RES 720

DUAL-BAND TIMING MODULE

USER GUIDE

For use with:

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

Firmware version 1.00 and later

Version 1.00
Revision DRAFT C
October 2021
P/N: 94472-00

Legal Notices

Corporate Office

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Component Technologies
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Time & Frequency Division

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Legal Notices

Release Notice

This is the October 2021 release (Revision DRAFT C) of the RES 720 Dual-Band Timing Module User Guide.

The Australian Consumer Law

Our goods come with guarantees that cannot be excluded under the Australian Consumer Law. You are entitled to a replacement or refund for a major failure and for compensation for any other reasonably foreseeable loss or damage. You are also entitled to have the goods repaired or replaced if the goods fail to be of acceptable quality and the failure does not amount to a major failure.

Trimble's warranty (set out below) is in addition to any mandatory rights and remedies that you may have under the Australian Consumer Law.

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Subject to the following terms and conditions, Trimble Inc. ("Trimble") warrants that for a period of one (1) year from date of purchase this Trimble product (the "Product") will substantially conform to Trimble's publicly available specifications for the Product and that the hardware and any storage media components of the Product will be substantially free from defects in materials and workmanship.

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If the Trimble Product fails during the warranty period for reasons covered by this limited warranty and you notify Trimble of such failure during the warranty period, Trimble will repair OR replace the nonconforming Product with new, equivalent to new, or reconditioned parts or Product, OR refund the Product purchase price paid by you, at Trimble’s option, upon your return of the Product in accordance with Trimble's product return procedures then in effect.

How to Obtain Warranty Service

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

– your name, address, and telephone numbers

– proof of purchase

– a copy of this Trimble warranty

– a description of the nonconforming Product including the model number

– an explanation of the problem

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

Warranty Exclusions and Disclaimer

This Product limited warranty shall only apply in the event and to the extent that: (a) the Product is properly and correctly installed, configured, interfaced, maintained, stored, and operated in accordance with Trimble's applicable operator's manual and specifications, and; (b) the Product is not modified or misused.

This Product limited warranty shall not apply to, and Trimble shall not be responsible for, defects or performance problems resulting from: (i) the combination or utilization of the Product with hardware or software products, information, data, systems, interfaces, or devices not made, supplied, or specified by Trimble;

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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.

Registration

To receive information regarding updates and new products, please contact your local Trimble authorized dealer or visit the Trimble website at www.trimble.com/register. Upon registration you may select the newsletter, upgrade, or new product information you desire.

Notices

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

– Reorient or relocate the receiving antenna.

– Increase the separation between the equipment and the receiver.

– Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

– Consult the dealer or an experienced radio/TV technician for help.

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

Canada

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

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

Europe

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

Notice to Our European Union Customers

For product recycling instructions and more information, please go to http://www.trimble.com/Corporate/Environmental_Compliance.aspx.

Recycling in Europe: To recycle Trimble WEEE (Waste Electrical and Electronic Equipment, products that run on electrical power.), Call +31 497 53 24 30, and ask for the "WEEE Associate". Or, mail a request for recycling instructions to:

Trimble Europe BV
C/O XPO Logistics
De Schakel 39-41
5651 GM Eindhoven
The Netherlands

Declaration of Conformity

We, Trimble Inc.,

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Sunnyvale, CA 94085-3913
United States of America
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declare under sole responsibility that the product: RES 720 and ICM 720 Timing Module Starter Kits comply with Part 15B of FCC Rules.

Operation is subject to the following two conditions:

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

Document History

Version	Date	Author	Changes
V1.00.00 Rev C	18. Oct. 2021	CV	Replaced application circuits, added TSIPv1 Client API chapter
V1.00.00 Rev B	23. Sept 2021	CV	Added carrier card and starter kit chapters, added DoC, removed 9.6kbps option from 0x91-00
V1.00.00 Rev A	July 2021	FAE	Initial version

List of Abbreviations

A-GPS	Assisted GPS
C/No	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
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-R AIM	Timing Receiver Autonomous Integrity Monitoring
TSIP	Trimble Standard Interface Protocol
T-S UTC	Universal Time Coordinated
VCC	Voltage at the Common Collector; positive supply voltage
VSWR	Voltage Standing Wave Ratio
VTS	Trimble 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 system 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 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.

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Introduction

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

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

Key features

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

The timing features include the following:

- Automatic self-survey of position for static operation
- Over-determined timing mode
- Accuracy <5 ns (1 sigma) with respect to GNSS-time or UTC-time when using both L1 and L5 constellations.

- T-RAIM (Timing module Autonomous Integrity Monitoring)
- Position Integrity Monitoring
- Cable delay compensation
- Anti-Jamming function
- Single-satellite timing mode with anti-jamming feature turned off
- Dual-satellite timing mode with anti-jamming feature turned on

Dual-band multi-constellation capability

With dual-band multi-constellation capability, the RES 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 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 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 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 720 timing module offers precision time synchronization with 5 nanosecond accuracy in normal mode of operation. The RES 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 signals meaconing, Trimble timing modules 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 720 timing module provides secure boot and anti-tampering features by default. Additionally, the RES 720 timing module offers T-RAIM to provide the highest level timing integrity.

Protocols and configuration

Trimble timing modules support industry standard NMEA (National Marine Electronics Association) and TSIP (Trimble Standard Interface Protocol) for configuration and control .

The RES 720 timing module module may be subject to various ITU-T recommendations for PRTC and it is expected that engineering refers to appropriate standards as applicable to GNSS PRTC while designing the GNSS PRTC boards. A technical report, ITU-T GSTR-GNSS, published by ITU-T discusses design, configuration and test criteria in great details and should be used as reference document. It is suggested that ITU-T G.8271 is also consulted for output parameters and accuracy thereof in addition to the aforementioned technical paper.

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. Trimble recommends that the those guideline are followed for the implementation of error correction mechanisms.

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Detailed Data Sheet

Data sheet

Features	Specifications
Bands	
L1 – 1602 Mhz and 1575.42 MHz	GPS L1CA, GLONASS L1OF, Galileo E1, BEIDou B1, 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 1 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	
Accuracy	<5 ns (1-sigma, clear sky, absolute mode) NOTE – Requires a phase-aligned or adjusted antenna, accurate cable delays, completed 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 (±5ns)/PP2S	
1 PPS pulse width	1 ms to 500 ms
1 PPS offset	-0.25 to 0.25 seconds
1 PPS (±5 ns) / PP2S / programmable 10 MHz / Sinewave 10 Mhz	
Raw data	
Measurement data	Carrier phase, code phase, and pseudorange. Doppler on all signals.
Message data	GPS, GLONASS, BeiDou, Galileo, QZSS, SBAS
Environmental data, quality and reliability	

Features	Specifications
Humidity	5% to 95% (non-condensing)
RoHS compliant (lead-free)	
Green (halogen-free)	
ETSI-RED compliant	
Qualification according to ISO 16750	
Manufactured and fully tested in ISO/TS 16949 certified production sites	
High vibration and shock resistance	
Electrical data	
Supply voltage	2.7 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 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 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.

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Hardware

The RES 720 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® application processor that operates at 26 MHz.

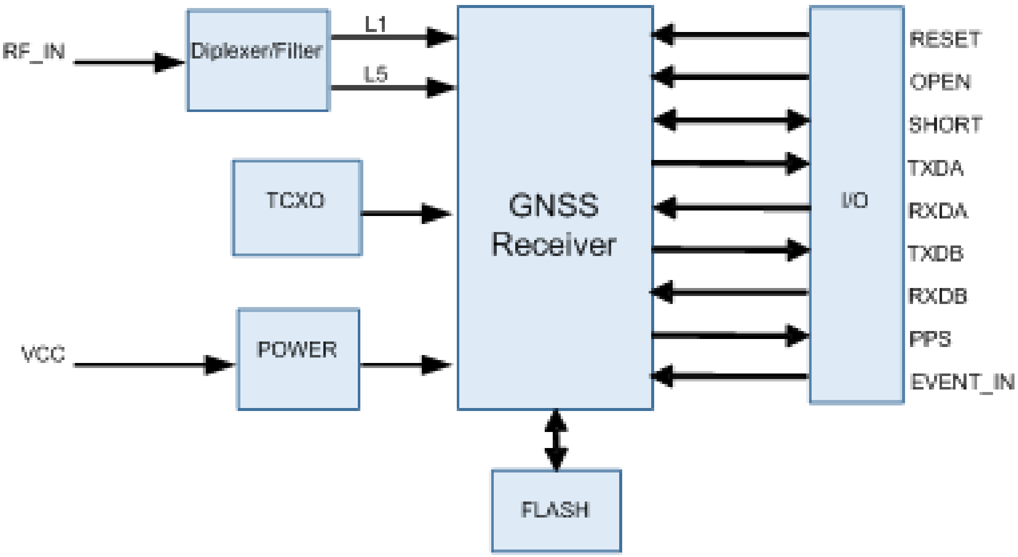
The GPS subsystem contains the RF and baseband circuits, which can track L1 and L5 satellites at the same time, and search GPS satellites using the L1 circuit.

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

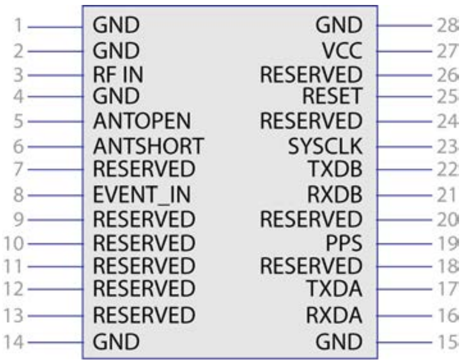
The IF frequency is 4.092 MHz.

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

RES 720 block diagram



RES 720 pin assignment



Pin assignment table

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.

Pin	Name	Description	Function	Note
5	ANTOPEN	Antenna OPEN	Input	Logic level from external antenna detection circuit. See Detailed pin description, page 31.
6	ANTSHORT	Antenna SHORT	Input / Output	Logic level from external antenna detection circuit. See Detailed pin description, page 31.
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	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.

Pin	Name	Description	Function	Note
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, 2.7 – 3.6 V DC.
28	GND	Ground	Ground	Signal ground. Connect to common ground.

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 RES 720S 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

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

- The cable delay compensation, enable state, and polarity can be controlled by TSIP packet 0x91-03 (see page 102).
- The PPS output options are set by TSIP packet 0x91-03.

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.

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[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.

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 720 timing module multi-GNSS timing module is critical to system performance. If the overall RF system is not implemented correctly, the RES 720 timing module multi-GNSS timing module performance may be degraded.

The radio frequency (RF) input on the RES 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 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 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 maximum of 1.5 dB. Trimble 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, Trimble 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 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, Trimble recommends that you keep the copper layer on which the RES 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 720 timing module GPS module and the board to which it is mounted, and that there is no interference with features beneath the RES 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, Trimble recommends that the layer immediately below the one to which the RES 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 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.

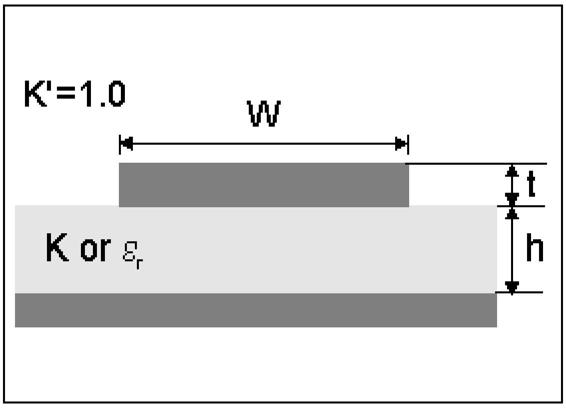
As a general guideline to prevent radiation and coupling, it helps to think of voltages and currents as electrical and magnetic fields. The electric field forms between a positive and negative charge. The magnetic field forms around a trace with current flow. You can minimize the radiation by keeping 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



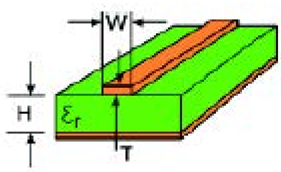
Ground plane design recommendation

Use a complete ground plane immediately under the PCB layer on which the RES 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)



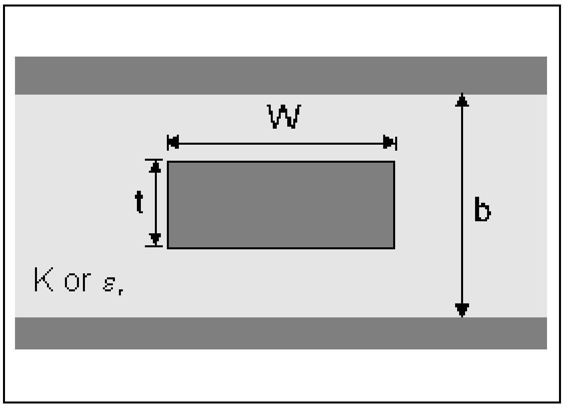
The following table shows typical track widths for an FR4 material PCB substrate (permittivity εr of 4.6 at 1.5 GHz) and different PCB thickness. The thickness of the top layer is assumed as being one ounce copper. If using a multi-layer PCB, the thickness is the distance from the signal track to the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

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

Microstrip design recommendation

Trimble 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, Trimble 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 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 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 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

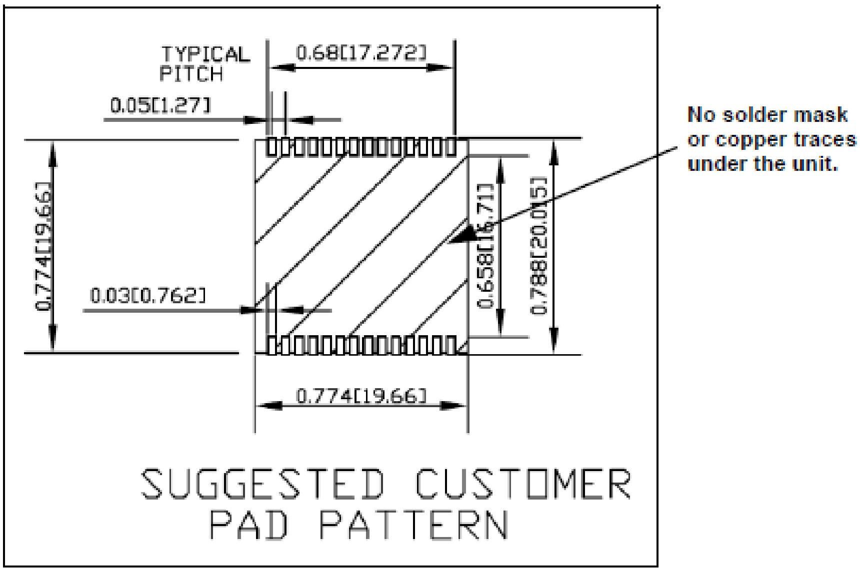
Soldering information

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, Trimble recommends a 4 Mil toe extension on the stencil.

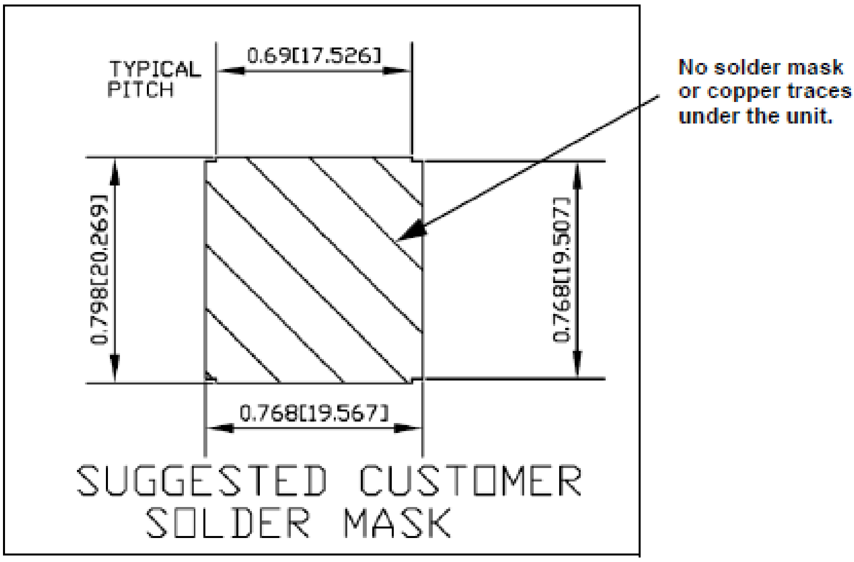
> **NOTE –** All units shown are in millimeters.

The required user pad pattern is shown below.



Solder mask

When soldering the RES 720 timing module multi-GNSS timing module to a PCB, keep an open cavity underneath the RES 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 720 timing module multi-GNSS timing module itself is not hermetically sealed. Trimble 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.

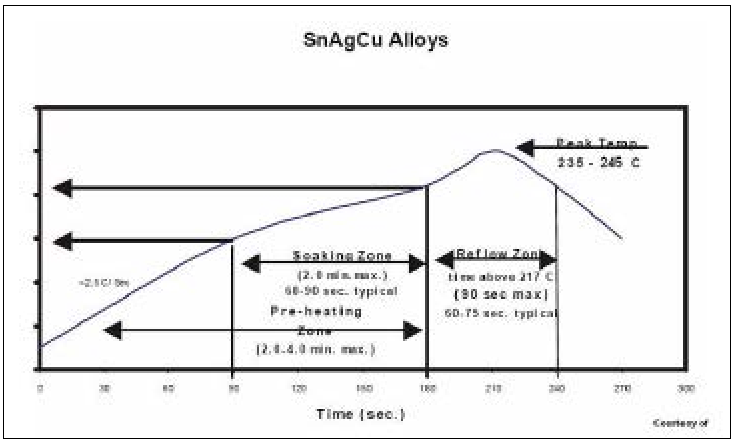
Solder reflow

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 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 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 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 720 timing module module is 220 °C, which means the solder will reflow during the assembly process on the host PCB, even with the Trimble recommended temperature profile. To prevent the module falling off the host PCB during soldering, and to prevent the shield falling off the RES 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 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 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 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

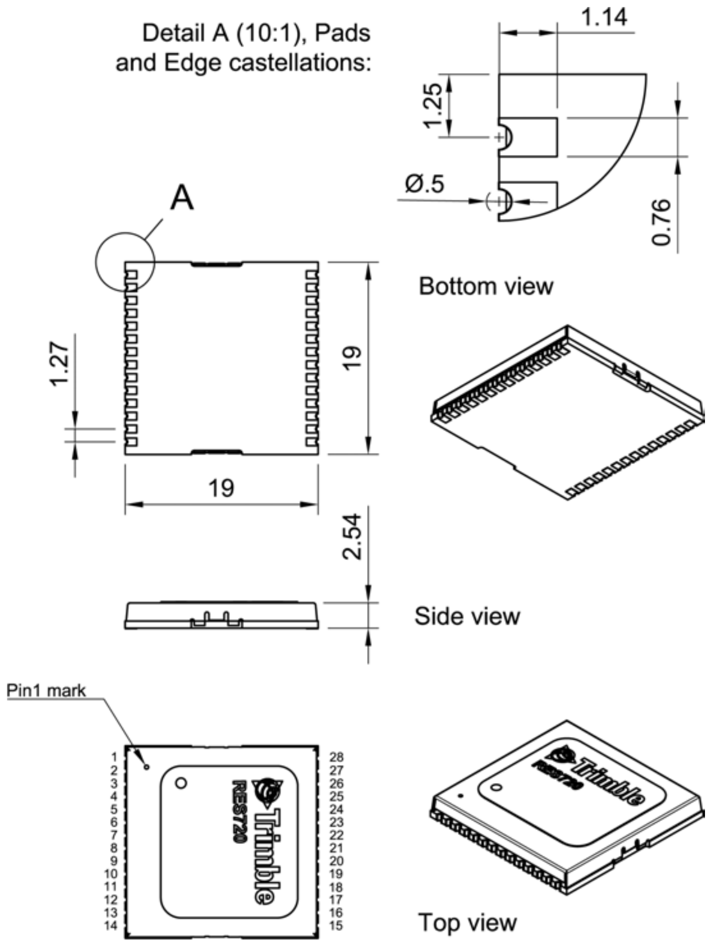
The RES 720 timing module timing module can withstand one rework cycle. The module can heat up to the reflow temperature to precede the rework. Never remove the metal shield and rework on the module itself.

Conformal coating

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

Mechanical Outline Drawing

Below is the RES 720 timing module footprint. All dimensions are in mm.



Below is the RES 720 timing module visual appearance.

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, which has a relatively unobstructed view of the horizon.
- Install the GNSS antenna vertically to the earth.
- Dense wood, concrete 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 ten 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 GPS operation

Start-up

- When the RES 720 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 RES 720 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 fixes the self-survey is complete.
- The position is saved to memory.
- At that time, the timing module automatically switches to overdetermined (OD) mode.

Satellite masks

- The RES 720 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	5°	Satellite elevation above the horizon
CN0	30	Signal strength
PDOP	6	Self-survey only

Elevation mask

- Satellites below 5° 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.

CN0 mask

- If the RES 720 timing module has a clear view of the sky (outdoor antenna placement), a CN0 mask of 35 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).

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 GNSS receiver can produce a reliable PPS by:

- making sure the received signal strength is adequate.
- determinings that the GNSS receiver completes the self-survey.
- ensuring the position has been stored.
- determining that the GNSS receiver 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 GNSS receiver.
3. Monitor the **0xA3-11** packet, byte 6. See Receiver Status (0xA3-11), page 136.
    - 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), page 134.
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

Action	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 added 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 15 minutes 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 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)			

Action	Yes	No	Comment
Bit 0 - Not tracking satellites			Check for adequate view of the sky.
Bit 1 - PPS bad			If not zero, then investigate presence of other alarms and RF signal quality.
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 - Jamming			Check for nearby source of jamming signal (radar, microwave etc).
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.

4

RES/ICM 720 on a Carrier Board

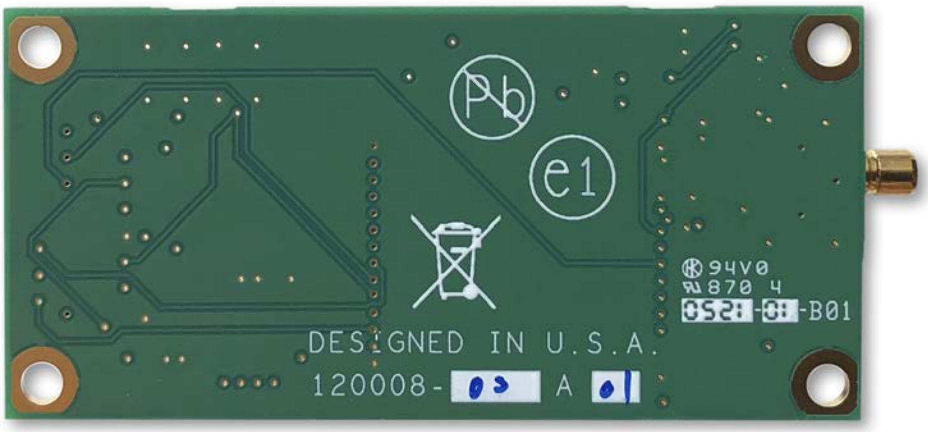
The RES 720 and ICM 720 timing modules are available on a carrier board with connectors for the RF antenna, power supply, and I/O signals.

RES 720 carrier board visual appearance

The following photos show the visual appearance of the RES 720 carrier board from the top-side (component side) and the bottom-side (non-component side). The RES 720 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.

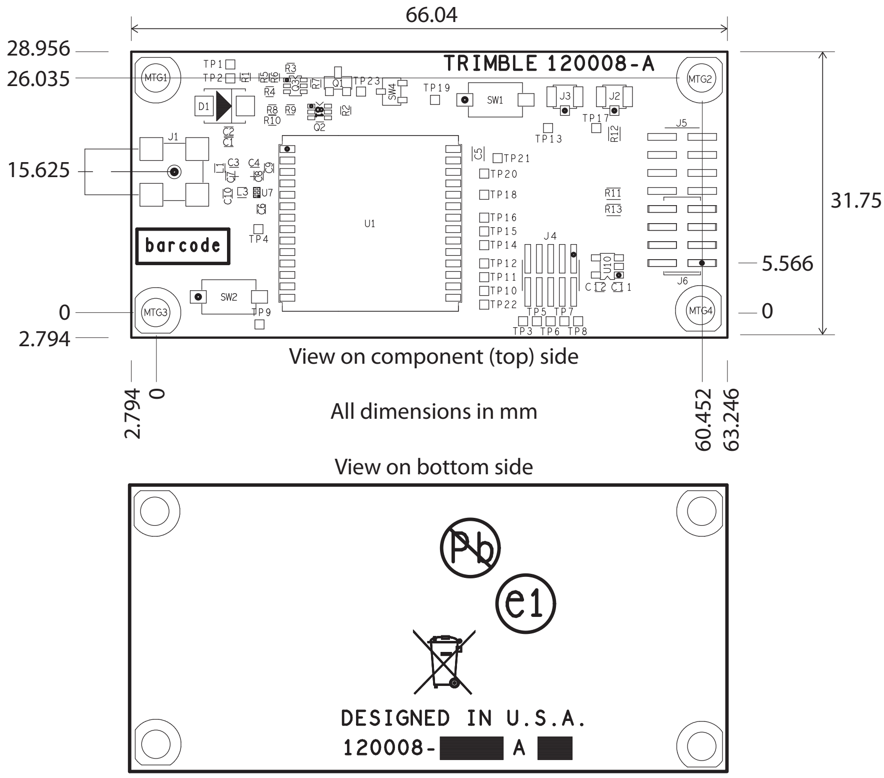
Carrier board top side:

Carrier board bottom side:



Mechanical specifications

The drawing below shows the mechanical dimensions of the RES 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 RES 720 PCB is an SMB right angle receptacle. The contact area of this connector is gold-plated.

Digital IO/Power connector

The RES 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	Reserved, do not connect	Reserved
5	RXDA	Port A receive, CMOS 3.3 V
6	1PPS	One pulse-per-second, CMOS 3.3 V
7	RXDB	Port A 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
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 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 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 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.

Trimble 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 RES720 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 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 Trimble 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.

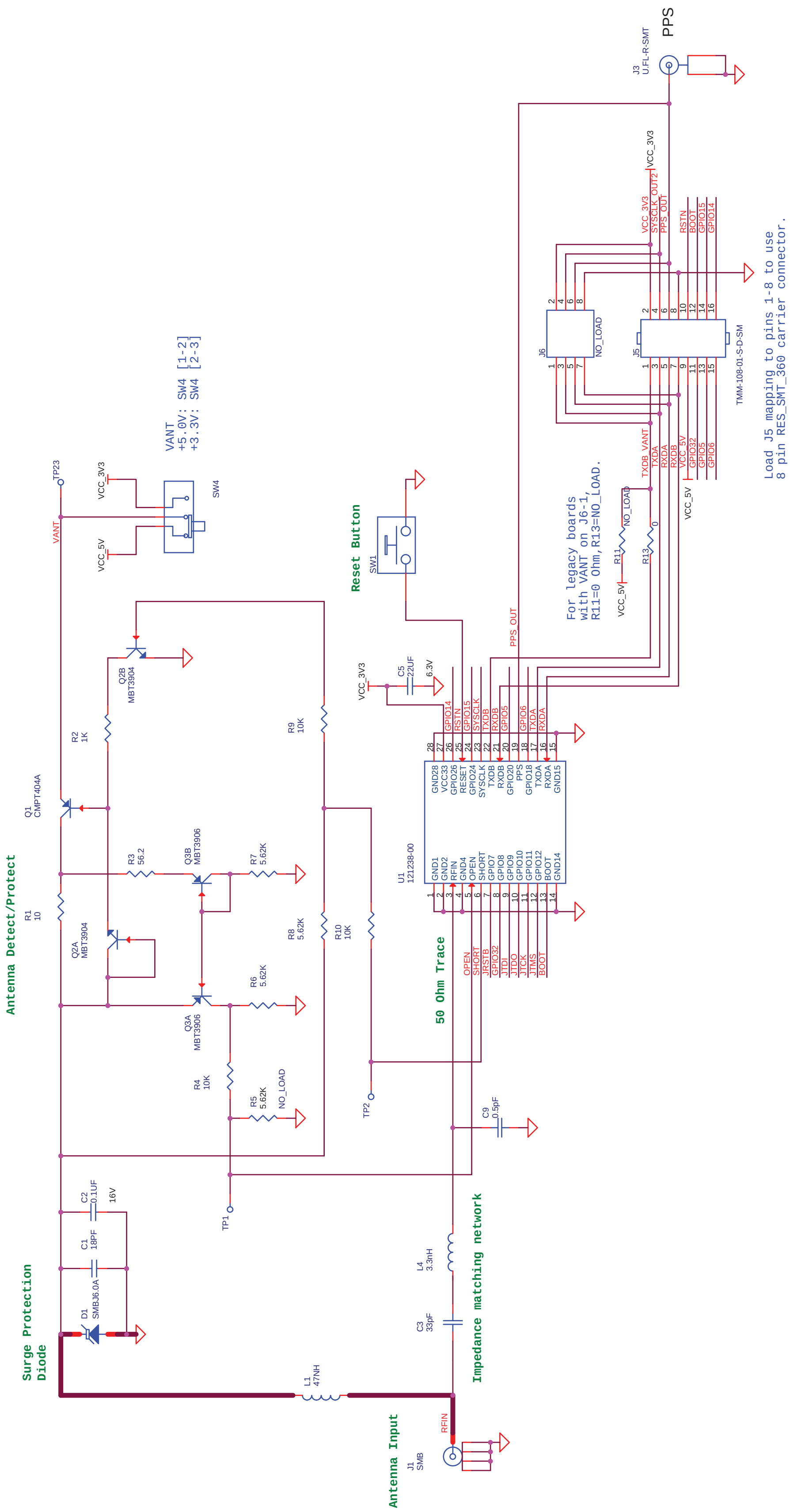
Use conductive metal standoffs for providing a good chassis ground connection from the GND vias to the chassis ground of the host system for surge protection.

Circuit diagram

The following picture shows the main circuit diagram of the RES 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 Trimble-internal purposes.

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


PPS
J3
U.FL-R-SMT
VCC_3V3
Load J5 mapping to pins 1-8 to use
8 pin RES_SMT_360 carrier connector.
TMM-108-01-S-D-SM
For legacy boards
with VANT on J6-1,
R11=0 Ohm,R13=NO_LOAD.
VANT
+5.0V: SW4 [1-2]
+3.3V: SW4 [2-3]
Reset Button
SW1
SW4
Antenna Detect/Protect
Q1
CMPT404A
50 Ohm Trace
U1
121238-00
Surge Protection
Diode
Impedance matching network
Antenna Input
J1
SMB

Antenna OPEN/SHORT detection

The circuit diagram shows the short circuit protection and OPEN/SHORT detection circuit of the RES 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 RES 720 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, Trimble recommends using either antennas with lower operating current (preferred), or antennas with wider supply voltage range.

Surge protection

The RF-input of the RES 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 RES 720 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. Trimble recommends using a fast first-level lightning protector that has 15 or 20 V clamping voltage.

Pulse-per-second (PPS)

The RES720 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
4	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 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

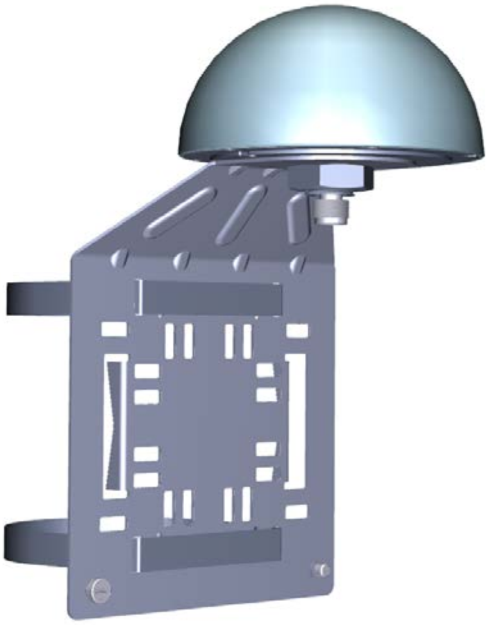
The antenna receives the GNSS satellite signals and passes them to the receiver. The GNSS signals are spread spectrum signals in the 1.5 GHz range and do not penetrate conductive materials. Therefore, the antenna must be located outdoors with a clear view of the sky.

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

> NOTE – The timing module can work at reduced performance with L1-only antennas but the full, specified performance is only achievable with an L1+L5 antenna. Trimble 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 Trimble active antenna includes a preamplifier that filters and amplifies the GNSS signals before delivery to the receiver.

Trimble recommends the Bullet™ 720 GPS antenna to use with the RES 720 timing module:



5

RES/ICM 720 Starter Kit

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

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
- 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 720module 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 720module 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 of ICM 720 module is only available on the connector of the ICM 720 carrier card. In order to access the SYSCLK output of the Starter Kit you need to open the UIM enclosure and run a wire to the SYSCLK pin of the I/O connector J2 of the ICM 720 carrier card.

> NOTE – The ICM 720 on carrier board product will have the SYSCLK on pin #4.

System requirements

Hardware

- The Trimble 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

- Trimble'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 Trimble'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 Trimble's website: https://timing.trimble.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.

6

Software

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

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.

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 are synchronized 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 by one second approximately every 18 to 24 months, usually 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 720 timing module can be configured to use one of the constellation combinations shown in the following table.

The table below shows the possible constellation options you can select.

Combination number	L1 GPS	L5 GPS	E1 Galileo	E5a Galileo	B1 BeiDou	B2a BeiDou	G1 GLONASS	L1 QZSS	L5 QZSS
1	√	√							
2							√		
3					√	√			
4			√	√					
5	√	√					√		
6	√	√			√	√			
7	√	√	√	√					
8	√	√						√	√
9	√	√	√	√	√	√	√		

NOTE – Each combination row number is a fixed set of tracking constellations. For example, in row 1, L1 GPS and L5 GPS are both selected; you cannot have L1 GPS only.

PPS and 10 MHz availability

Trimble 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. Trimble 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

Automatic operation

Automatic operation

When the RES 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, it performs a self-survey. After a number of valid position fixes, the self-survey is complete. At that time, the RES 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 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 Trimble Standard Interface Protocol, page 86.

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 2,000 position fixes.

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.

Using the default anti-jamming setting, 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/No), 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 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.
- Trimble takes into account component choice using low-noise, high-spec parts.
- Component layout
- PCB trace layout
- Grounding techniques

About the software algorithms

- TRAIM (Time-Receiver Autonomous Integrity Monitoring) is used in OD mode using stringent thresholds to improve anti-jamming detection and mitigation.
- TRAIM 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. Trimble measures from the median pseudorange value instead of the last value.

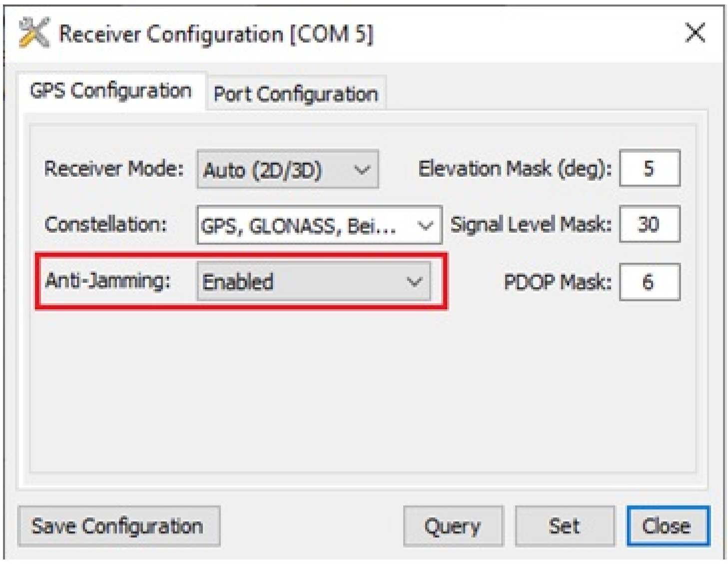
The RES 720 timing module has anti-jamming enabled as a default configuration; ***it cannot be disabled***.

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 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.

To enable or disable anti-jamming, refer to GNSS Configuration (0x91-01), page 95. It also can be set in the VTS tool as shown:



Cable delay compensation

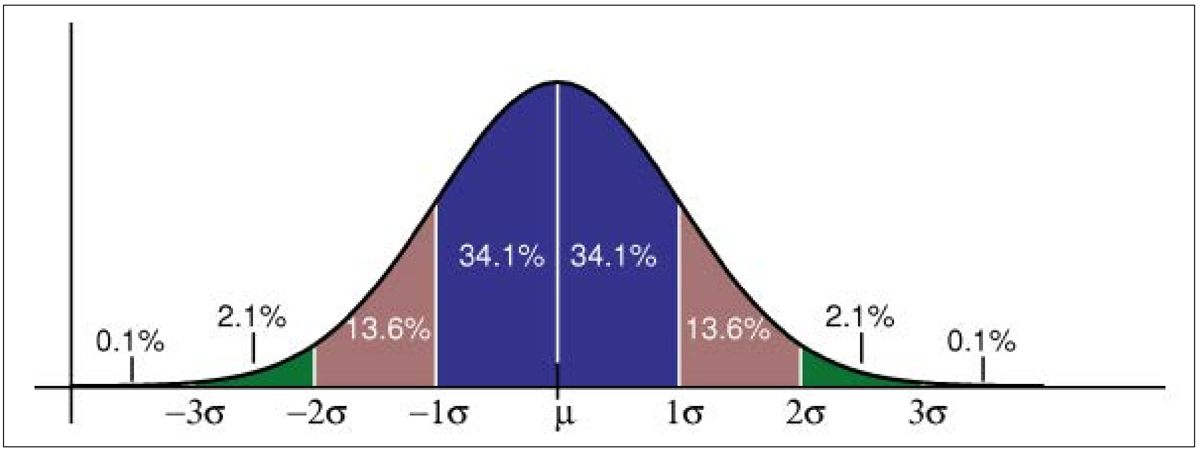
The default configuration of the timing module provides optimal timing accuracy. The only item under user- or host-control that can affect the receiver's absolute PPS accuracy is the delay introduced by the antenna cable. For long cable runs, this delay can be significant. TSIP packet 0x91-01 sets the 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.

Timing module performance

The time reference can be configured by the user with the 0x91-03 TSIP command. See Timing Configuration (0x91-03), page 102.

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 Trimble'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, ZD message

- Ensure that the almanac is complete and current 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 122) or NMEA packet ZDA+ZD 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 102) or the falling edge.
- If using TSIP, capture the time from TSIP packet 0xA1-00 (see page 122). If using NMEA, capture the time from NMEA packet ZDA (see page 156) or ZD (see page 160).
- 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 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 memory (flash) to be retained during loss of power and through resets with TSIP command 0x92-00 (see page 112). 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 0x92-00 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 0x92-00 to save the settings in nonvolatile memory (flash). Check for the TSIP packet 0x92-00 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 RES 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 page 100).

Protocols

The following protocols are available:

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

[1] Requires use of Trimble-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]	921 kbps	8	None	1	None
	RXDB	21	Not set[1]	921 kbps	8	None	1	None

[1] Use the TSIP 0x91-00 command (see page 92) on Port A to configure protocol for Port B, and then use the TSIP 0x91-02 command (see page 100) to save the configuration.

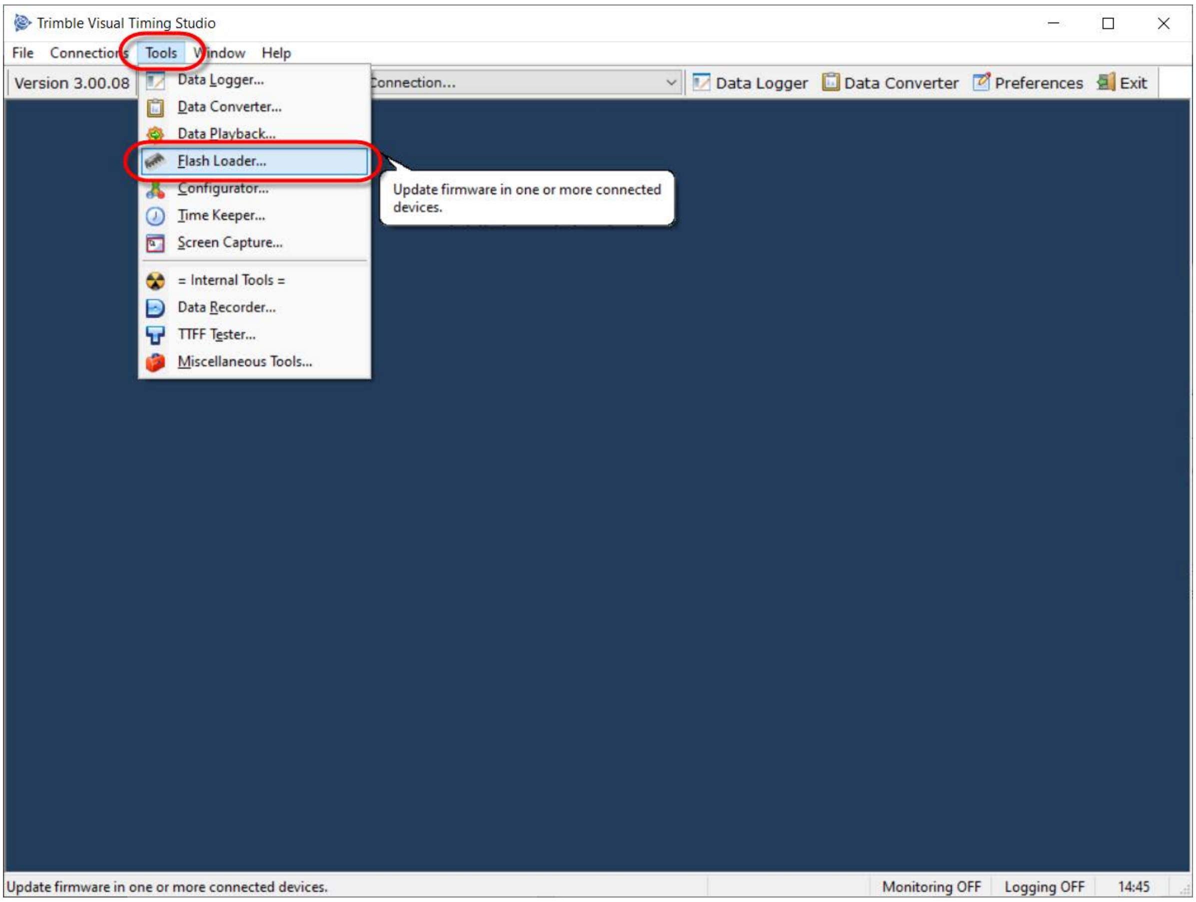
- Baud rate, data bits, parity, and stop bits are user configurable.
- Flow control is not available on the serial ports.

Updating the firmware

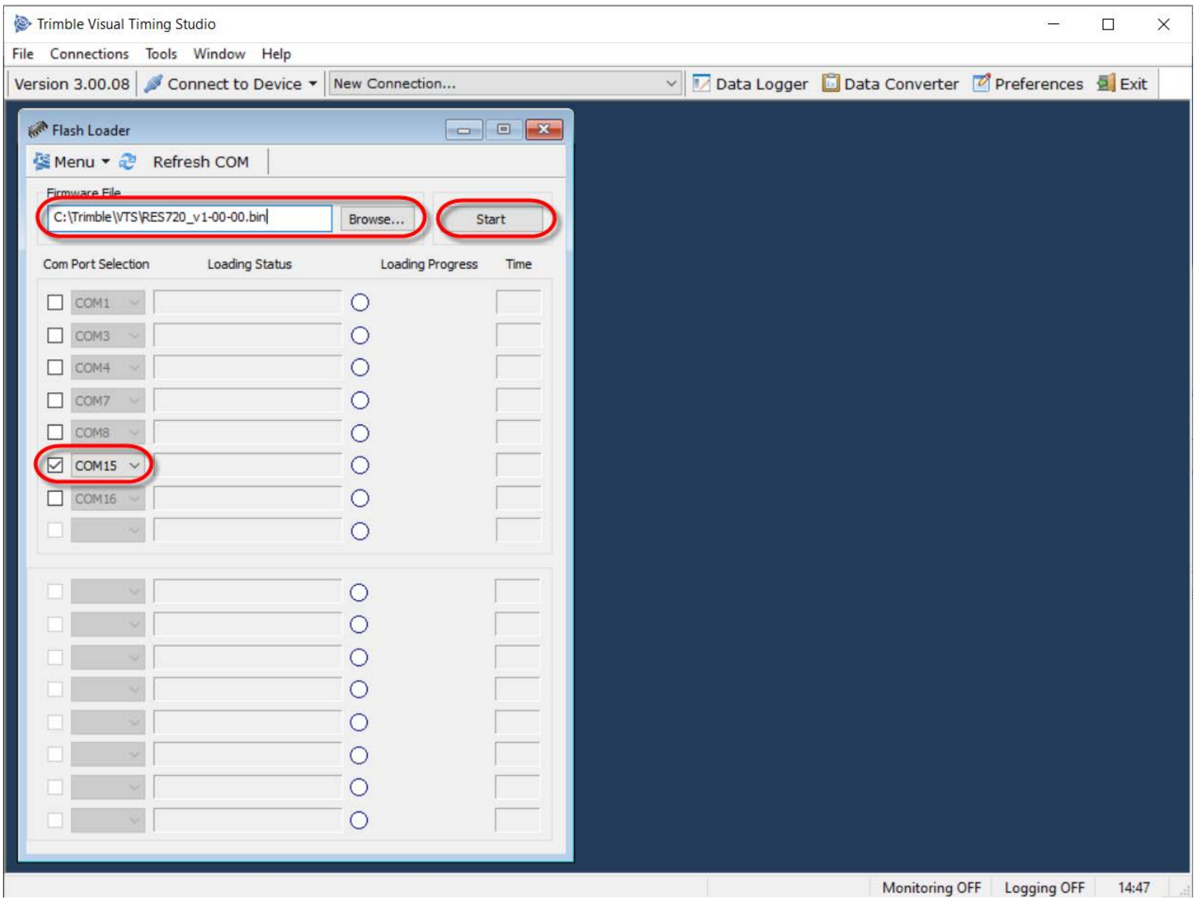
Use the VTS Flashloader tool to load firmware to the RES 720 timing module.

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 Trimble Visual Timing Studio.
2. From the **Tools** menu, select **Flash Loader**:



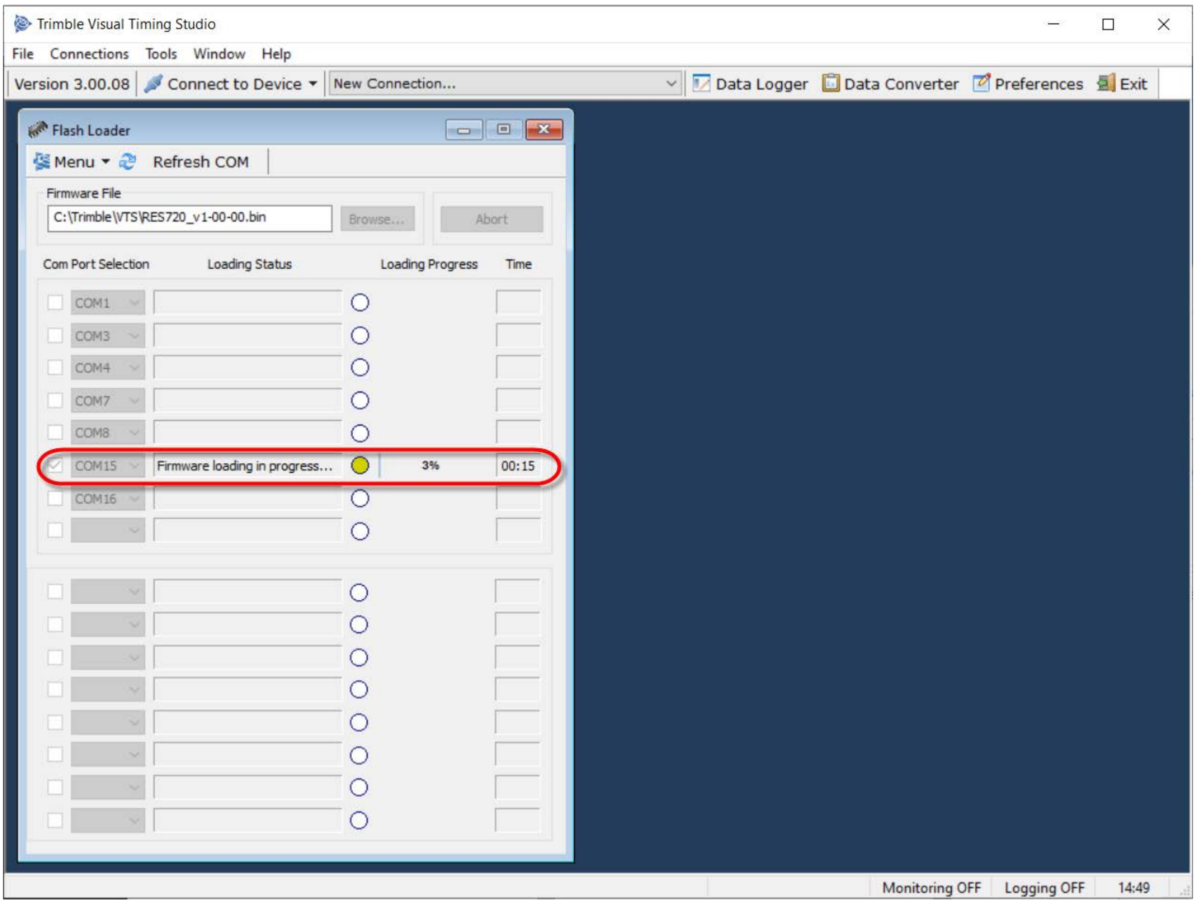
The following dialog appears:



3. Select the check box of the COM port that is connected to port A of the RES 720 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:

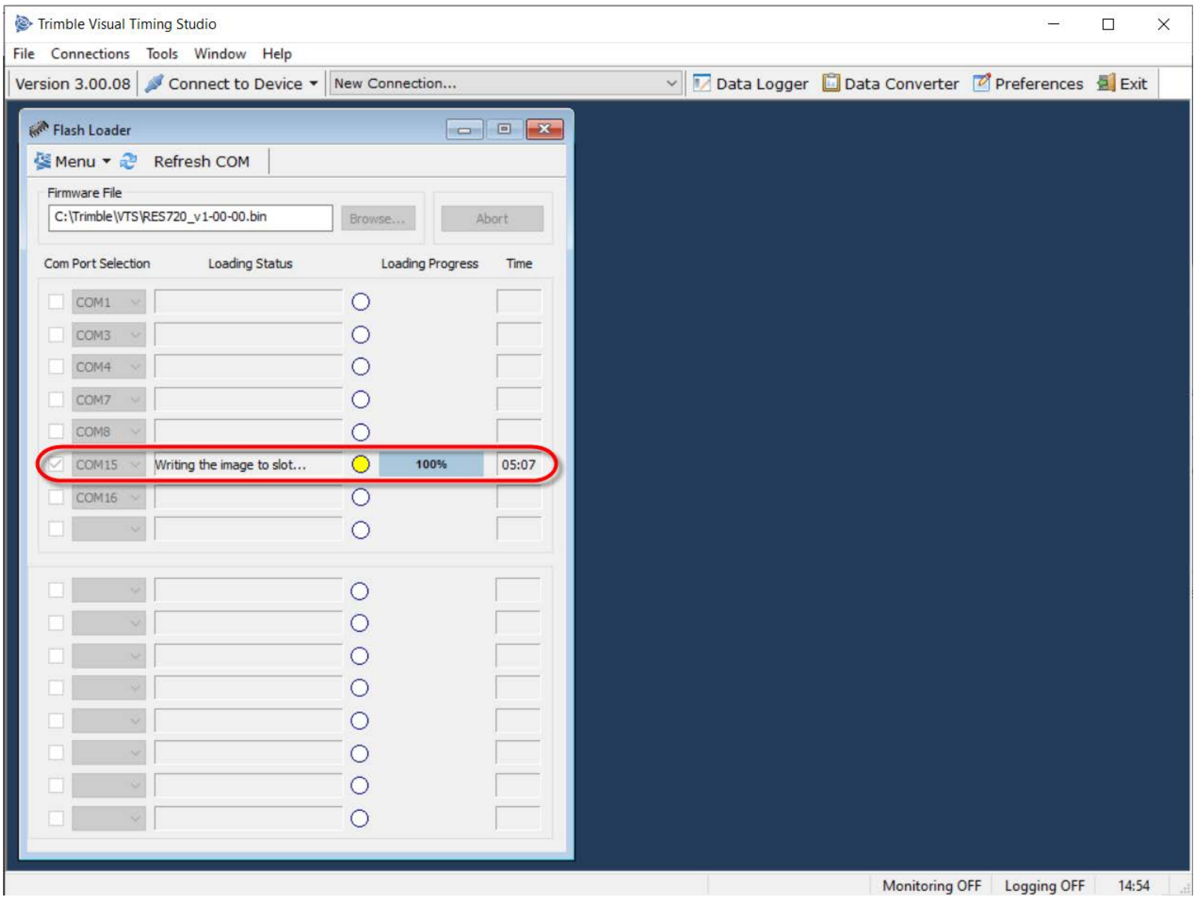


You will see the loading status, the loading progress and the time elapsed in the respective fields.

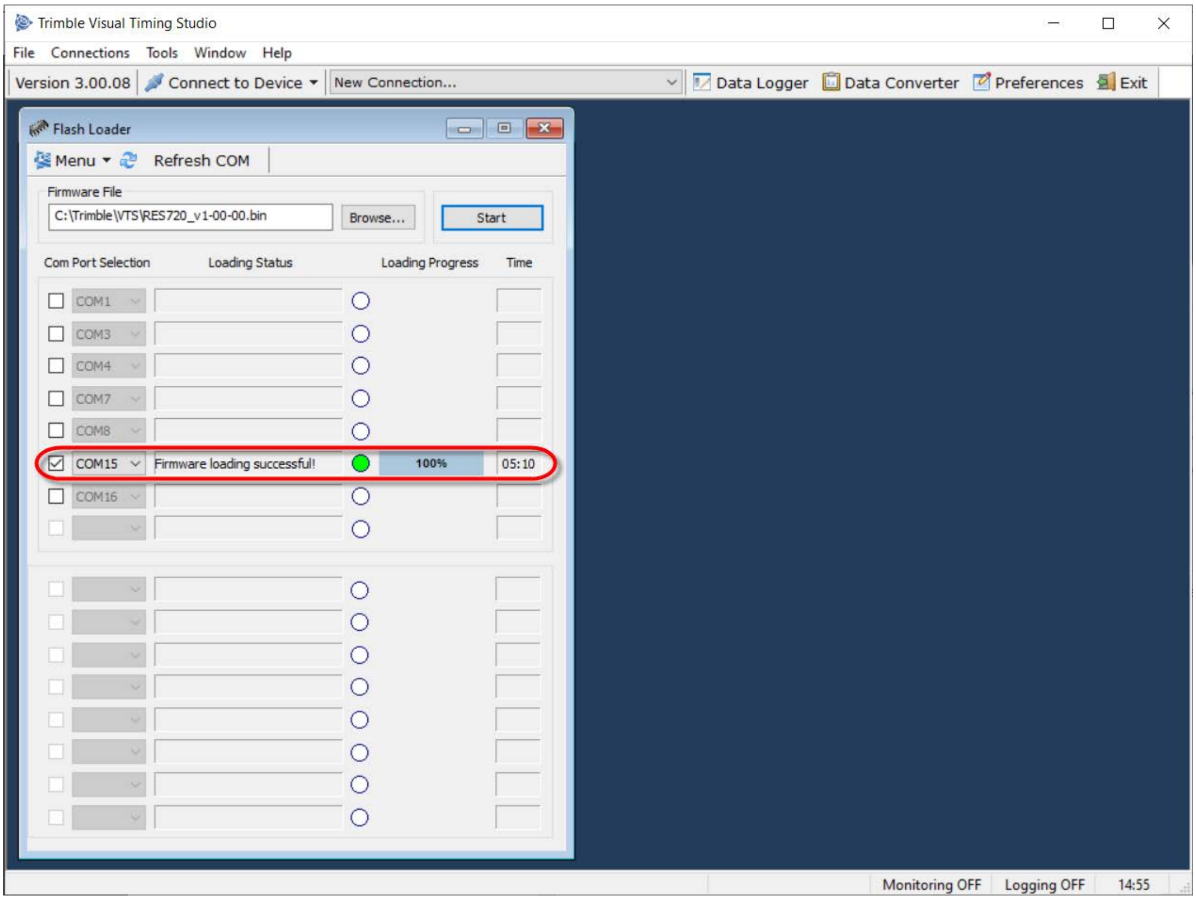
The receiver continues to operate normally during the file upload process. The firmware file is stored in a separate memory area and is not used before the upload process is 100% complete and successful.

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 720 timing module. Ensure that you are seeing the new firmware version in the software version information fields in the Monitor window.

Trimble Standard Interface Protocol

The RES 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.

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

Description	Value
Start of packet	0x10
Packet ID	0x90
Subpacket ID	0x00
Length (16-bit)	0x0003
Mode	0x00
Data	0x04
Checksum	0x12
End of packet 1	0x10
End of packet 2	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.

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

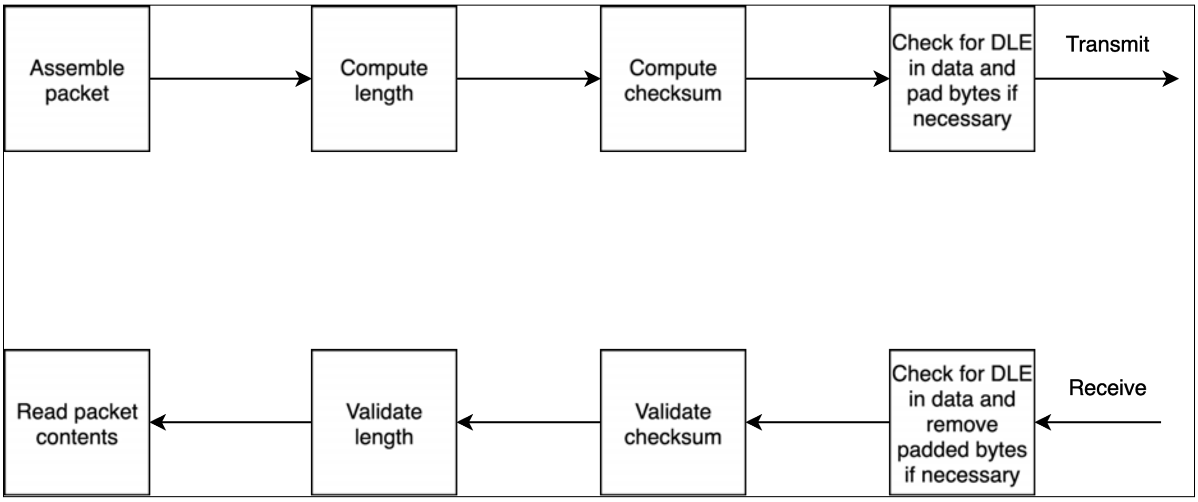
Mode for each command will be either one of Query (0x00) or Set (0x01) or Response (0x02).

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
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

Value	Name	Description
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	
0xD0	Debug and logging	

Protocol Version (0x90-00)

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

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

Byte	Item	Type	Value	Description
6	NMEA Major Version	UINT8	Any	NMEA Major Version
7	NMEA Minor Version	UINT8	Any	NMEA Minor Version
8	TSIP Version	UINT8	Any	Trimble TSIP Version
9	Trimble NMEA Version	UINT8	Any	Trimble 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

Query:

10 90 00 00 02 00 92 10 03

Response:

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

Receiver Version Information (0x90-01)

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

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
11-12	Year	INT16	Any	Firmware Build Year
13-14	Hardware ID	UINT16		Hardware code

Byte	Item	Type	Value	Description
15	Length of Product Name	UINT8	Any	The length of product name (L1)
16 (= 15+L1)	Product Name	UINT8	String	Product name in ASCII
17 (= 16 + 1)	Checksum	UINT8	Any	
18	Delimiter 1	UINT8	0x10	End of packet 1
19	Delimiter 2	UINT8	0x03	End of packet 2

Query:

10 90 01 00 02 00 93 10 03

Response:

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

Port Configuration (0x91-00)

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

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
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

Byte	Item	Type	Value	Description
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

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

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	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)

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

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 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 - IRNSS L5 (not supported, for future use) 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	

Byte	Item	Type	Value	Description
32	Checksum	UINT8	Any	
33	Delimiter 1	UINT8	0x10	End of packet 1
34	Delimiter 2	UINT8	0x03	End of packet 2

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 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 - IRNSS L5 (not supported, for future use) Bit 27 - Reserved Bit 28 - Reserved Bits 29-31 - Reserved Set bits indicate enabled constellation and frequency

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
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:
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)

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

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

Timing Configuration (0x91-03)

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

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
6	Time base	UINT8	Any	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)

Byte	Item	Type	Value	Description
7	PPS base	UINT8	Any	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)
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
9–12	Reserved	UINT32	Any	
13–14	PPS Width	UINT16	Any	In milliseconds
15–22	PPS offset	DOUBLE	Any	In seconds
23	Checksum	UINT8	Any	
24	Delimiter 1	UINT8	0x10	End of packet 1
25	Delimiter 2	UINT8	0x03	End of packet 2

Set example:

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

Response

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

Byte	Item	Type	Value	Description
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 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 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
9–12	Reserved	UINT32	Any	
13–14	PPS Width	UINT16	Any	In milliseconds
15–22	PPS offset	DOUBLE	Any	In seconds
23	Checksum	UINT8	Any	
24	Delimiter 1	UINT8	0x10	End of packet 1

Byte	Item	Type	Value	Description
25	Delimiter 2	UINT8	0x03	End of packet 2

Response to query/set:

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)

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:

10 91 04 00 02 00 97 10 03

Response:

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

Set, enable survey, save position, 200 fixes, 40m horiz, 40m vert:

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 to set:

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

Receiver Configuration (0x91-05)

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: 0xA1-02 Frequency information 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

Byte	Item	Type	Value	Description
2	Subpacket ID	UINT8	0x05	Subpacket ID
3–4	Length	UINT16	Any	Total length of mode + data + checksum
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 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	
23	Checksum	UINT8	Any	
23	Delimiter 1	UINT8	0x10	End of packet 1
24	Delimiter 2	UINT8	0x03	End of packet 2

Receiver Reset (0x92-00)

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)

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

Byte	Item	Type	Value	Description
9	Delimiter 2	UINT8	0x03	End of packet 2

NOTE – This packet is sent by the unit on every startup and can also be queried.

Production Information (0x93)

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
31	Build Hour	UINT8	0–23	Hour of board build day

Byte	Item	Type	Value	Description
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)

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 4 MB.

Template

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	0-2	1: Set 2: Response
6	Command	UINT8	Any	0x00: Firmware Request 0x01: Program Slot 0x02: Image Checksum
7	Checksum	UINT8	Any	
8	Delimiter 1	UINT8	0x10	End of packet 1
9	Delimiter 2	UINT8	0x03	End of packet 2

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

Byte	Item	Type	Value	Description
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

Byte	Item	Type	Value	Description
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

Slot Erase (For internal testing only/ Not operational)

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	0x03: Slot Erase
7	Module	UINT8	0-1	0: P5 1: T5
8	Slot	UINT8	0-1	Slot which needs to be erased
9	Checksum	UINT8	Any	
10	Delimiter 1	UINT8	0x10	End of packet 1
11	Delimiter 2	UINT8	0x03	End of packet 2

10 A0 00 00 04 01 03 00 00 0C 10 03

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 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

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.

Timing Information (0xA1-00)

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

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
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

Byte	Item	Type	Value	Description
17–18	Year	UINT16	Any	Four digits of year
19	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)
20	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)
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	
28–31	Bias	SINGLE	Any	In seconds
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

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

Frequency Information (0xA1-02)

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

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
6-9	DAC Voltage	Single	Any	DAC voltage applied to OCXO
10-11	DAC Value	UINT16	Any	DAC value
12	Holdover status	UINT8	Any	
13-16	Holdover Time	UINT32	Any	In second
17-20	Temperature	SINGLE	Any	In degree Celsius
21	Checksum	UINT8	Any	
22	Delimiter 1	UINT8	0x10	End of packet 1
23	Delimiter 2	UINT8	0x03	End of packet 2

Position Information (0xA1-11)

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
7	Checksum	UINT8	Any	
8	Delimiter 1	UINT8	0x10	End of packet 1
9	Delimiter 2	UINT8	0x03	End of packet 2

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

Byte	Item	Type	Value	Description
32-35	X Velocity/ East Velocity	SINGLE	Any	Both in meters/second East velocity: + For east, - for west
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

Byte	Item	Type	Value	Description
56	Checksum	UINT8	Any	
57	Delimiter 1	UINT8	0x10	End of packet 1
58	Delimiter 2	UINT8	0x03	End of packet 2

Example response:

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)

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

Byte	Item	Type	Value	Description
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 - IRNSS L5 (Not supported, for future use) 27 - 255 - Reserved
7	SV PRN	UINT8	0-32	0 - All satellites in selected SV type 1-32 - SV PRN
8	Checksum	UINT8	Any	
9	Delimiter 1	UINT8	0x10	End of packet 1
10	Delimiter 2	UINT8	0x03	End of packet 2

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

Byte	Item	Type	Value	Description
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
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 - IRNSS L5 (Not supported, for future use) 27 - 255 - Reserved
8	SV PRN	UINT8	Any	1–99 - 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
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.

System Alarms (0xA3-00)

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

Example query:

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 - Bit 6 - Reserved Bit 7 - Spoofing/multipath Bit 8 - Jamming
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

Example response:

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)

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

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	
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
29-32	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

Example response:
10 A3 11 00 1D 02 06 FF 64 3F 57 0A 3D 3E DC 28 F6 3F 38 51 EC 3E D1 EB 85 42 07 9D 85 FF FF FF FF 35 10 03

Error Codes (0xA3-21)

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)
9	Checksum	UINT8	Any	
10	Delimiter 1	UINT8	0x10	End of packet 1
11	Delimiter 2	UINT8	0x03	End of packet 2

AGNSS (0xA4)

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	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, 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

Debug Output type packet (0xD0-00)

Query

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0xD0	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

Set

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0xD0	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	Debug output type	UINT8	0, 1	Which debug output type. Setting to any value other than 'None' forces the output baud to that shown: 0: None 1: Trimble style debug, baud 921600 2: Raw GNSS binary debug, baud 921600 3: Encapsulated GNSS binary data, baud 921600 4: Raw GNSS binary syslog data, baud 3 Mb 5: Encapsulated GNSS binary syslog data (future), baud 3Mb
7	Checksum	UINT8	Any	

Byte	Item	Type	Value	Description
8	Delimiter 1	UINT8	0x10	End of packet 1
9	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	0xD0	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	Debug output type	UINT8	0, 1	Which debug output type: 0: None 1: Trimble style ASCII debug 2: Raw GNSS binary debug 3: Encapsulated GNSS binary data 4: Raw GNSS binary syslog data 5: Encapsulated GNSS binary syslog data
7	Checksum	UINT8	Any	
8	Delimiter 1	UINT8	0x10	End of packet 1
9	Delimiter 2	UINT8	0x03	End of packet 2

Trimble Debug Cfg packet (0xD0-01)

Query

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0xD0	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	Debug Type	UINT8	Any	Which debug type, 0xFF for all. Response packet generated for each debug type.
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	0xD0	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
6	Debug Type	UINT8	Any	Which debug type, 0xFF. Response packet generated for each debug type.
7	Debug level	UINT8	Any	Debug level for the type: 0: No debug output 1–6: Log level 1–6
8	Checksum	UINT8	Any	

Byte	Item	Type	Value	Description
9	Delimiter 1	UINT8	0x10	End of packet 1
10	Delimiter 2	UINT8	0x03	End of packet 2

Response, separate response for each debug type requested/set

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0xD0	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	Debug Type	UINT8	Any	Which debug type. Will be 0xFF to indicate the end of the list if the 0xFF Debug Type was specified in the request.
7	Debug level	UINT8	Any	Debug level for the type: 0: No debug output 1–6: Log level 1–6
8	Checksum	UINT8	Any	
9	Delimiter 1	UINT8	0x10	End of packet 1
10	Delimiter 2	UINT8	0x03	End of packet 2

Trimble Raw GNSS Debug Output packet (0xD0-40)

Query not available. This is an auto-generated packet only that is enabled with the Encapsulated GNSS binary data option in 0xD0-00.

Response

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0xD0	Packet ID
2	Subpacket ID	UINT8	0x40	Subpacket ID
3-4	Length	UINT16	Any	Total length of mode + data + checksum
5	Mode	UINT8	2	2: Response
6-(6+Len-2) (=X)	Binary GNSS Data	UINT8	any	This is the raw GNSS data sent by the receiver
X+1	Checksum	UINT8	Any	
X+2	Delimiter 1	UINT8	0x10	End of packet 1
X+3	Delimiter 2	UINT8	0x03	End of packet 2

Trimble Raw GNSS Debug Output packet (0xD0-41)

Query not available. This is an auto-generated packet only that is enabled with the Encapsulated GNSS binary data option in 0xD0-00.

Response

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0xD0	Packet ID
2	Subpacket ID	UINT8	0x40	Subpacket ID
3–4	Length	UINT16	Any	Total length of mode + data + checksum
5	Mode	UINT8	2	2: Response
6-(6+Len-2) (=X)	Binary GNSS data	UINT8	Any	This is the raw GNSS data sent by the receiver
X+1	Checksum	UINT8	Any	
X+2	Delimiter 1	UINT8	0x10	End of packet 1
X+3	Delimiter 2	UINT8	0x03	End of packet 2

Trimble Debug Output packet (0xD0-40)

Query not available. This is an auto-generated packet only that is enabled when Trimble debug data is output on a port with TSIP enabled.

Response

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0xD0	Packet ID
2	Subpacket ID	UINT8	0x40	Subpacket ID
3–4	Length	UINT16	Any	Total length of mode + data + checksum
5	Mode	UINT8	2	2: Response
6-(6+Len-2) (=X)	Binary GNSS data	UINT8	Any	Raw Trimble debug data. Binary or ASCII data.
X+1	Checksum	UINT8	Any	
X+2	Delimiter 1	UINT8	0x10	End of packet 1
X+3	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 720 timing module.

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.

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 Trimble:

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.

Type	Symbol	Definition
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		
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 RES 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 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 0x7A), and this setting has been stored in flash memory (using Packet 0x8E-26), 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 timing module proprietary NMEA messages

Message	Description
CR	Query or set GPS receiver configuration information.
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>

```
$GPGGA,hhmmss.sss,llll.lll,a,nnnnn.nnnnnn,b,t,uu,
v.v,w.w,M,x.x,M,,*hh <CR><LF>
```

Field	Description
1	UTC of Position
2, 3	Latitude, N (North) or S (South)
4, 5	Longitude, E (East) or W (West)
6	GPS Quality Indicator: 0 = No GPS, 1 = GPS
7	Number of satellites in use
8	Horizontal Dilution of Precision (HDOP)
9, 10	Antenna Altitude in Meters, M = Meters
11, 12	Geoidal Separation in Meters, M=Meters. Geoidal separation is the difference between the WGS-84 earth ellipsoid and mean-sea-level.
13	Age of Differential GPS Data. Time in seconds since the last Type 1 or 9 update
14	Differential Reference Station ID (0000 to 1023)
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>

```
$GPGLL,llll.llllll,a,yyyyy.yyyyyy,b,hhmmss.sss,c,d*hh <CR>
<LF>
```

Field	Description
1, 2	Latitude, N (North) or S (South)
3, 4	Longitude, E (East) or W (West)
5	UTC of Position
6	Status, A=Valid, V=Invalid
7	Mode Indicator: Mode A=Autonomous Mode D=Differential Mode E=Estimated (dead reckoning) Mode M=Manual Input Mode S=Simulated Mode N=Data Not Valid
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>

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

Where *id* is GP, GL or GN, dependent on if the sentence contains GPS, GLONASS or both constellations respectively.

Field	Description
m	Mode: M = Manual, A = Automatic. In manual mode, the receiver is forced to operate in either 2D or 3D mode. In automatic mode, the receiver is allowed to switch between 2D and 3D modes subject to the PDOP and satellite masks.
s	Current Mode: 1 = fix not available, 2 = 2D, 3 = 3D
n1 ... n12	Satellite ID's used in solution (position fix), null if unused. Refer to GNSS identification table, page 162.
x.x	Position dilution of precision (PDOP)
x.x	Horizontal dilution of precision (HDOP)

Field	Description
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>

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

Where *id* is GP or GL, dependent on if the sentence contains GPS or GLONASS satellites.

Field	Description
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, page 162
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, page 162
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.

```
$GPRMC,h-
hmmss.ss,a,llll.lllll,b,n-
nnnn.nnnnnn,c,x.xx,yyy,ddmmyy,,,d*hh<CR><LF>
```

Field	Description
1	UTC of Position Fix.
2	Status: A – Valid, V - Navigation receiver warning
3, 4	Latitude, N (North) or S (South)
5. 6	Longitude, E (East) or W (West)
7	Speed over the ground (SOG) in knots
8	Track made good in degrees true.
9	Date: dd/mm/yy 1
10, 11	Magnetic variation in degrees, E = East / W= West
12	Position System Mode Indicator A - Autonomous D - Differential E - Estimated (Dead Reckoning) M - Manual Input S - Simulation Mode N - Data Not Valid
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).

```
$GPVTG,xxx,T,,M,y.yyy,N,z.zzz,K,a*hh<CR><LF>
```

Field	Description
1,2	Track made good in degrees true.
3,4	Track made good in degrees magnetic.
5,6	Speed over the ground (SOG) in knots
7,8	Speed over the ground (SOG) in kilometer per hour
9	Position System Mode Indicator A - Autonomous D - Differential E - Estimated (Dead Reckoning) M - Manual Input S - Simulation Mode N - Data Not Valid
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. It can also be queried using the command $GPGPQ,ZDA*hh<CR><LF>

```
$GPZDA,hhmmss.sss,dd,mm,yyyy,,*hh<CR><LF>
```

Field	Description
1	UTC
2	Day (01 to 31)
3	Month (01 to 12)
4	Year
5	Unused
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 NMEA receiver configuration information.

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

Field	Description
a	Mode: Q – Query S – Set R – Response
x.x	Signal level mask in dB-Hz (default = 0 dB-Hz).
x.x	Elevation mask in degrees (default = degrees).
x.x	Reserved
x.x	Reserved
x.x	Reserved
A	Receiver Mode: 0 – automatic 7 – overdetermined clock
a	Reserved
A	Reserved
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 to query or Set sentence format is:

```
$PTNLRPT,xxxxxx,b,b,b,h,h*hh<CR><LF>
```

When the Set is issued, the first Response sentence is sent using the old parameters and the second response sentence is sent using the new parameters. If there is an error, an error response is sent. If there is no error, no additional response is sent.

Field	Description
a	Mode: Q – Query S – Set R – Response
xxxxxx	Baud rate (115200, 230400, 460800, 926100), Default baud rate is 115200
b	# of data bits (7 or 8)
b	Parity (N - none, O - odd, E - even)
b	# of stop bits (1 or 2)
h	Input protocol, hex value (bit 0: reserved, bit1: TSIP, bit2: NMEA, bit 3: Reserved). Bits can be combined to enable multiple input protocols. This field cannot be 0.
h	Output protocol, hex value (bit 0: reserved, bit1: TSIP, bit2: NMEA, bit 3: reserved). It is not recommended to combine multiple output protocols
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>
```

where a is S = Application firmware, H=Hardware information

The Response to query sentence format is:

```
$PTNLRaVR,b,c..c,xx.xx.xx,xx,xx,xxxx*hh<CR><LF>
```

Application firmware

Field	Description
a	Mode: Q - Query R – Response
b	Application firmware (S)
c..c	Receiver Name
xx	Major version
xx	Minor version
xx	Build version
xx	Month
xx	Day
xxxx	Year
hh	Checksum

Hardware version

Field	Description
a	Mode: Q - Query R – Response
b	Hardware information indicator (H)
c..c	Receiver name
xxxx	Hardware ID
xxxxxxx	Serial number
xx	Build month
xx	Build day
xxxx	Build year
xx	Build hour
hh	Checksum

ZD - Extended Time and Date

This message reports extended time and date information - UTC, day, month, year, local time zone and UTC to GPS leap second.

Setting the data is not supported.

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

Query format:

```
$PTNLQZD*hh<CR><LF>
```

Response to query format:

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

Field	Description
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
ls	Current leap second offset between GPS and UTC time
lsp	Pending leap second. If non-zero (+/- 1) then a leap second is scheduled to occur at the end of the day. The sign indicates the direction of the leap second.
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

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

System	Satellite ID	Signal ID	Signal channel
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
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

7

TSIPv1 Client API Library

7

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.

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

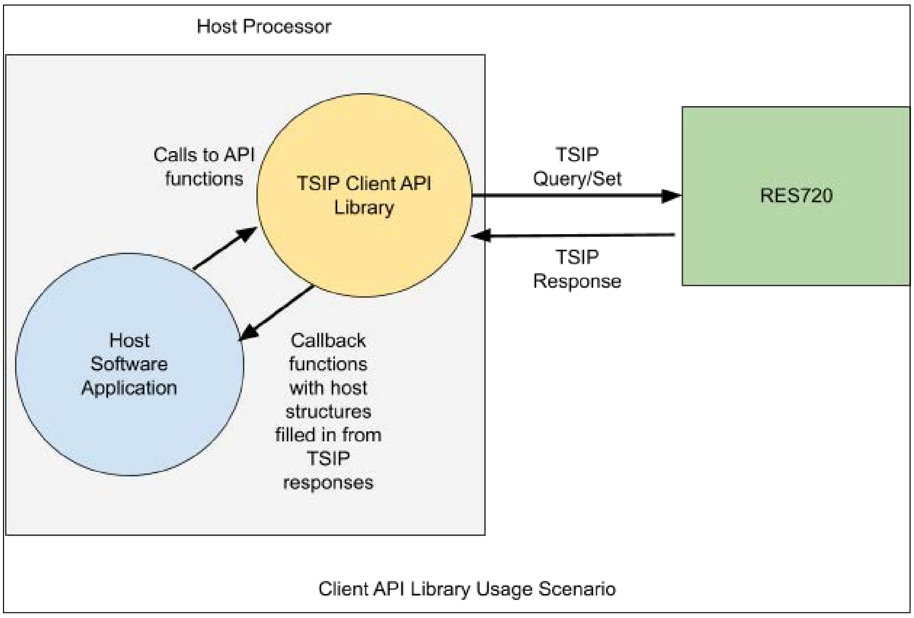
Users can use this code either as an example and replicate its behavior or use it as a reference for their own development.

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.

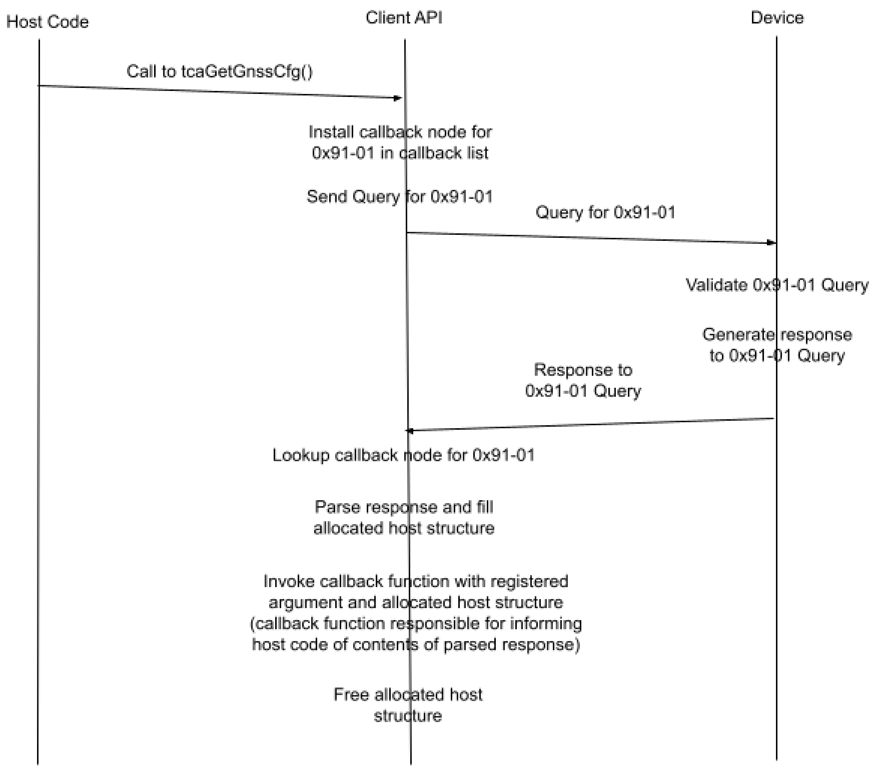
The code is written in C, assuming at least C99 extensions. In addition libm, libc and pthread operations are assumed to be available.

Principles of Usage

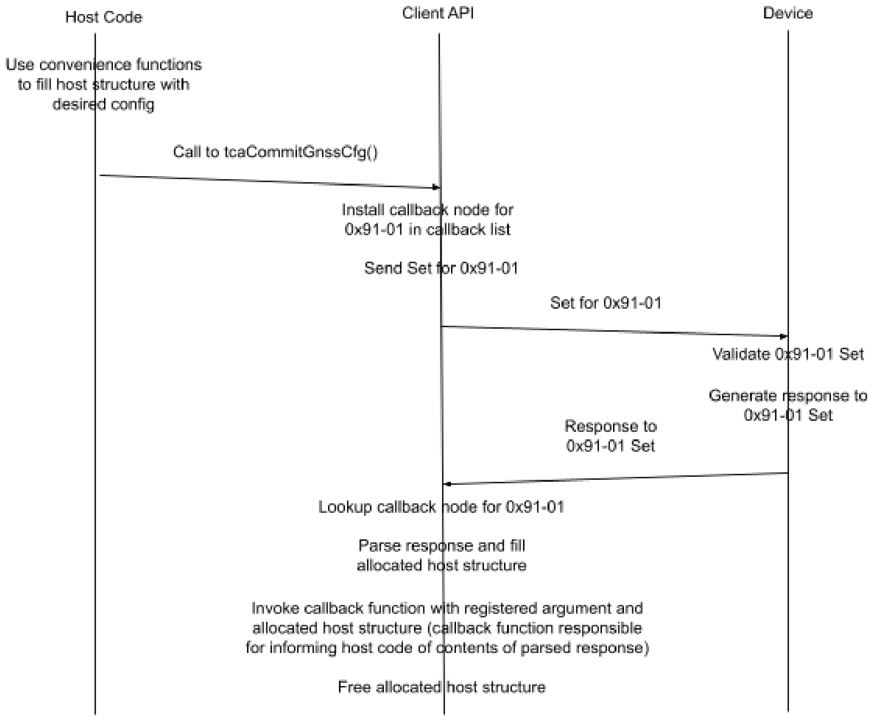
The basic principles for the utilization of the TSIPv1 Client API library are to provide software API functions to interact with a RES 720 over a serial port using TSIPv1 with notification of responses from the RES 720 receiver handled asynchronously through callback functions. The users of the TSIPv1 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 720. They will also be largely unaffected by any changes in the exact formatting needed due to future modifications of the TSIPv1 protocol.



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:



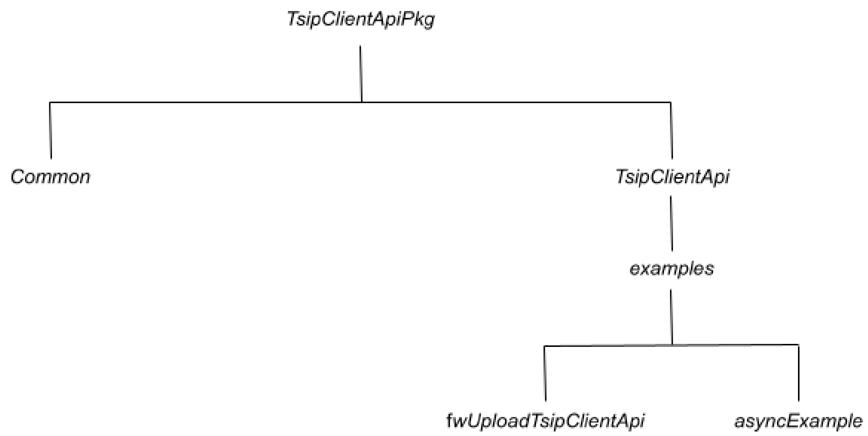
Installation

Users can download the TSIPv1 Client API as a ZIP archive from Trimble's file repository at Box.com. Contact your sales representative or tsgsupport@trimble.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:



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 720 Receiver.

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 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 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 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 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 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 720 using the TSIPv1 Client API. As you can see from the example code, the first interaction with the RES 720 (after successfully initializing the TSIPv1 Client API) is to query for the current Periodic Message Configuration (0x91-05) that exists on the RES 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 720 receiver 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 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 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 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 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 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 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 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 720.

As can be seen by these two example applications, the TSIPv1 Client API allows a host application to interact with the RES 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 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 720 with additional qualifiers or when setting the fields of the host structure to be committed to the RES 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.

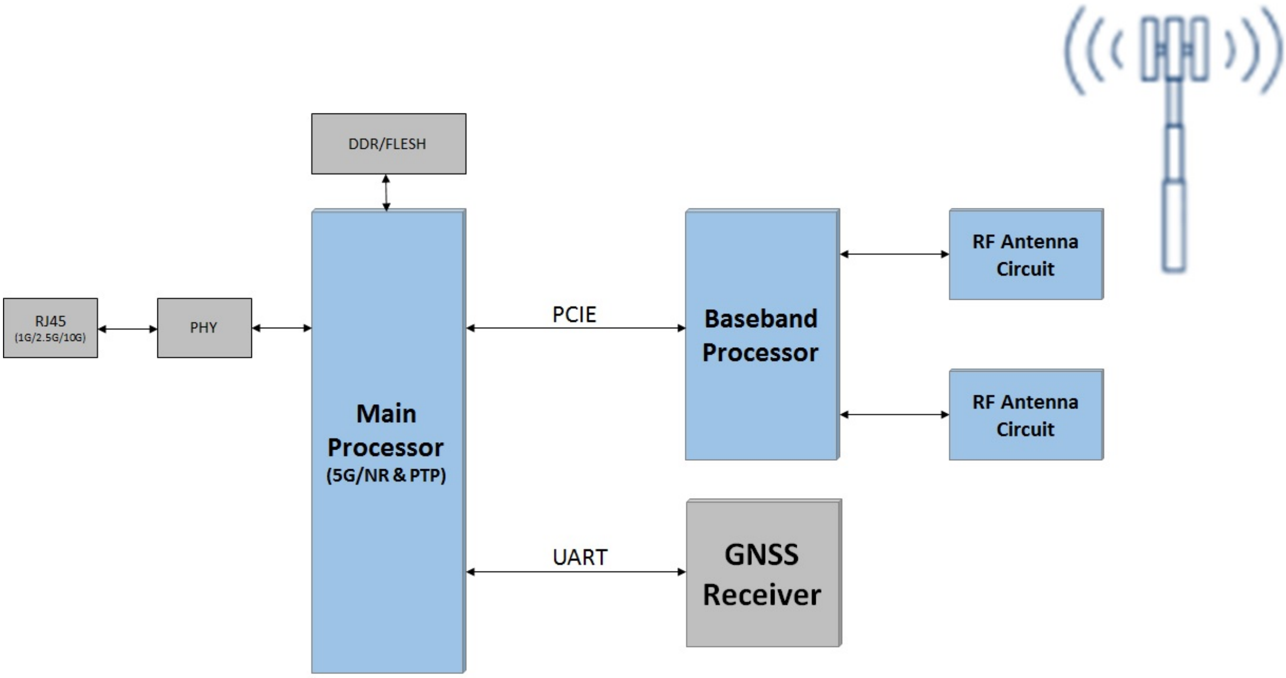
Finally, not all Packet and Sub-Packet ID key pairs have a Query and Set command. There should eventually be a TSIPv1 Client API function available to allow the caller to interact with the RES 720 using the messages identified in the "TSIP Design and Packets" document. The document is periodically enhanced 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.

8

Integration Examples

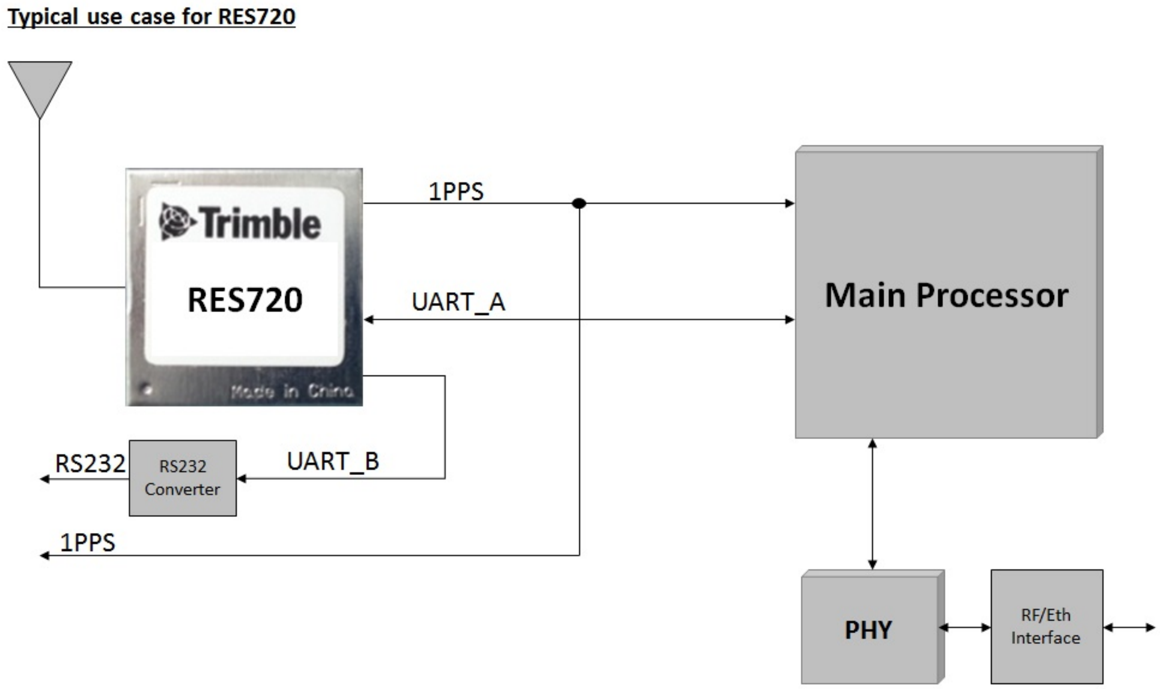
The timing module has many potential applications for both indoor and outdoor applications. The following shows typical small cell circuit diagram and deployment diagram of DCSG (Disaggregated Cell Site Gateway) or CSR (Cell Site Routers) with the timing module. The DCSG or CSR are widely deployed in 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.

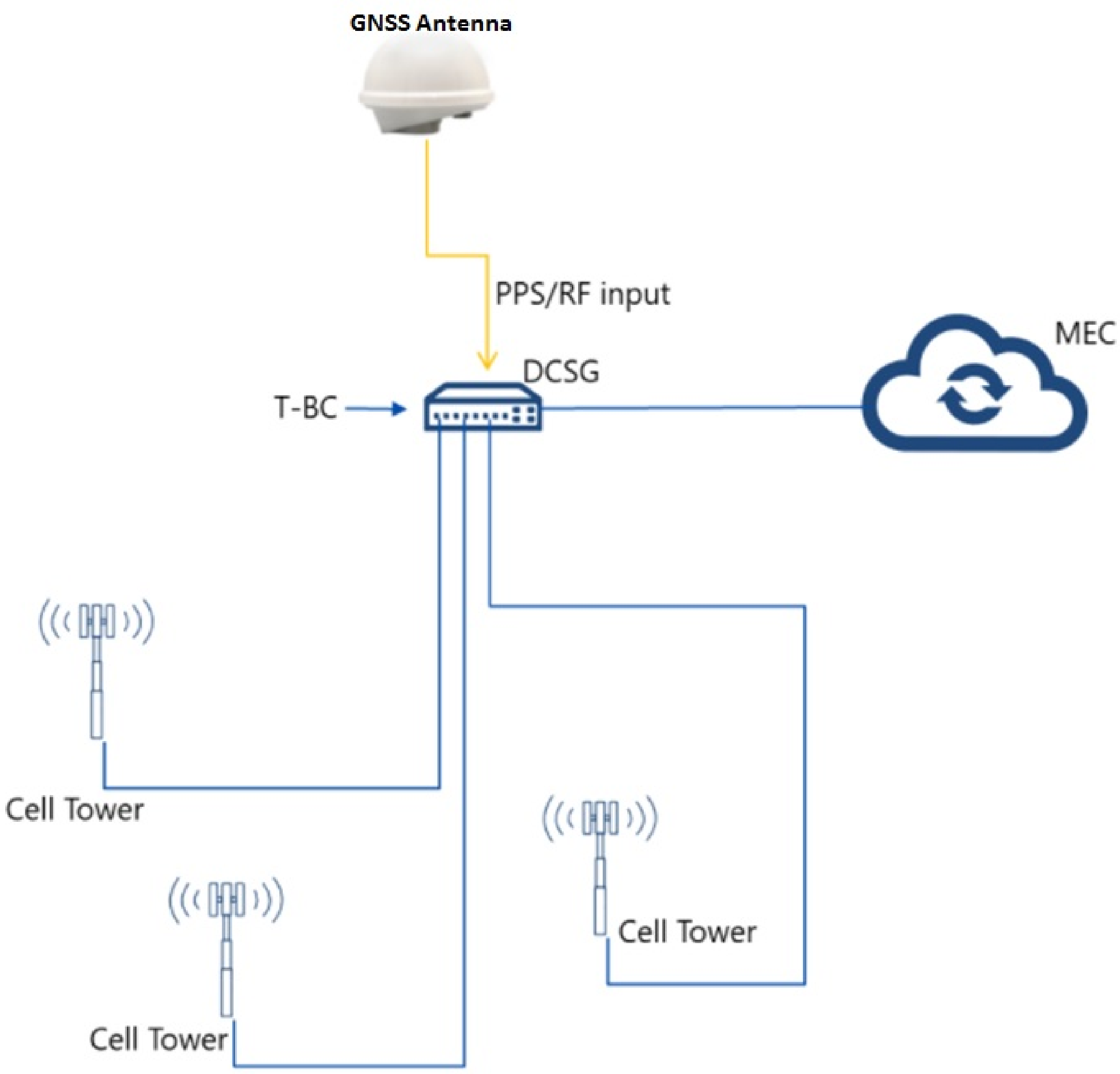


The RES 720 timing module can be applied for the small cell application depending on whether the PLL logic block is used and 10 MHz system frequency output is required or not.

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

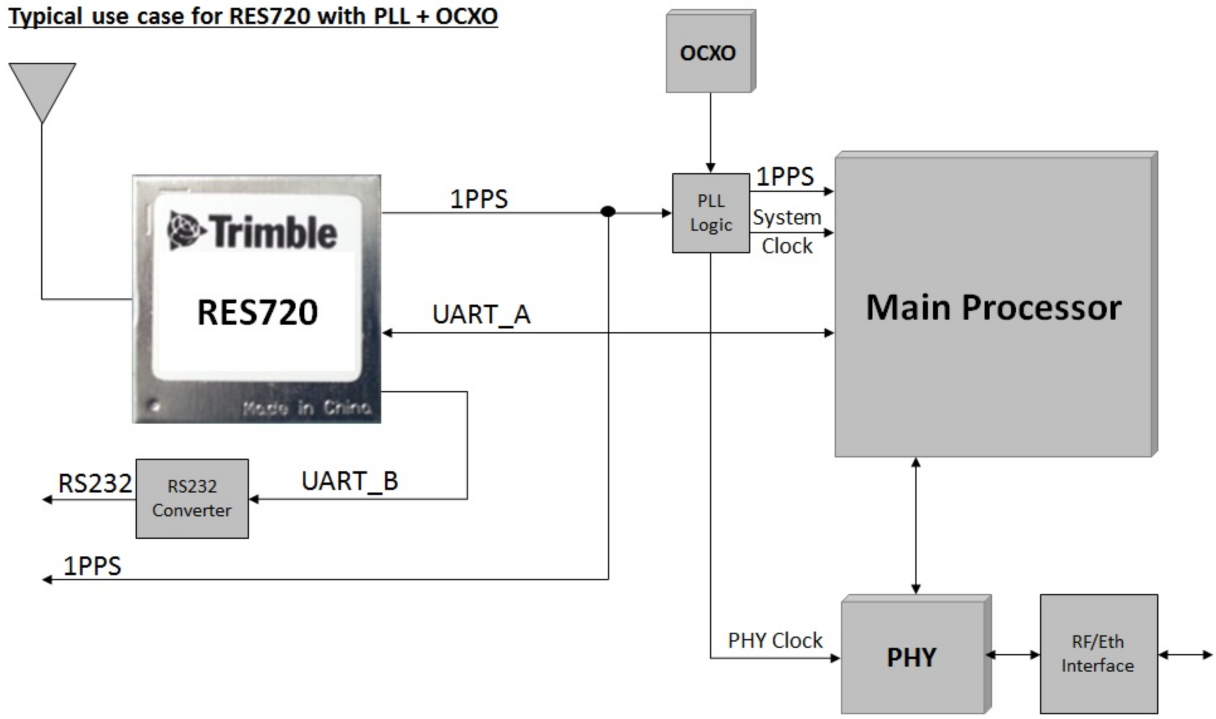


In the CSR (Cell Site Routers) application, below is a typical circuit diagram with a GNSS receiver.



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.



9

Installation and Application Circuits

This chapter provides several circuit examples for antenna feed and monitoring circuits to power and monitor active GNSS antennas for use with the RES 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 Trimble timing receiver, it shall not exceed 25 dB. But if you are unsure, please contact your Trimble representative for assistance.

SNR or CN0: What is the “signal strength” the receiver reports?

GNSS modules don't actually report signal strength. They report CN0 in dB-Hz, or carrier-to-noise ratio. It is just that, a ratio. How much signal there is versus noise. The ratio reported is set at the first LNA. After that if you have enough gain to overcome signal path loss and receiver noise figure, the reported CN0 stays the same for a given input.

The CN0 reading is a measure of signal-to-noise ratio of the GNSS signal. Notice that this number is a ratio of signal versus noise and actually doesn't tell you anything about the absolute strength of the signal at a receiver. If you amplify a GNSS signal, you increase its signal level as well as its noise level and the CN0 ratio doesn't change. This is a common mistake—larger CN0 doesn't necessarily mean a stronger signal.

As for the LNA gain, what is important is to have enough gain to meet the requirement of the GNSS receiver. For example, in most timing receivers’ case Trimble is specifying at least 15 dB, optimal 20 dB, of external gain at the input of the receiver. As long as you have at least this amount of gain, the CN0 level should be approximately constant even with higher levels of gain. So, if you see a CN0 value of 40 with 15 dB of LNA gain, you should still see a value of 40 with 25 dB of LNA gain. The signal level is much higher with a gain of 25 dB, but the CN0 level stays the same.

Now, if you start to drive the receiver with less gain than that, you will reach a point where the CN0 level starts to drop with reduction in gain. Here you are operating without the required gain and will start to see undesirable effects. For example, you might move a cable and slightly change the amount of gain loss and see a variation in tracking level. Or, say, in a test system with 100 locations, there could be variations in cable or other loss to each location that would show up as inconsistent results.

With regards to noise figure of our receiver, it turns out that value really doesn't make that much practical difference either. That is a measurement of loss at the receiver when no gain is applied, but this is not a condition at which the customer should be operating. The effect on the system with 15 dB of external gain will be the noise figure divided by 15. So, we were measuring noise figures of about 5 to 6 dB. That translates into 5/15=0.33 dB and 6/15=0.4 dB in NF, so you lose about that much in CN0 level due to the noise figure of the receiver.

For Time & Frequency products, Trimble specifies a required amount of external gain. The customer should be operating and testing at those levels to ensure consistent results. Trimble does not guarantee proper operation below and above that level.

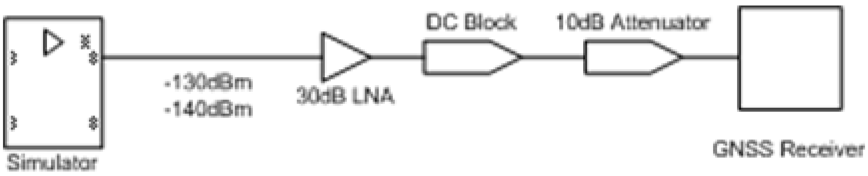
Experiment: How can I test I am receiving a good RF signal?

Trimble has a requirement of a certain gain at the RF input so that the module may reflect the true signal incident on the antenna.

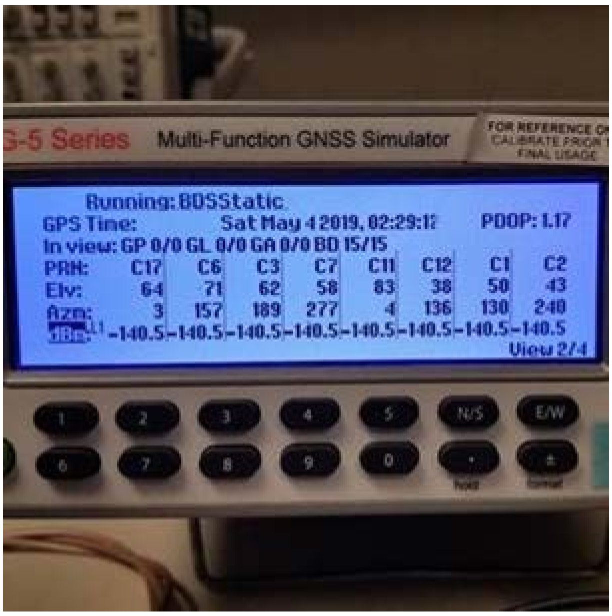
Trimble uses Spectracom GSG5/6 and Spirent GSS6700 simulators.

Below is a quick desktop test for testing the receiver response to a simulator signal. If the receiver has a linear response to the simulator output, then we know we are on the way to provide a healthy timing solution.

The idea is that the Trimble receiver will report the simulator output of -130 dBm or -140 dBm with and without the 10 dB attenuator in the circuit. The RES 720 timing module is acting as a "GPS O'meter", it reports the CN0 (± a couple of dB) at the signal (or antenna) source, not what is at the RF input of the timing module. This is dependent on a good 50 Ohm trace on the PCB and proper LNA amplification. In the example below, the 30 dB LNA and 10 dB attenuator can deliver the required minimum 20 dB (Trimble recommends 20 dB to 35 dB) of gain to the timing module front end.



Two signal outputs were used: -130 dBm and -140 dBm:



A 10 dB attenuator was inserted to change the gain sent to GNSS receiver from 30 dB to 20 dB.

The following image shows the 30 dB LNA and 10 dB attenuator:

To summarize...

Test 1:

Simulator output: -130 dBm

Total LNA Gain: 30 dB (10 dB attenuator not included)

Measured signal by GNSS: -130 dBm

Test 2:

Simulator output: -130 dBm

Total LNA Gain: 20 dB (10 dB attenuator added inline)

Measured signal by GNSS: -130 dBm (the same as Test 1)

Test 3:

Simulator output: -140 dBm

Total LNA Gain: 30 dB (10 dB attenuator not included)

Measured signal by GNSS: -140 dBm

Test 4:

Simulator output: -140 dBm

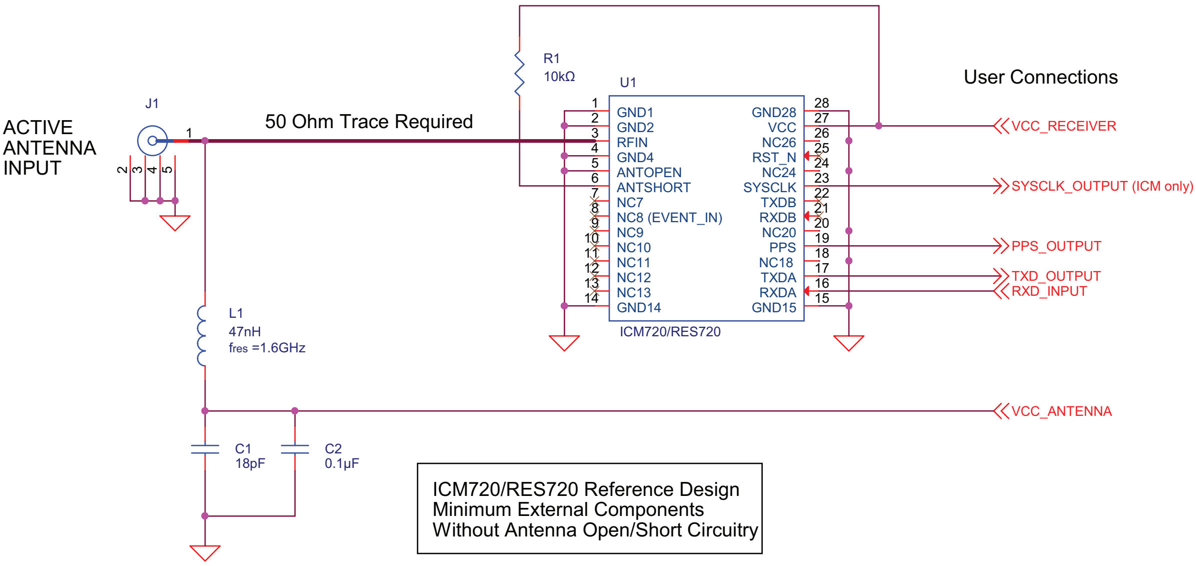
Total LNA Gain: 20 dB (10 dB attenuator added inline)

Measured signal by GNSS: -140 dBm (the same as Test 3)

Conclusion

The LNA gain (in dB) does not affect the measured signal coming in from the signal source. You can change the simulator output to “any” level and the module will follow it, providing you maintain a suitable LNA at the input. If the receiver is not reporting the signal level delivered at the source (via simulator or real antenna) then there is something wrong with the LNA gain or the PCB trace tuning. There will always be a few dBm variations due to connectors, non-ideal impedance traces and so forth.

Active antenna – no antenna status



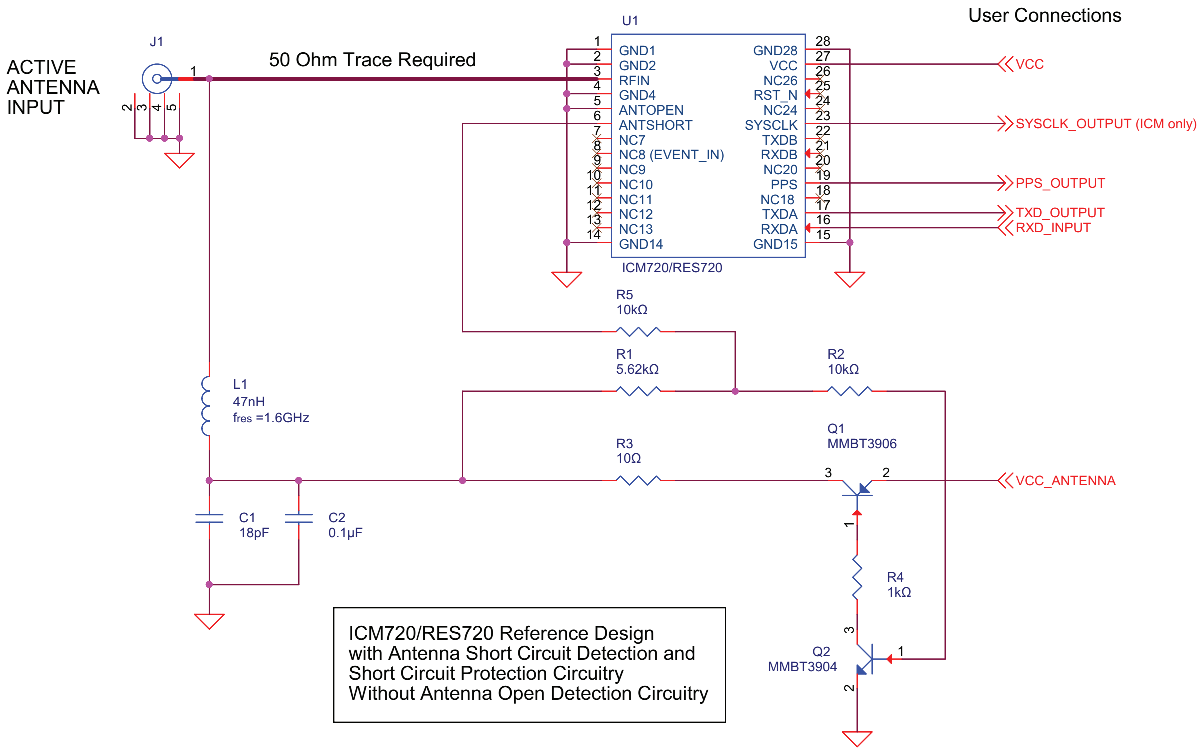
In this schematic without antenna detection:

- 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:

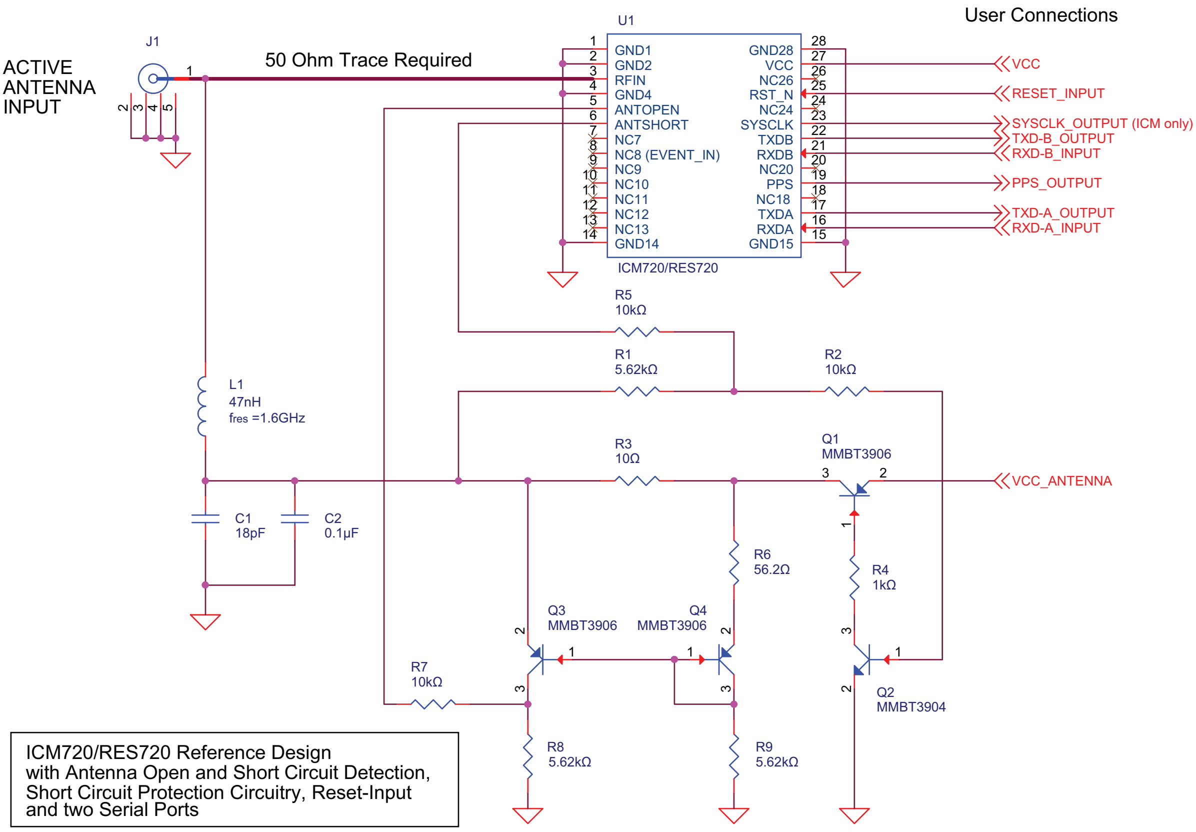
- An active antenna is used.
- There is no hardware reset ability through the External Reset pin, as this is left disconnected.
- Only serial port A is connected. Port B is not available as this is left disconnected.
- Antenna short detection and protection is provided by this circuit. Antenna open detection 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

Component	Description	Manufacturer	Part Number
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

Component	Description	Manufacturer	Part Number
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

10

Packaging

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.

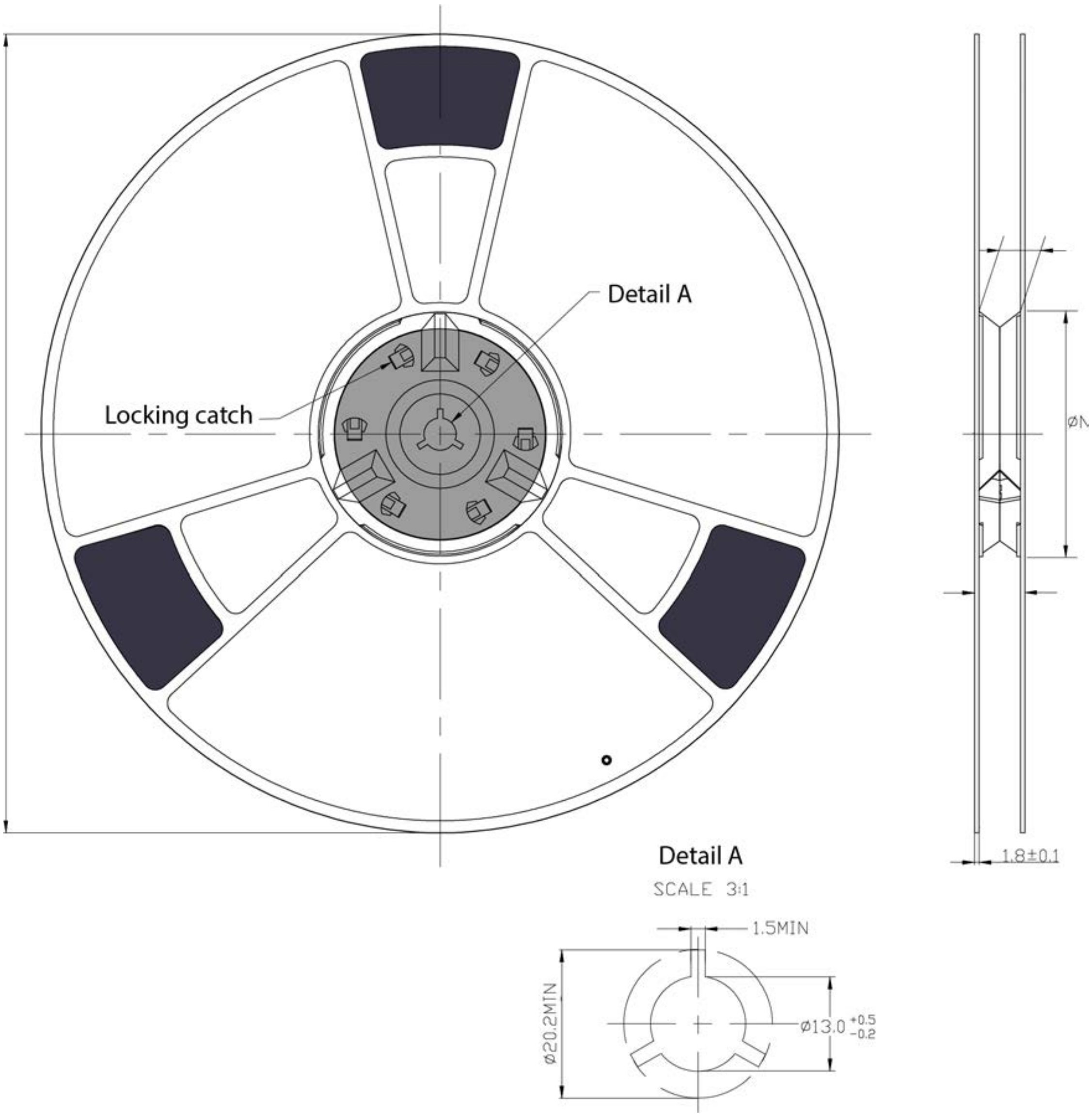
Introduction

The timing modules are packaged in tape and reel for mass production. One reel holds 500 modules. See Label, page 196 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.

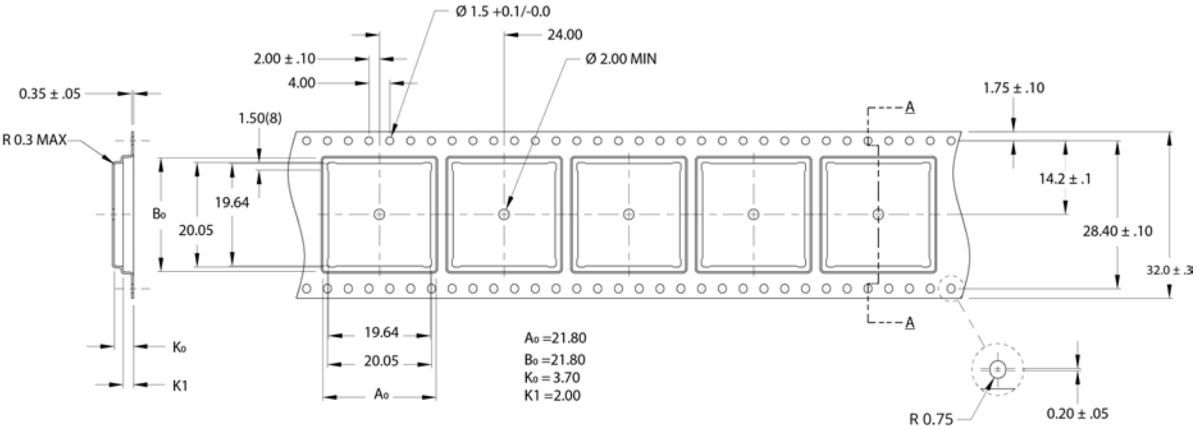


Weight

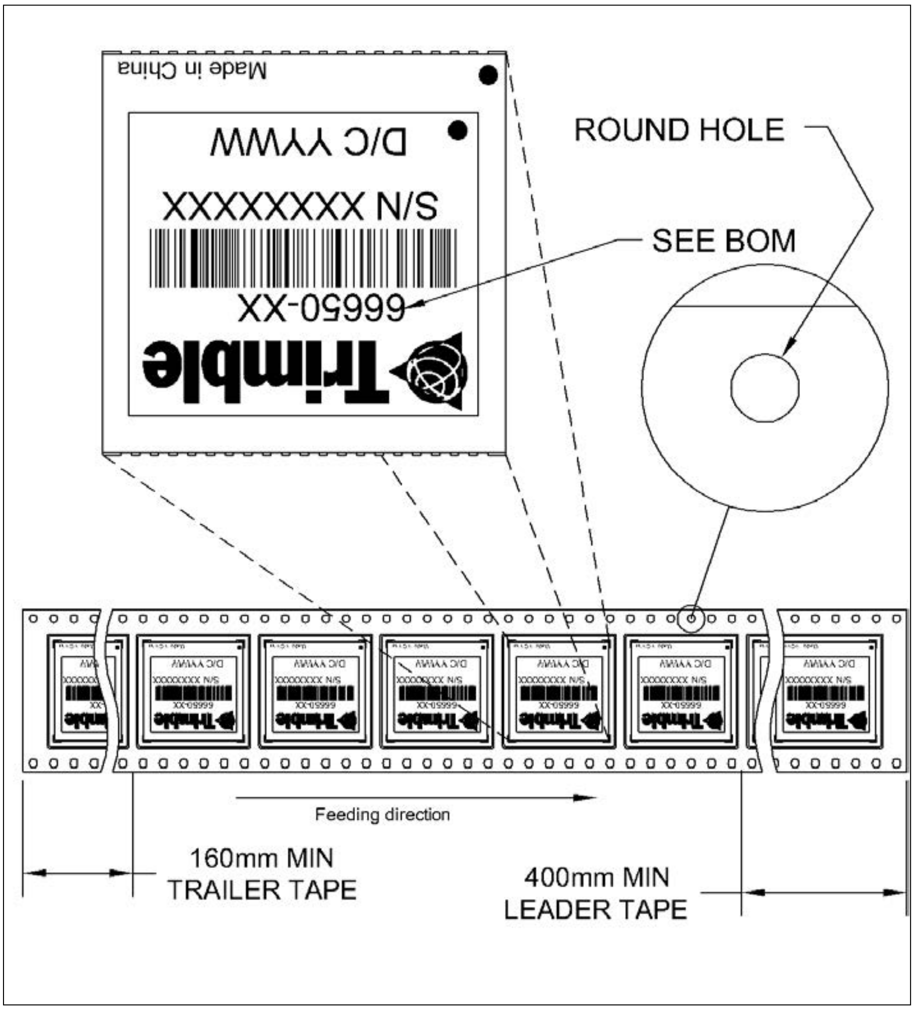
Unit description	Weight (approx.)
500 pieces with reel packaging, desiccant, and humidity indicator	1,380 g
500 pieces with reel packaging, desiccant, humidity indicator and white carton box	1,595 g

Tapes

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

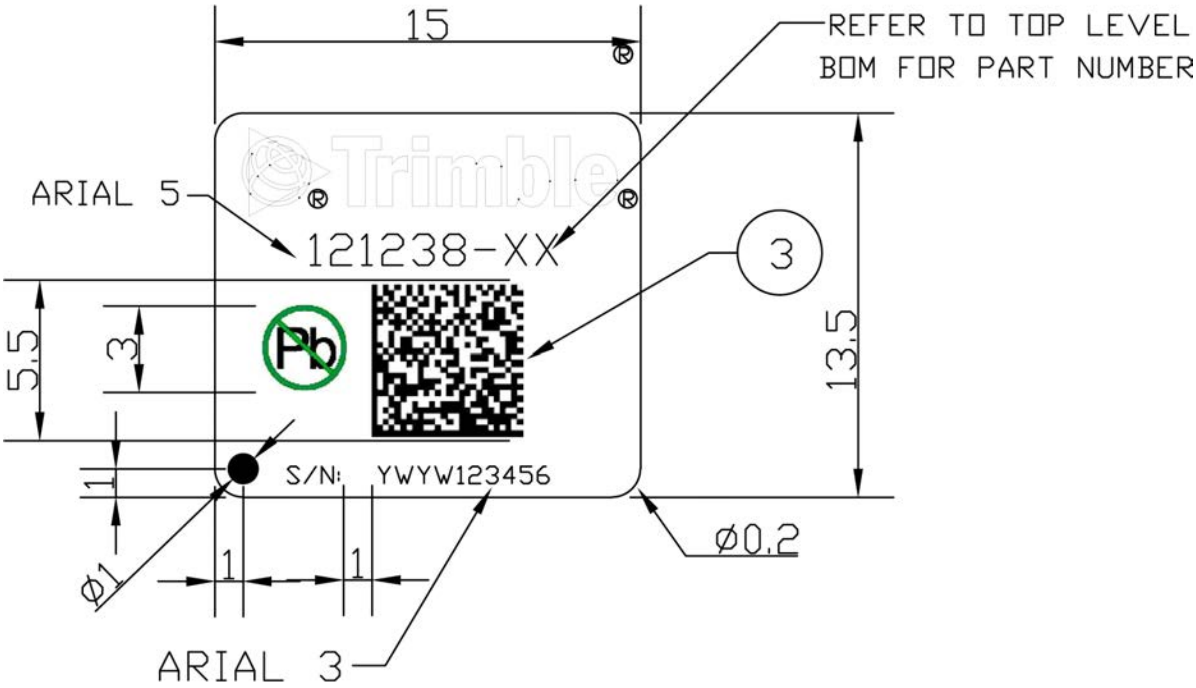


The feeding direction is illustrated below:



Label

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



11

Shipping and Handling

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

4
Level

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.

Baking procedure

If baking is necessary, Trimble 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.