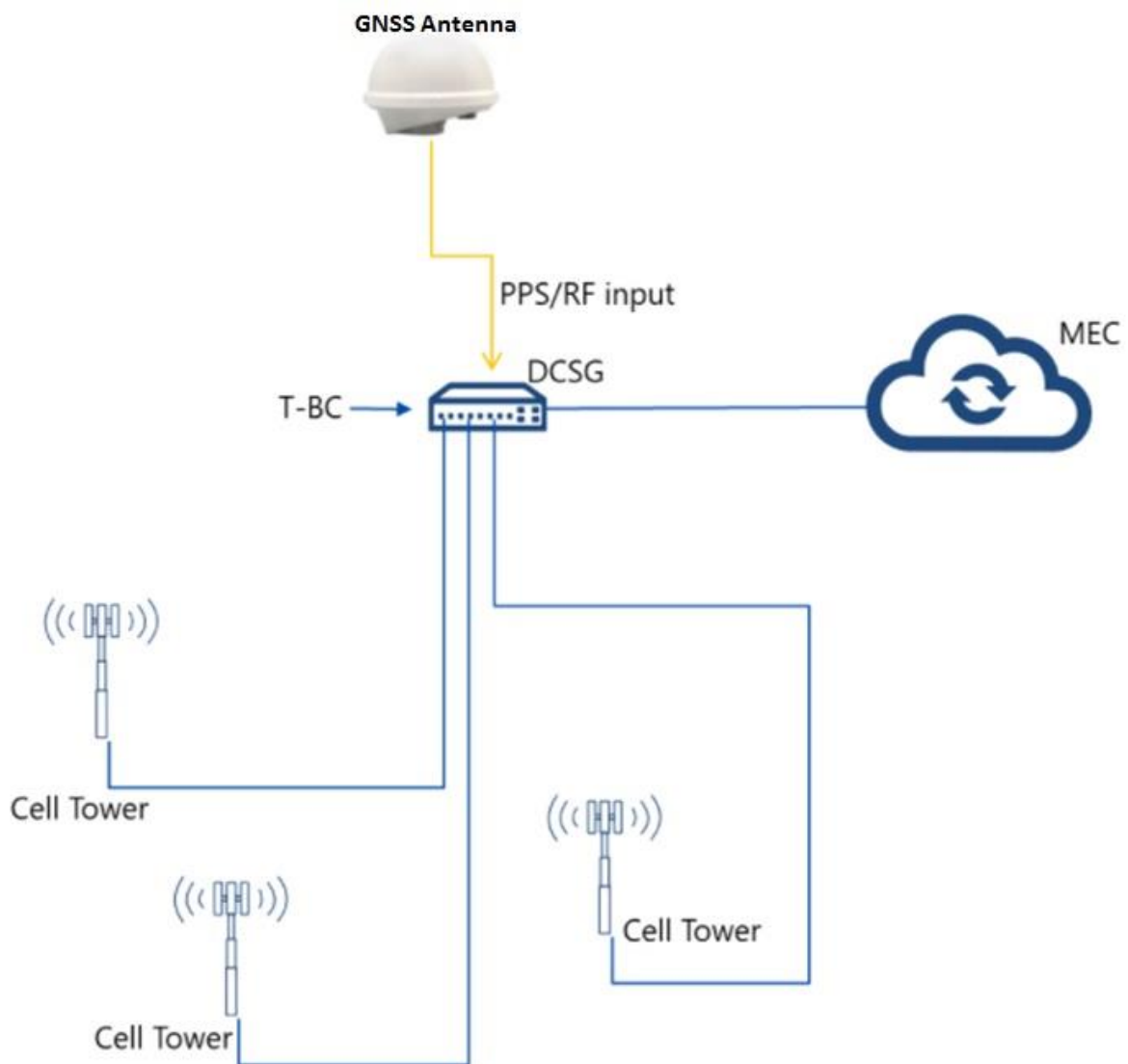
The timing module can be applied for the CSR application depending on whether the PLL logic block is used and 10 MHz system frequency output is required or not.

This example is for a CSR application with the RES 720 timing module, which does not output 10 MHz system frequency.

Typical use case for RES720 with PLL + OCXO
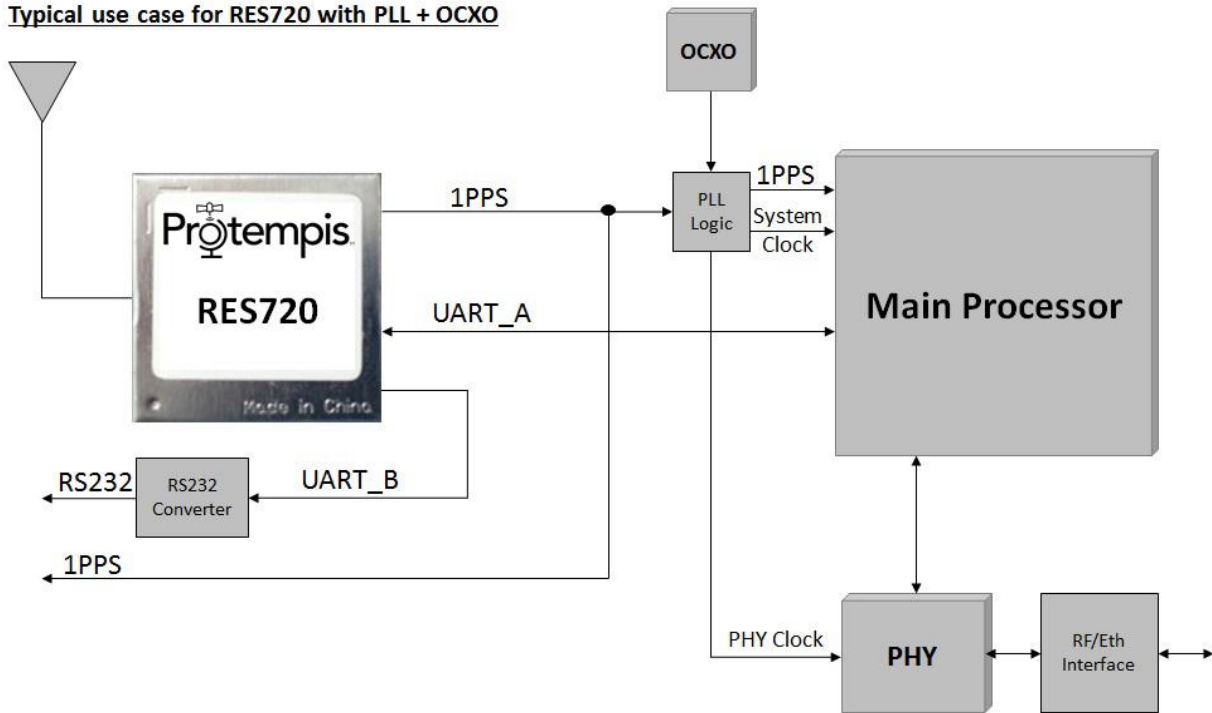
This example is for a CSR application with the ICM 720 timing module, which does output 10 MHz system frequency.

Typical use case for ICM720 with PLL + OCXO

10
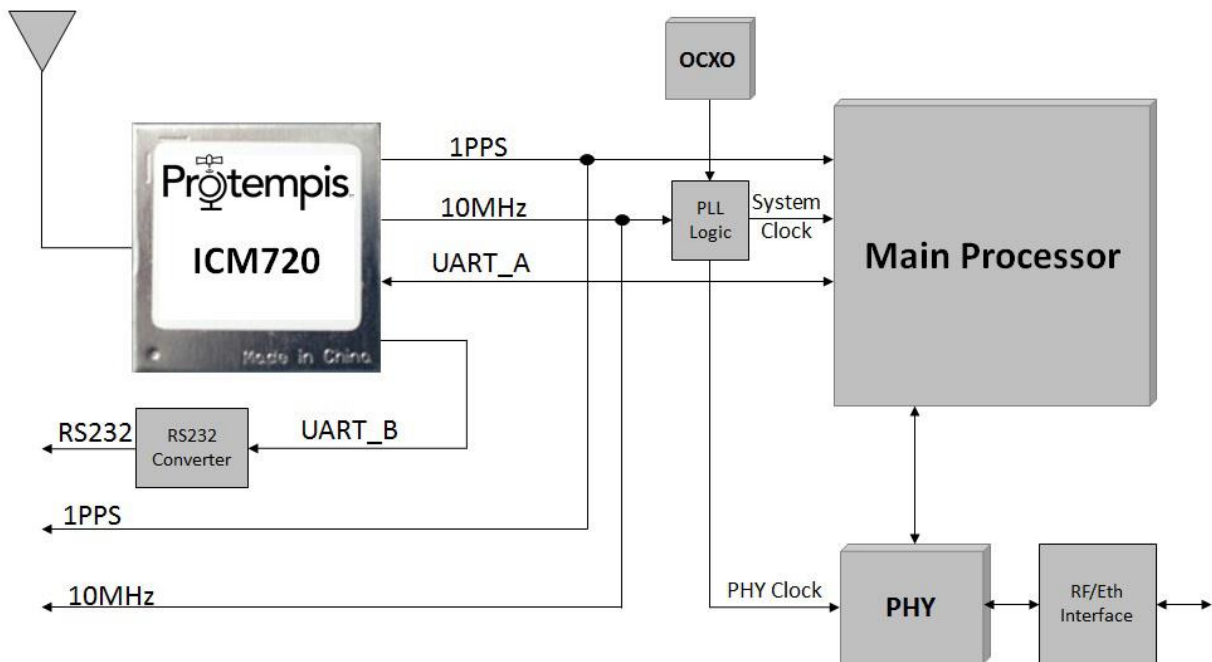
Installation and Application Circuits

▶ RF considerations

▶ Active antenna - no antenna status

▶ Active antenna - antenna short protection

▶ Active antenna - antenna open and short protection

This chapter provides several circuit examples for antenna feed and monitoring circuits to power and monitor active GNSS antennas for use with the RES/ICM 720 timing module modules.

RF considerations

This topic contains frequently asked questions on considerations for RF planning to enable a receiver to perform with the best possible signal.

Why do I need an LNA?

A low-noise amplifier (LNA) is an electronic amplifier that amplifies a very low-power signal without significantly degrading its signal-to-noise ratio.

By using an LNA close to the signal source, the effect of noise from subsequent stages of the receive chain in the circuit is reduced by the signal gain created by the LNA, while the noise created by the LNA itself is injected directly into the received signal. The LNA boosts the desired signals' power while adding as little noise and distortion as possible. The work done by the LNA enables optimum retrieval of the desired signal in the later stages of the system.

With a low noise figure, an LNA must have high gain. An LNA without high-gain allows the signal to be affected by LNA circuit noise; the signal may become attenuated, so the LNA's high gain is an important parameter.

A regular amplifier increases the power of both the signal and the noise present at its input. LNAs are designed to minimize additional noise.

Placing an LNA in the RF feed can also overcome any shortcomings in the PCB layout.

How much gain does my LNA need?

You need more than 15 dB of gain to be present at the RF front end of the receiver. 20 dB is recommended. You should calculate the dB loss between the LNA output and through all the cables to the RF input of the receiver. The LNA output gain minus the calculated losses should not go below 15 dB. Using gain lower than 15 dB may result in reduced sensitivity of the receiver.

For example, if you have calculated that there is 10 dB of loss in the cable and connectors between the LNA output and the RF input of the receiver, then you would want an LNA of about 30 dB.

Can you have too much gain?

The RF-input of a GNSS receiver goes into an AGC (Automatic Gain Control) for being conditioned for the following stages up to the analogue to digital conversion. The AGC range has upper and lower limits. The input signal shall be kept in a range that allows the AGC to operate within its full dynamic range. Too much gain can drive the AGC into compression, which reduces the dynamic range, causes misleading signal strength indications and can generate artefacts in the signals that may affect the receiver's operation in unforeseen ways. Another issue becomes that of handling out-of-band signals (and noise). Any additional gain more than necessary to preserve the system noise figure results in reduced large (out-of-band) signal handling capability. In other words, the receiver is more susceptible to overload with excess gain.

As a general guide for the maximum gain to be presented to an RF input of a Protempis timing receiver, it shall not exceed 35 dB25 dB. But if you are unsure, please contact your Protempis representative for assistance.

Active antenna – no antenna status

In this schematic without antenna detection:

- An active antenna is used.

- There is no hardware reset ability through the External Reset pin, as this is left disconnected.

- Only serial port A is connected. Port B is not available as this is left disconnected.

- Antenna open and short detection or protection is not provided. If pin 5 and pin 6 are left floating, the unit reports an antenna open condition. To avoid this, pull SHORT high with a 10 kΩ resistor and pull OPEN low.

- The resonance frequency of the antenna feed inductor L1 shall be in the frequency range of the GNSS signals to provide an efficient RF barrier.

The following table shows the component information:

Component	Description	Manufacturer	Part Number
C1	18pF, 0402 capacitor, COG	KEMET	C0402C180J5GAC
C2	0.1µF, 0402 capacitor, X7R	CAL-CHIP	GMC04X7R10K16NTLF
J1	SMB Connector	Chin Nan	24-12-11-TGG
L1	47nH, 0402 inductor, surface	Murata	LQG15HN47NJ02D

Active antenna - antenna short protection

In this schematic with antenna detection:

- An active antenna is used.

- There is no hardware reset ability through the External Reset pin, as this is left disconnected.

- Only serial port A is connected. Port B is not available as this is left disconnected.

- Antenna short detection and protection is provided by this circuit. Antenna open detection is not provided, however. If pin 5 is left floating, the unit reports an open condition. To avoid this pull OPEN low. The combination of the OPEN and SHORT pins (pins 5 and 6) report the antenna status.

- The resonance frequency of the antenna feed inductor L1 shall be in the frequency range of the GNSS signals to provide an efficient RF barrier.

The following table shows the component information:

Component	Description	Manufacturer	Part Number
C1	18pF, 0402 capacitor, COG	KEMET	C0402C180J5GAC
C2	0.1µF, 0402 capacitor, X7R	CAL-CHIP	GMC04X7R10K16NTLF
J1	SMB Connector	Chin Nan	24-12-11-TGG
L1	47nH, 0402 inductor, surface	Murata	LQG15HN47NJ02D
Q1	PNP transistor	Philips	MMBT3906
Q2	NPN transistor	Philips	MMBT3904

Active antenna – antenna open and short protection

In this schematic with open and short antenna detection:

- An active antenna is used.

- There is hardware reset ability through the External Reset pin.

- Both serial ports are connected.

- Antenna open and short detection and protection is provided. The combination of the OPEN and SHORT pins (pins 5 and 6) reports the antenna status.

- The resonance frequency of the antenna feed inductor L1 shall be in the frequency range of the GNSS signals to provide an efficient RF barrier.

The following table shows the component information:

Component	Description	Manufacturer	Part Number
C1	18pF, 0402 capacitor, COG	KEMET	C0402C180J5GAC
C2	0.1μF, 0402 capacitor, X7R	CAL-CHIP	GMC04X7R10K16NTLF
J1	SMB connector	Chin Nan	24-12-11-TGG
L1	47nH, 0402 inductor, surface	Murata	LQG15HN47NJ02D
Q1	PNP transistor	Philips	MMBT3906
Q2	NPN transistor	Philips	MMBT3904
Q3	PNP transistor	Philips	MMBT3906
Q4	PNP transistor	Philips	MMBT3906

11

Packaging

- ▶ Introduction
- ▶ Reel
- ▶ Weight
- ▶ Tapes
- ▶ Label

This chapter provides detailed information about the packaging and labeling of the timing module.

Follow the instructions in this chapter to ensure the integrity of the packaged and shipped modules.

See the Label section for the serial number format.

Introduction

The timing modules are packaged in tape and reel for mass production. One reel holds 500 modules. See Label for the dimensions and serial number format.

> **CAUTION –** The reel is sealed in a moisture-proof dry-pack bag. Please follow all the directions printed on the package for handling and baking.

Reel

You can mount the 13-inch reel in a standard feeder for the surface mount pick and place machine. All dimensions are in millimeters.
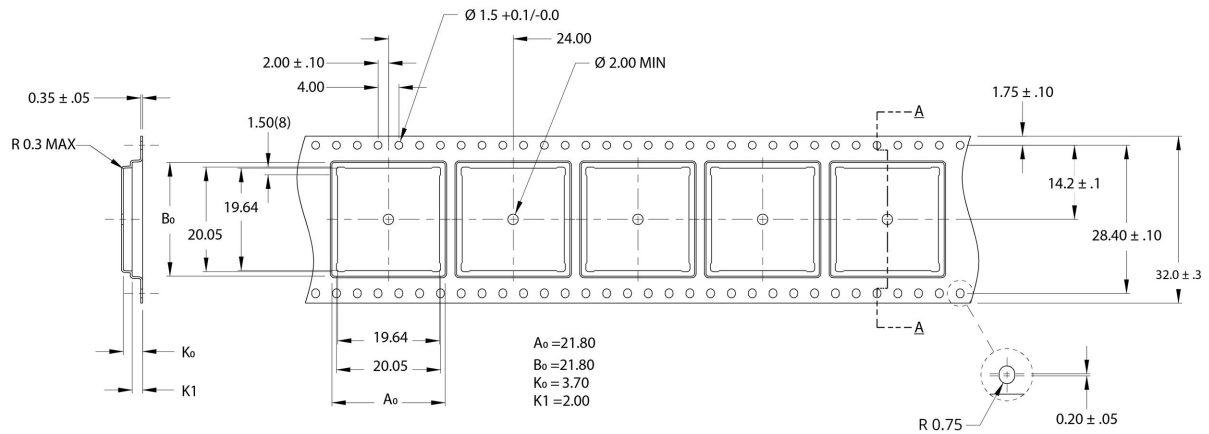
Detail A
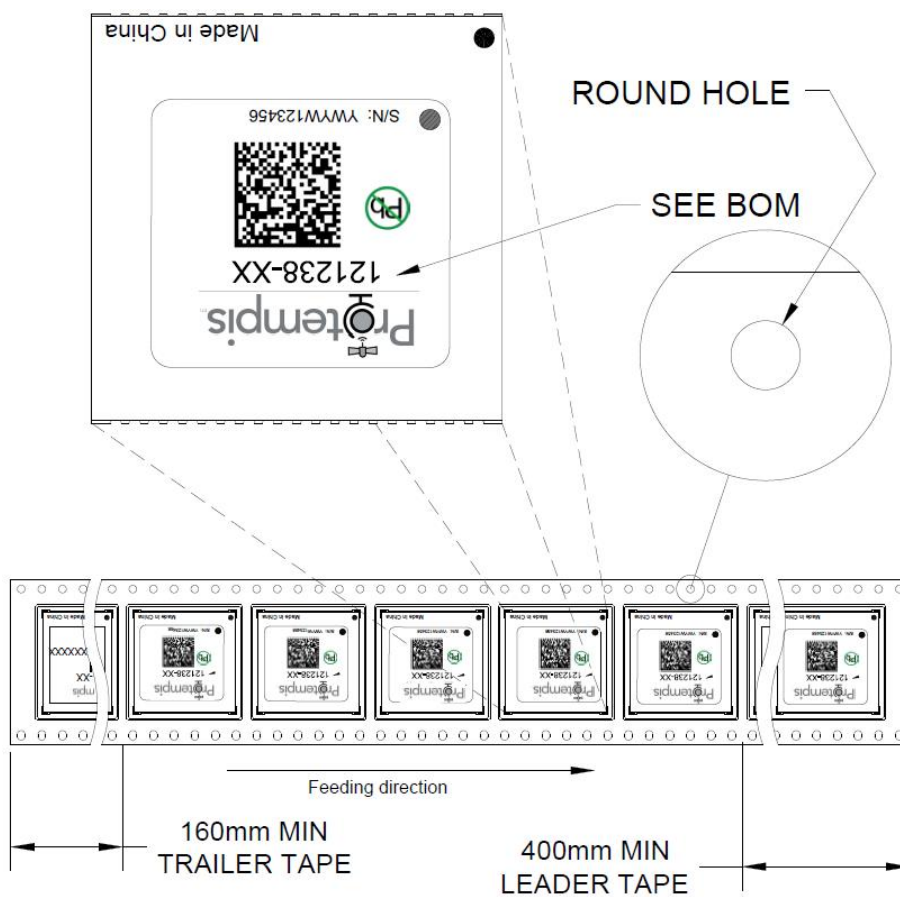
Locking catch

ØN

1.8±0.1

Detail A

SCALE 3:1

1.5MIN

Ø20.2MIN

$\varnothing 13.0^{+0.5}_{-0.2}$
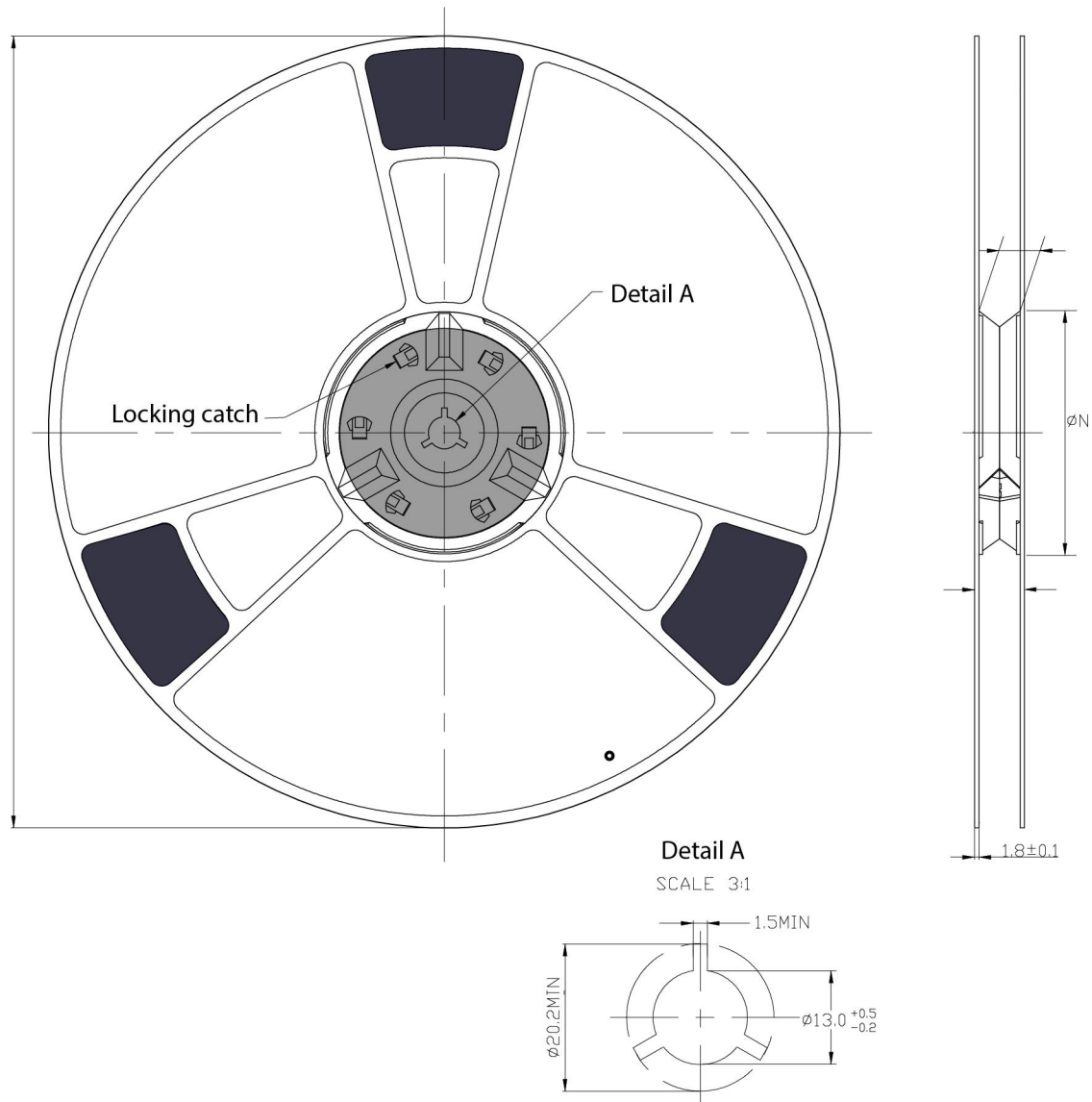
Weight

Unit description	Weight (approx.)
500 pieces with reel packaging, desiccant, and humidity indicator	1,380 g
500 pieces with reel packaging, desiccant, humidity indicator and white carton box	1,595 g

Tapes

The tape dimensions illustrated in the diagram below are in inches. The metric units appear in brackets [ ].
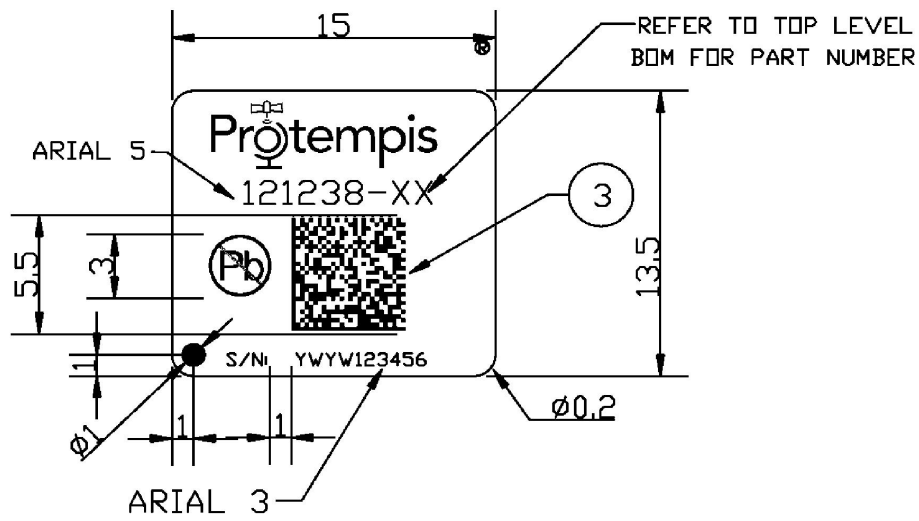

$A_0 = 21.80$
$B_0 = 21.80$
$K_0 = 3.70$
$K_1 = 2.00$

The feeding direction is illustrated below:

ROUND HOLE

SEE BOM

Made in China

S/N: YYWWV123456

121238-XX

Feeding direction

160mm MIN
TRAILER TAPE

400mm MIN
LEADER TAPE

Label

The label dimensions and number format are shown in the drawing below.

12

Shipping and Handling

▶ Shipping and handling guidelines

▶ Moisture precondition

▶ Baking procedure

This chapter provides detailed guidelines for shipping and handling the timing modules to ensure compliance with the product warranty.

Shipping and handling guidelines

Handling

The timing modules are shipped in tape and reel for use with an automated surface mount machine. This is a lead-free module with gold plating. Do not allow bodily fluids or lotions to come in contact with the bottom of the module.

> **CAUTION –** The timing module is packed according to ANSI/EIA-481-B and JSTD-033A. All of the handling and precautions procedures must be followed. Deviation from following handling procedures and precautions voids the warranty.

Shipment

The reel of the timing module is packed in a hermetically-sealed moisture barrier bag (DryPac) then placed in an individual carton. Handle with care to avoid breaking the moisture barrier.

Storage

The shelf life for the sealed DryPac is 12 months if stored at <40 °C and with <90% relative humidity.

Moisture Indicator

A moisture indicator is packed individually in each DryPac to monitor the environment—it has five indicator spots that are blue when the pack leaves the factory. If the indicator changes to pink, follow the instructions printed on the moisture barrier and bake as required.

Floor Life

The reel of the timing module is vacuum sealed in a moisture barrier bag (DryPac). Once the bag is opened, moisture will bond with the modules. In a production floor environment, an open reel needs to be processed within 72 hours, unless it is kept in a nitrogen-purged dry chamber. If the moisture indicator changes to pink, follow the baking instructions printed on the moisture barrier.

The timing module is a lead-free component and is RoHS-II compliant. The pins are plated with immersion gold that makes soldering easier.

> **CAUTION –** Operators should not touch the bottom solder pads by hand or with contaminated gloves. Ensure that no hand lotion or regular chlorinated faucet water comes in contact with the module before soldering.

Moisture precondition

You must take precautions to minimize the effects of the reflow thermal stress on the module. Plastic molding materials for integrated circuit encapsulation are hygroscopic and absorb moisture. This is dependent on the time and the environment.

Absorbed moisture will vaporize during the rapid heating of the solder reflow process, generating pressure to all the interface areas in the package, followed by swelling, delamination, and even cracking of the plastic. Components that do not exhibit external cracking can have internal delamination or cracking which affects yield and reliability.

CAUTION

THIS BAG CONTAINS MOISTURE SENSITIVE DEVICES.
Do not open except under controlled conditions.
shelf life in sealed bag: 12 months @ <40C and <90% RH.
1) Peak package body temperature 245C.
2) After this bag is opened, devices that will be subjected to IR reflow vapor-phase reflow, or equivalent processing must be:
a. Mounted within 72 hrs @ factory conditions of <30C/60% RH or
b. Stored at <20% RH.
3) Devices require baking, before mounting if:
a. Humidity card is >20% when read at 23C+-5C or
b. 2a or 2b are not met.
4) if baking is required, devices may be baked for 24 hrs minimum at 125C-0/+5C.
Bag Seal Date: mm/dd/yy
expiration date: 12 months from seal date.

4 Level

Baking procedure

If baking is necessary, Protempis recommends baking in a nitrogen purge oven.

Temperature	125 °C
Duration	24 hours
After baking	Store in a nitrogen-purged cabinet or dry box to prevent absorption of moisture

CAUTION – Do not bake the units within the tape and reel packaging. Repeated baking processes will reduce the solderablity.