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 A
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Legal Notices

Release Notice

This is the July 2021 release (Revision A) 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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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.

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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.

CE 0700

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

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.

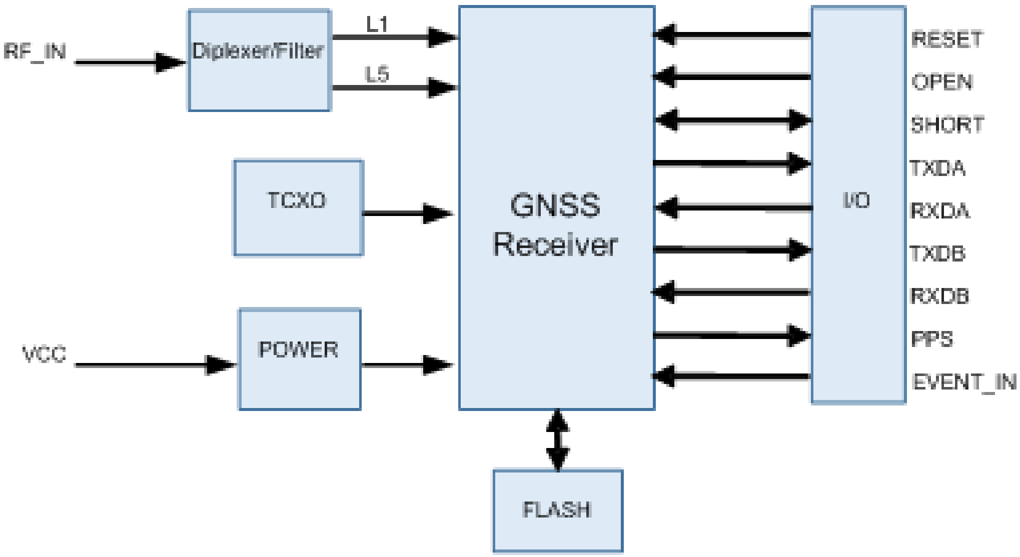
The GPS subsystem contains the RF and baseband circuits, which can track L1 and L5 satellites at the same time, and search GPS satellites using the L1 circuit.

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

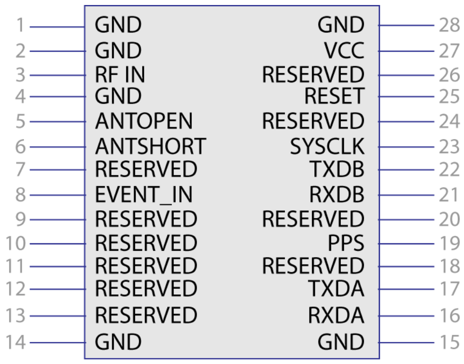
The IF frequency is 4.092 MHz.

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 Antenna detect truth table, page 1.
6	ANTSHORT	Antenna SHORT	Input / Output	Logic level from external antenna detection circuit. See Antenna detect truth table, page 1.
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.

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.

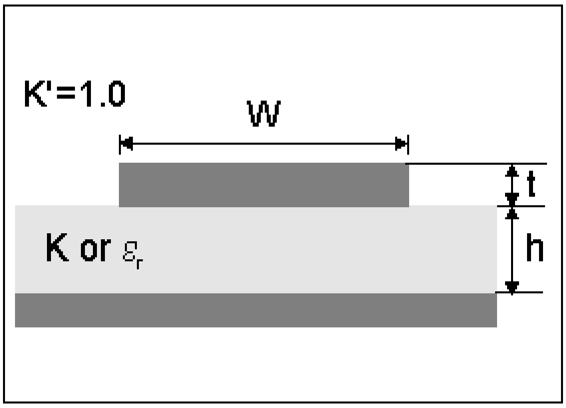
- Keep the path of supply currents and their GND return currents together as close as possible. The same applies for signal currents and their GND return currents.
- Keep signal traces, which are likely to interfere with each other, apart and separate them with GND areas.
- Route supply traces and their 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



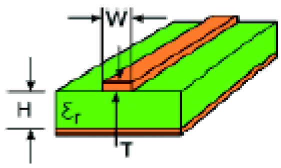
Ground plane design recommendation

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)



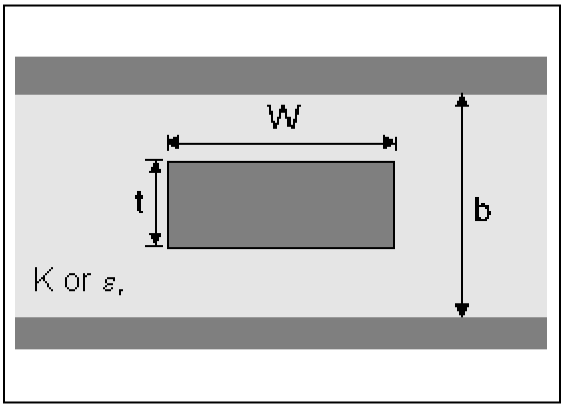
The following table shows typical track widths for an FR4 material PCB substrate (permittivity εr of 4.6 at 1.5 GHz) and different PCB thickness. The thickness of the top layer is assumed as being one ounce copper. If using a multi-layer PCB, the thickness is the distance from the signal track to the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

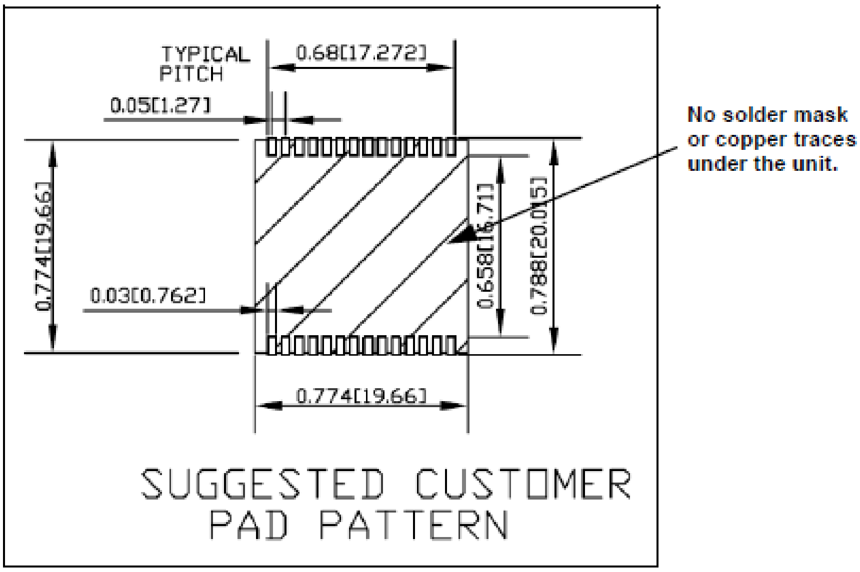
Soldering information

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.

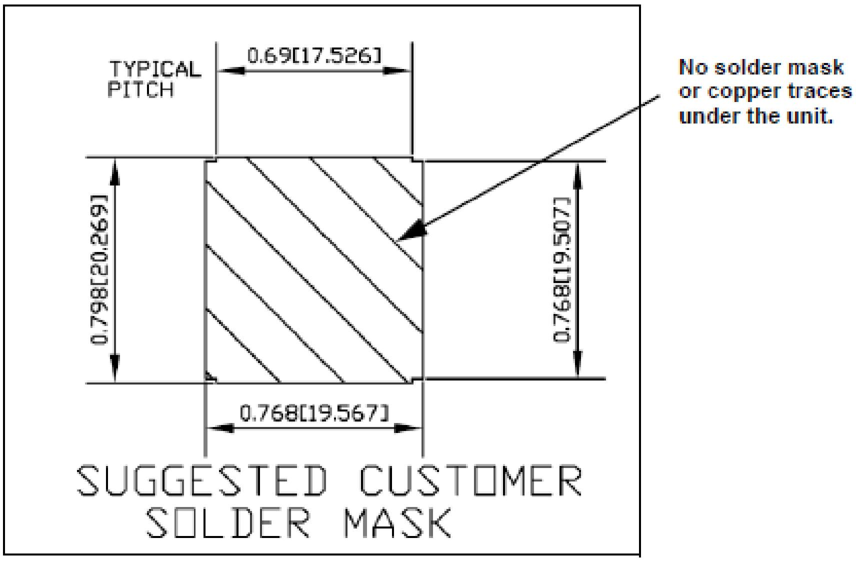
> **NOTE –** All units shown are in millimeters.

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.

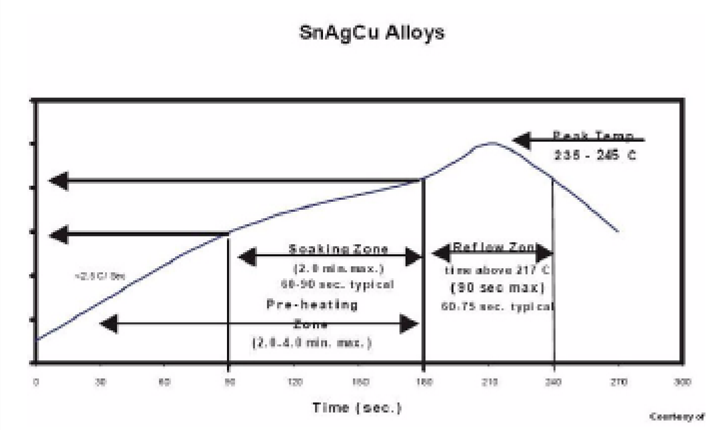
Solder reflow

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

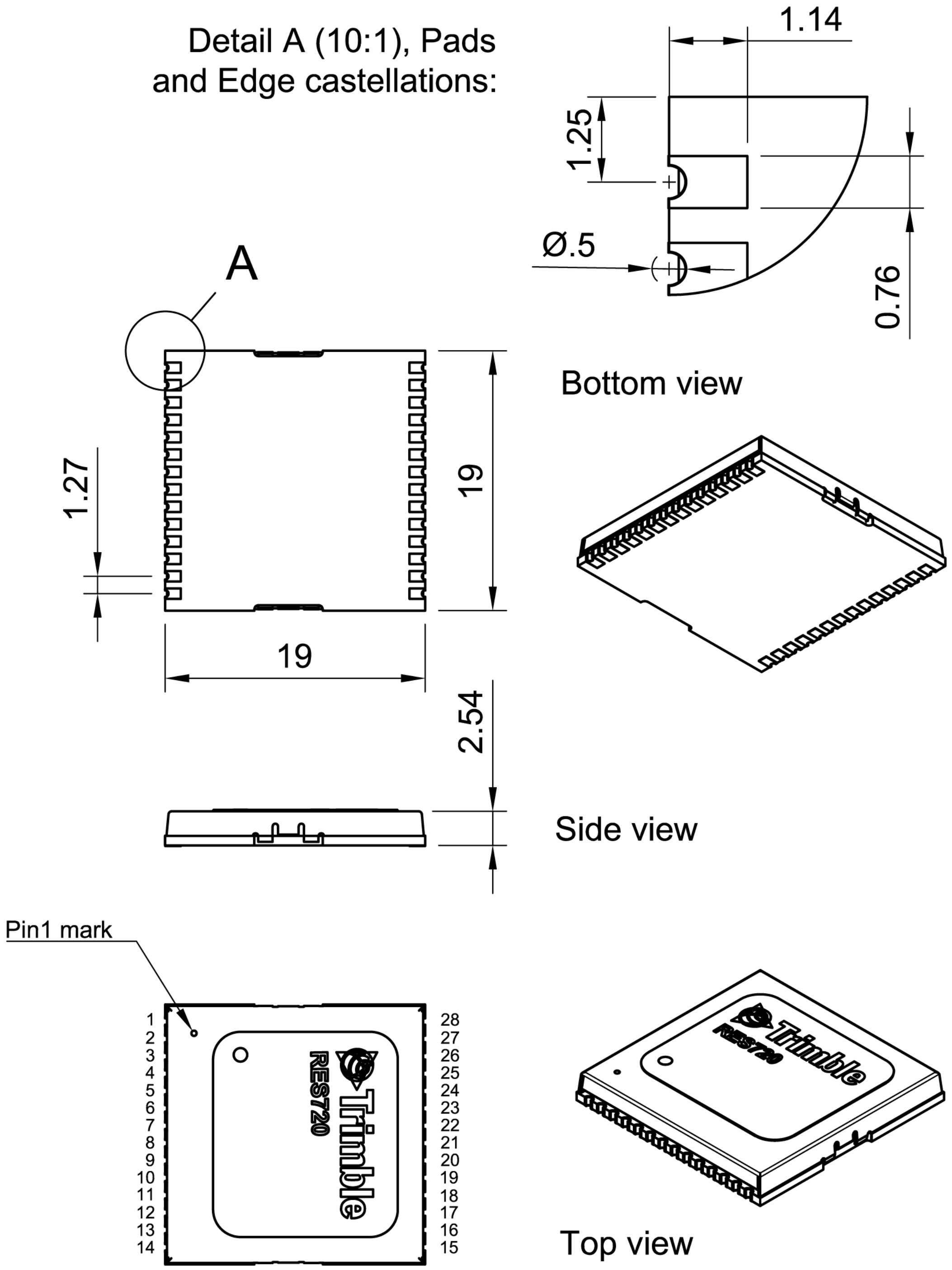
The RES 720 timing module timing module can withstand one rework cycle. The module can heat up to the reflow temperature to precede the rework. Never remove the metal shield and rework on the module itself.

Conformal coating

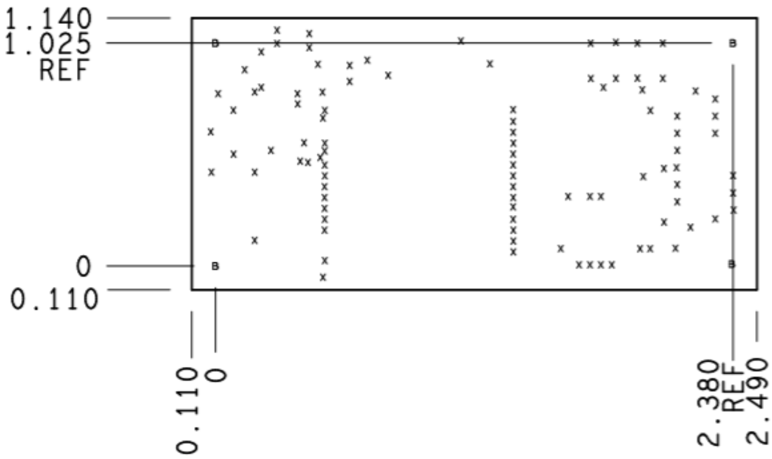
Conformal coating on the RES 720 timing module multi-GNSS timing module is not allowed and will void the warranty.

Mechanical outline drawing

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



Carrier board mechanical outline



The thickness of the carrier board PCB is 0.044 inches (0.111 cm).

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 113.
    - 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 111.
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

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

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 63.

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.

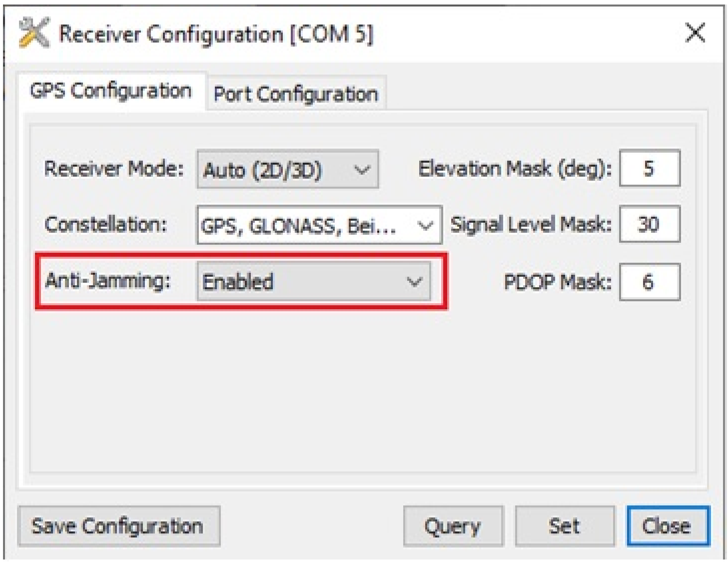
The RES 720 timing module has anti-jamming enabled as a default configuration; ***it cannot be disabled***.

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 72. It also can be set in the VTS tool as shown:



Cable delay compensation

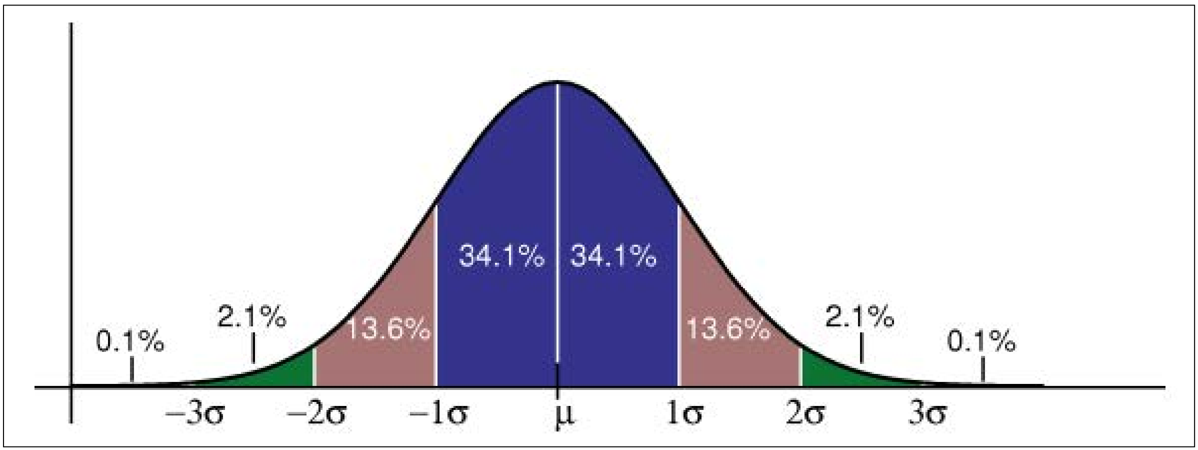
The default configuration of the timing module provides optimal timing accuracy. The only item under user- or host-control that can affect the receiver's absolute PPS accuracy is the delay introduced by the antenna cable. For long cable runs, this delay can be significant. TSIP packet 0x91-01 sets the 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 79.

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 99) 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 79) or the falling edge.
- If using TSIP, capture the time from TSIP packet 0xA1-00 (see page 99). If using NMEA, capture the time from NMEA packet ZDA (see page 133) or ZD (see page 1).
- 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 89). 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 83). 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 77).

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 69) on Port A to configure protocol for Port B, and then use the TSIP 0x91-02 command (see page 77) to save the configuration.

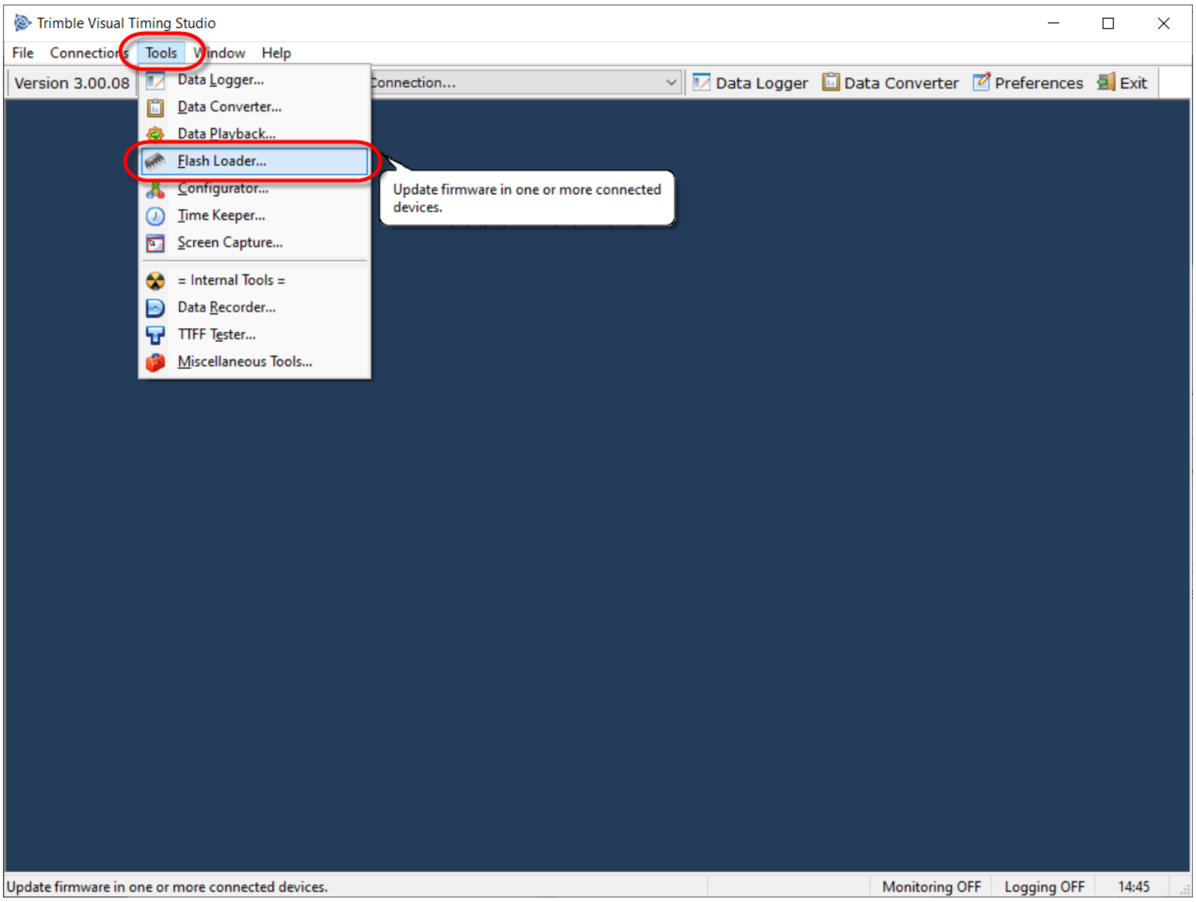
- Baud rate, data bits, parity, and stop bits are user configurable.
- Flow control is not available on the serial ports.

Updating the firmware

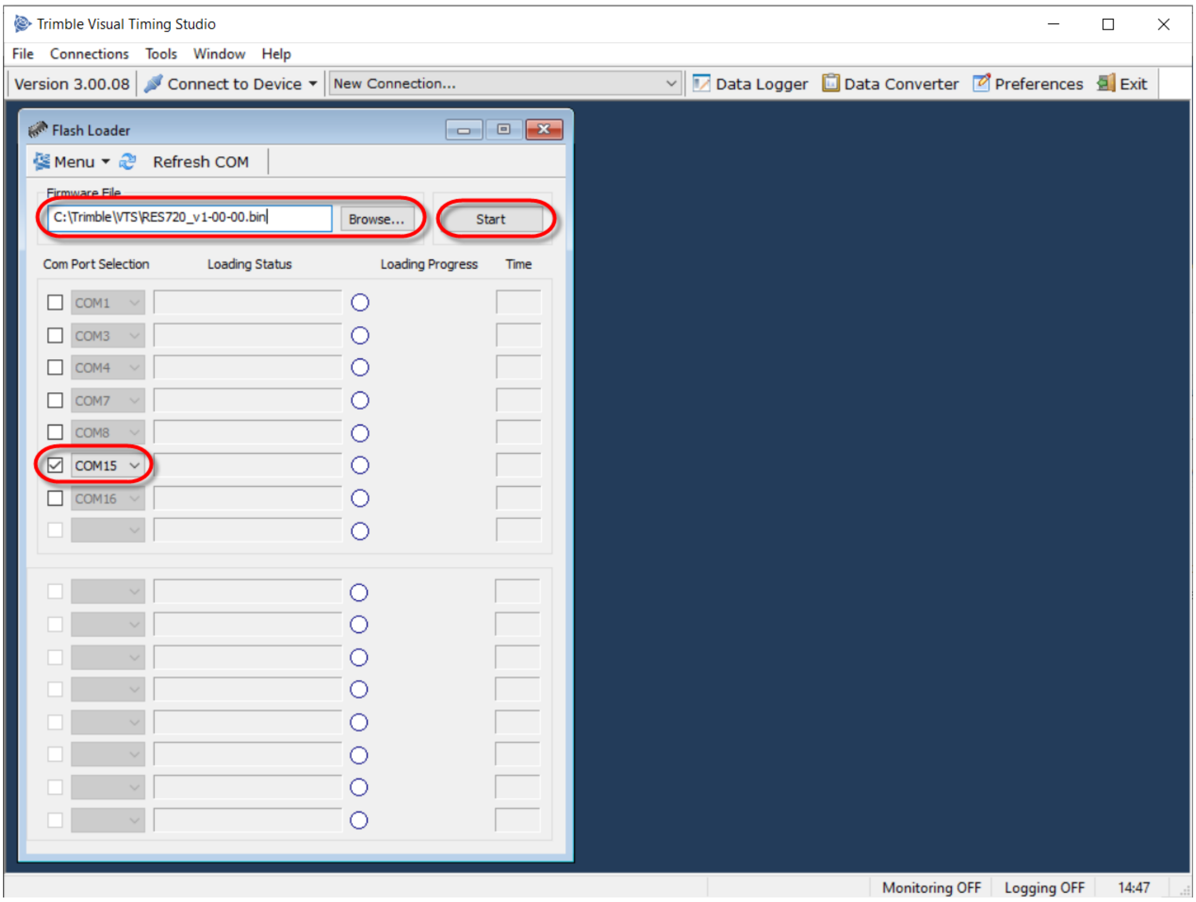
Use the VTS Flashloader tool to load firmware to the RES 720 timing module.

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**:



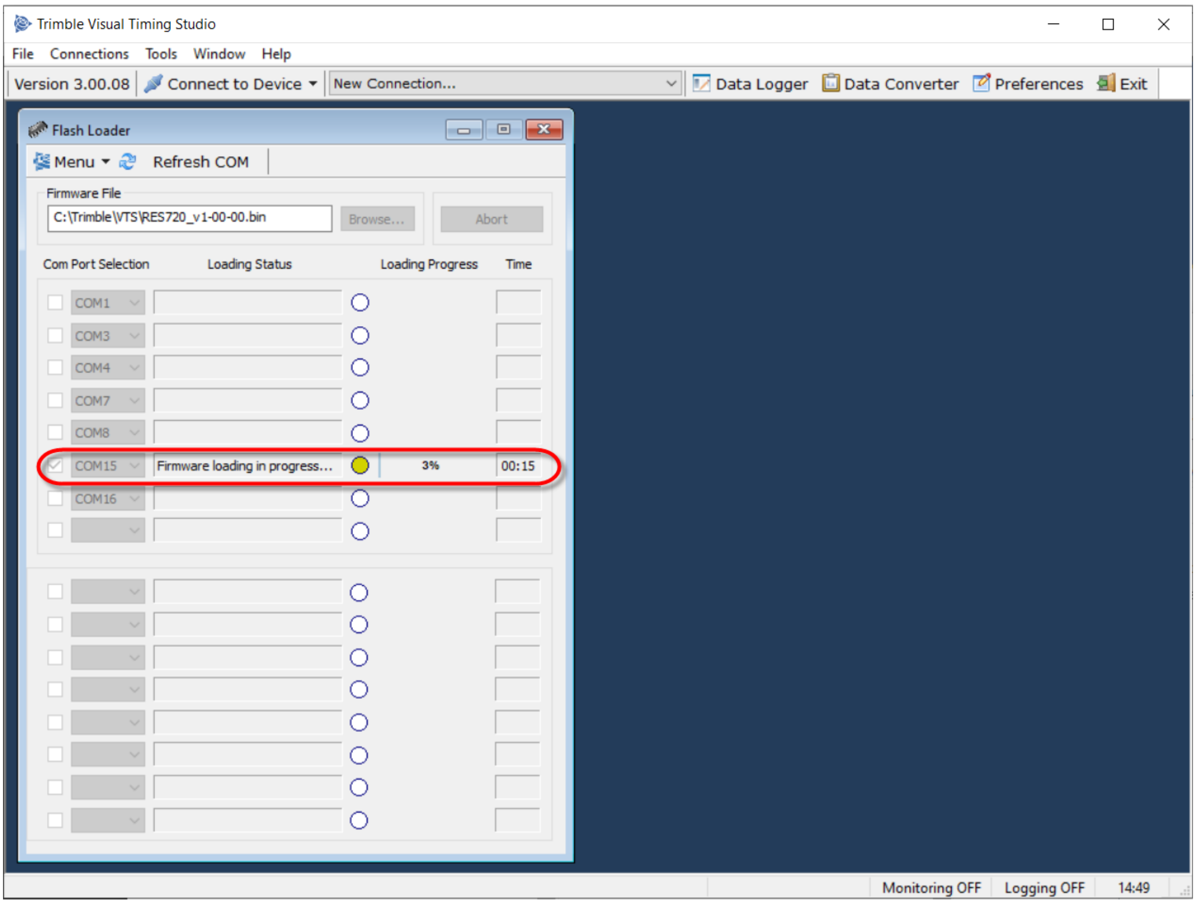
The following dialog appears:



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:

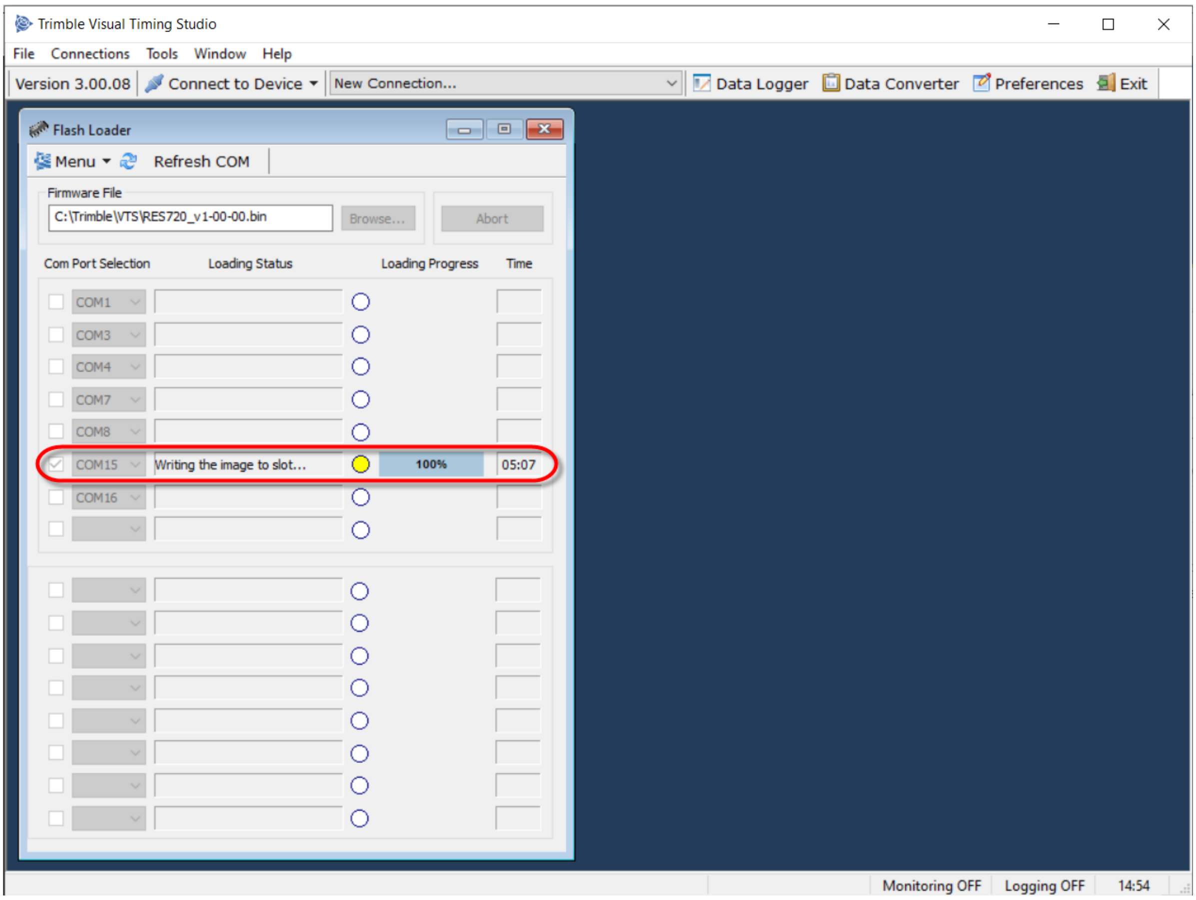


You will see the loading status, the loading progress and the time elapsed in the respective fields.

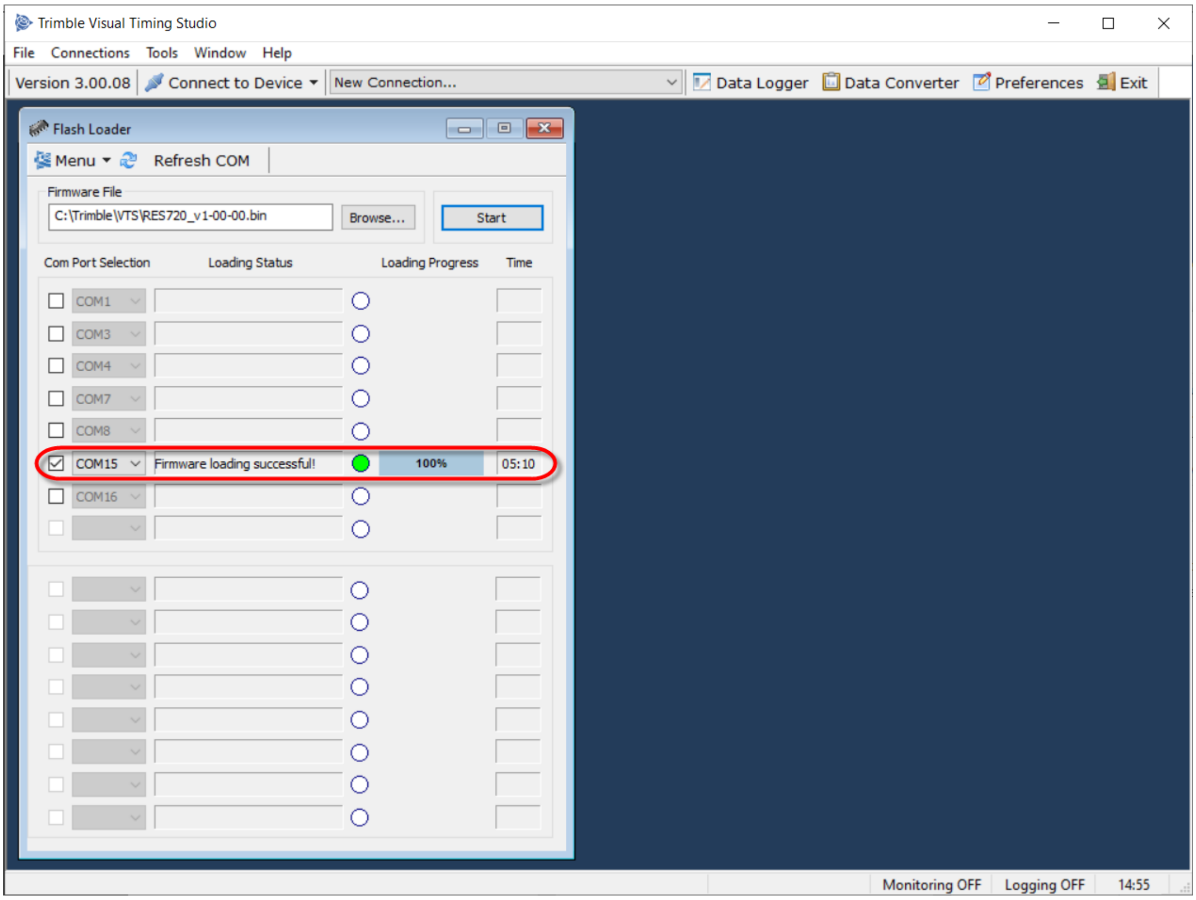
The receiver continues to operate normally during the file upload process. The firmware file is stored in a separate memory area and is not used before the upload process is 100% complete and successful.

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

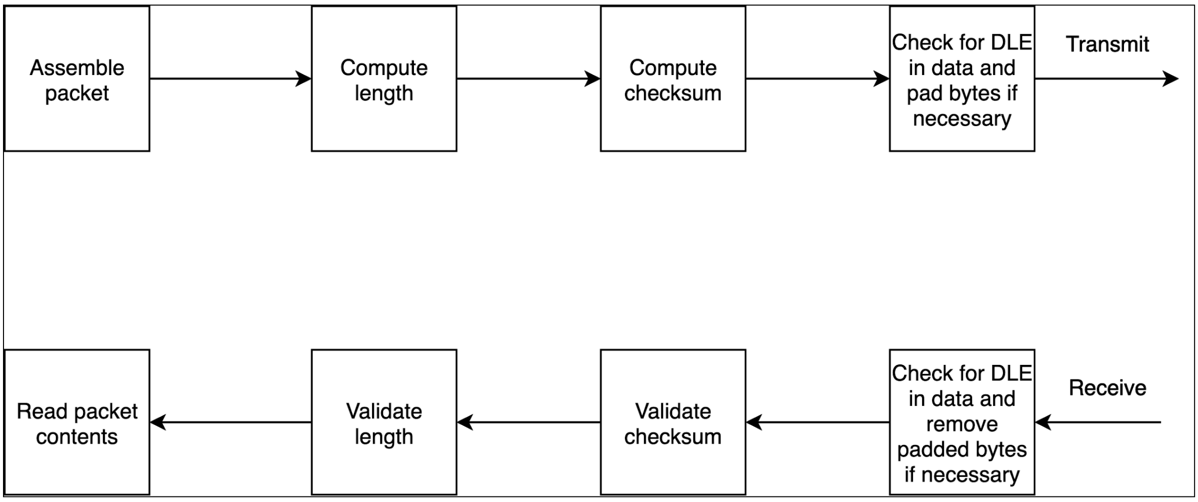
Mode for each command will be either one of Query (0x00) or Set (0x01) or Response (0x02).

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	7, 11-14	7: 9600 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
11–14	Type of output	UINT32	Any	Reserved
15–18	Type of output	UINT32	Any	Reserved
19–22	Type of output	UINT8	Any	Reserved
23	Checksum	UINT8	Any	
23	Delimiter 1	UINT8	0x10	End of packet 1
24	Delimiter 2	UINT8	0x03	End of packet 2

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

Response

Byte	Item	Type	Value	Description
0	Start Byte	UINT8	0x10	Start of packet
1	Packet ID	UINT8	0x91	Packet ID
2	Subpacket ID	UINT8	0x05	Subpacket ID
3–4	Length	UINT16	Any	Total length of mode + data + checksum
5	Mode	UINT8	2	2: Response
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
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	0-5	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
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 138.
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 138
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 138
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

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

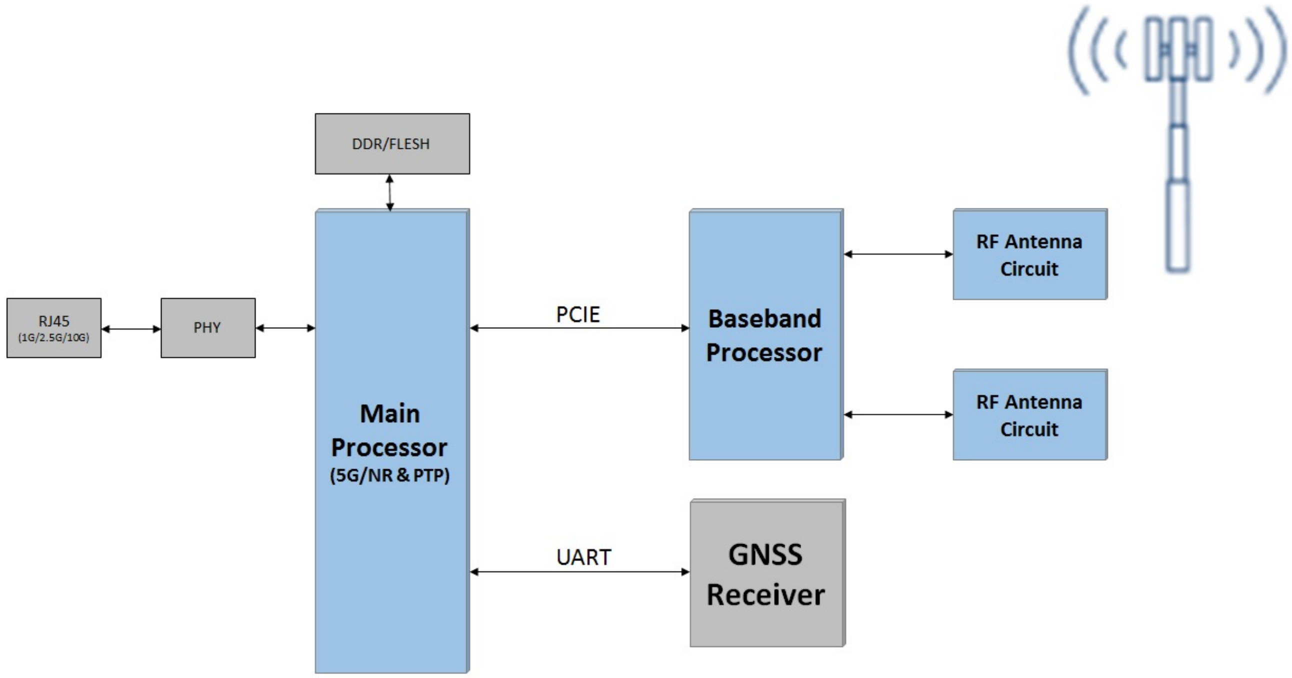
System	Satellite ID	Signal ID	Signal channel
BeiDou	1 – 64 for Beidou 65 – 99 undefined	0 1 2 3 4 5 6 7 8 9 A B C D – F	All signals B1I B1Q B1C B1A B2-a B2-b B2 a+b B3I B3Q B3A B2I B2Q Reserved
QZSS	1 – 10 for QZSS 55 – 63 for QZSS SBAS 64 – 99 undefined	0 1 2 3 4 5 6 7 8 9 A B - F	All signals L1 C/A L1C (D) L1C (P) LIS L2C-M L2C-L L5-I L5-Q L6D L6E Reserved

5

Integration Examples

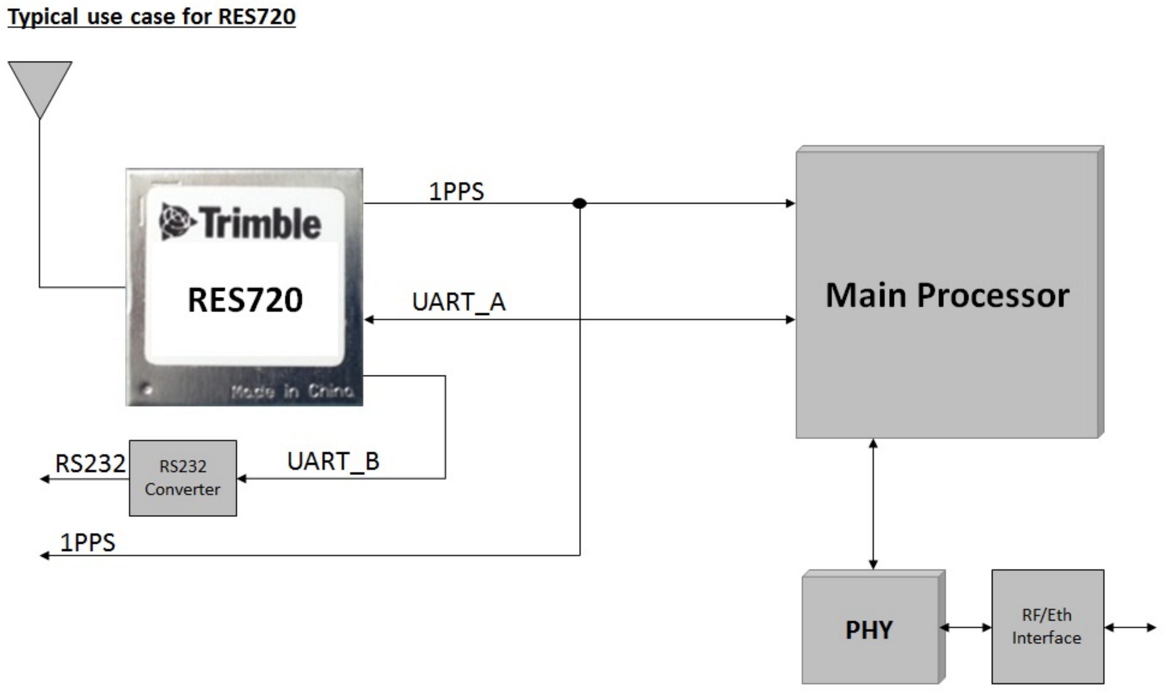
The timing module has many potential applications for both indoor and outdoor applications. The following shows typical small cell circuit diagram and deployment diagram of DCSG (Disaggregated Cell Site Gateway) or CSR (Cell Site Routers) with the timing module. The DCSG or CSR are widely deployed in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

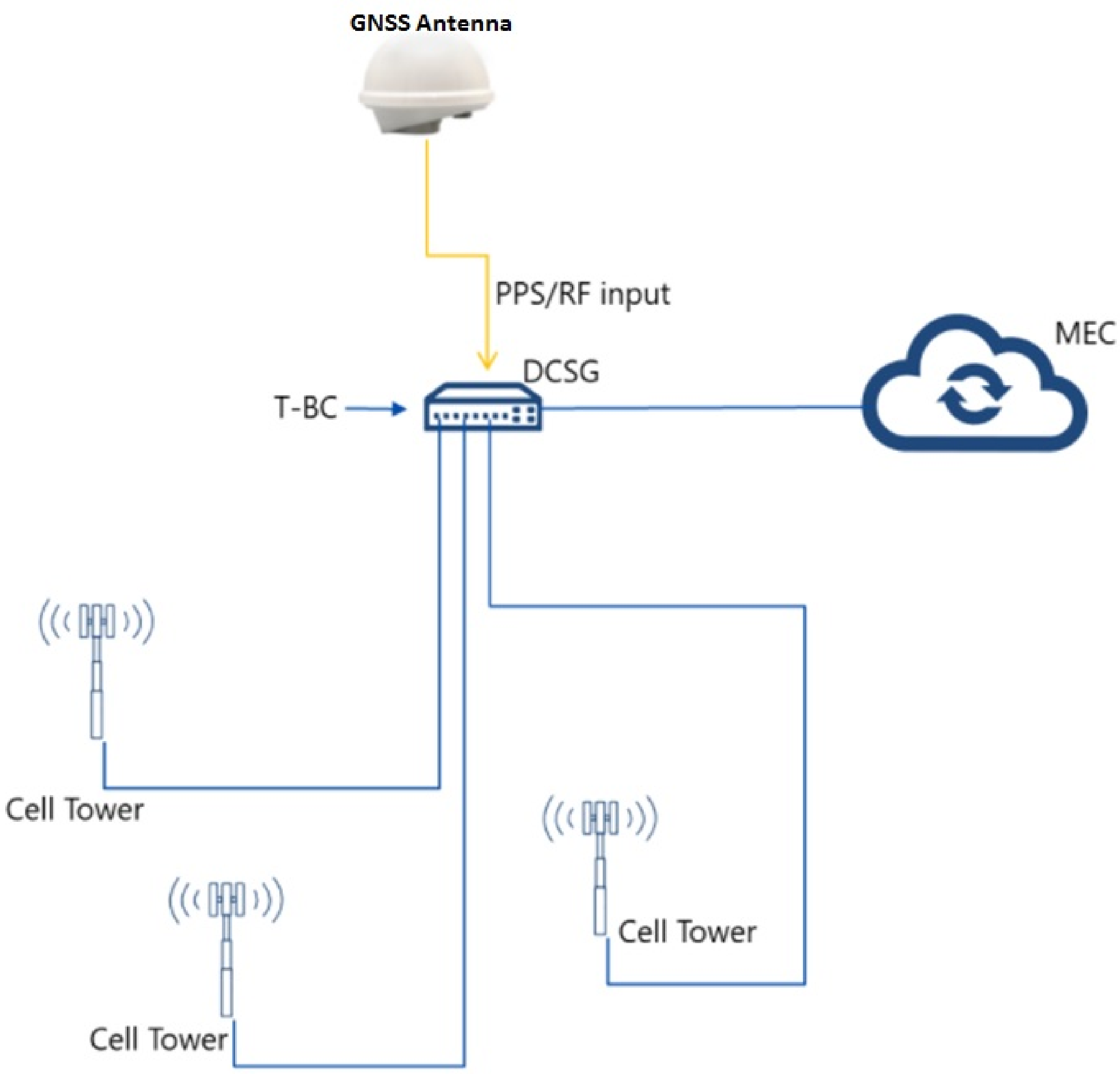


The RES 720 timing module can be applied for the small cell application depending on whether the PLL logic block is used and 10 MHz system frequency output is required or not.

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

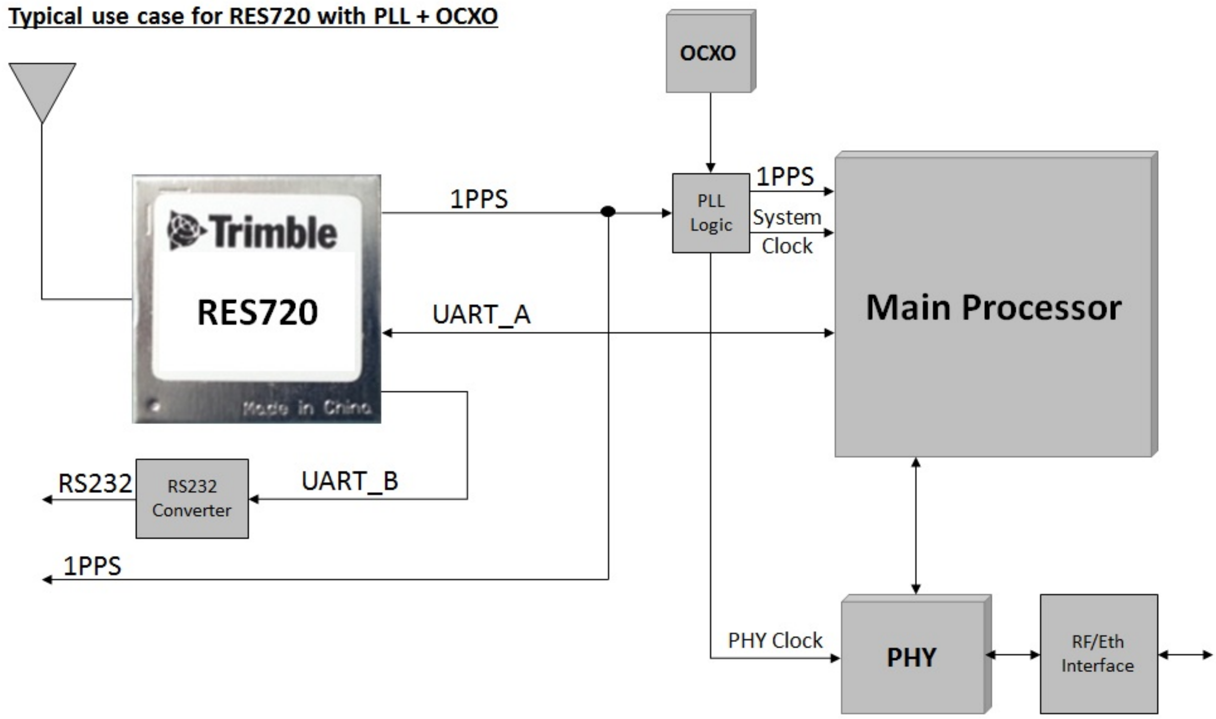


In the CSR (Cell Site Routers) application, below is a typical circuit diagram with a GNSS receiver.



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.



6

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.

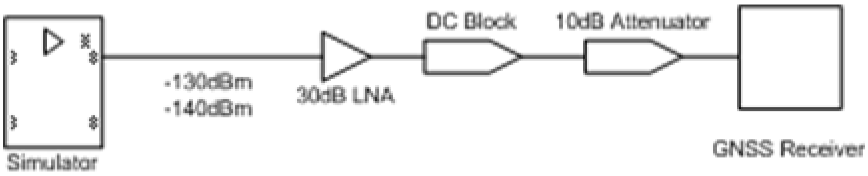
Experiment: How can I test I am receiving a good RF signal?

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.

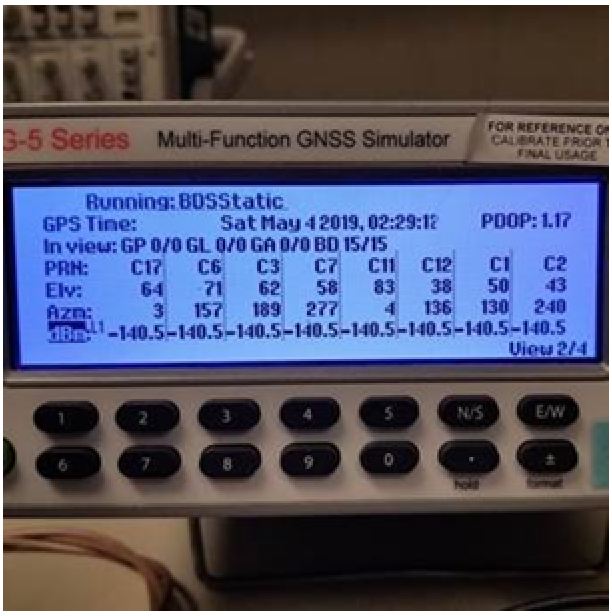
Trimble uses Spectracom GSG5/6 and Spirent GSS6700 simulators.

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.

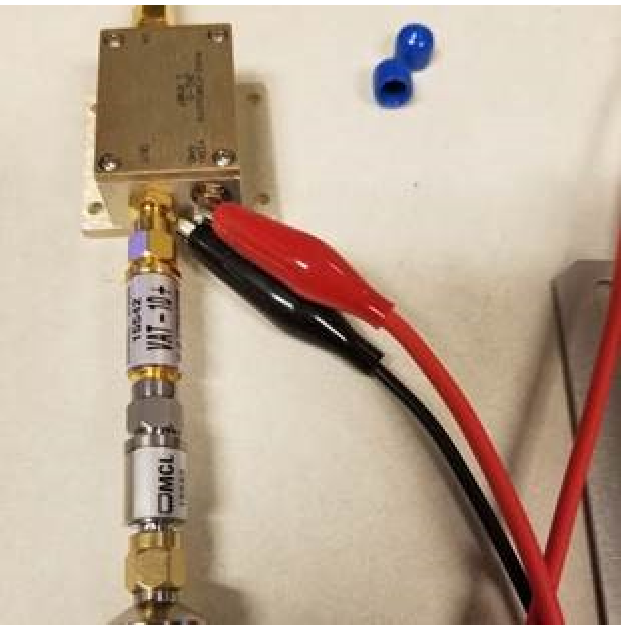


Two signal outputs were used: -130 dBm and -140 dBm:



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

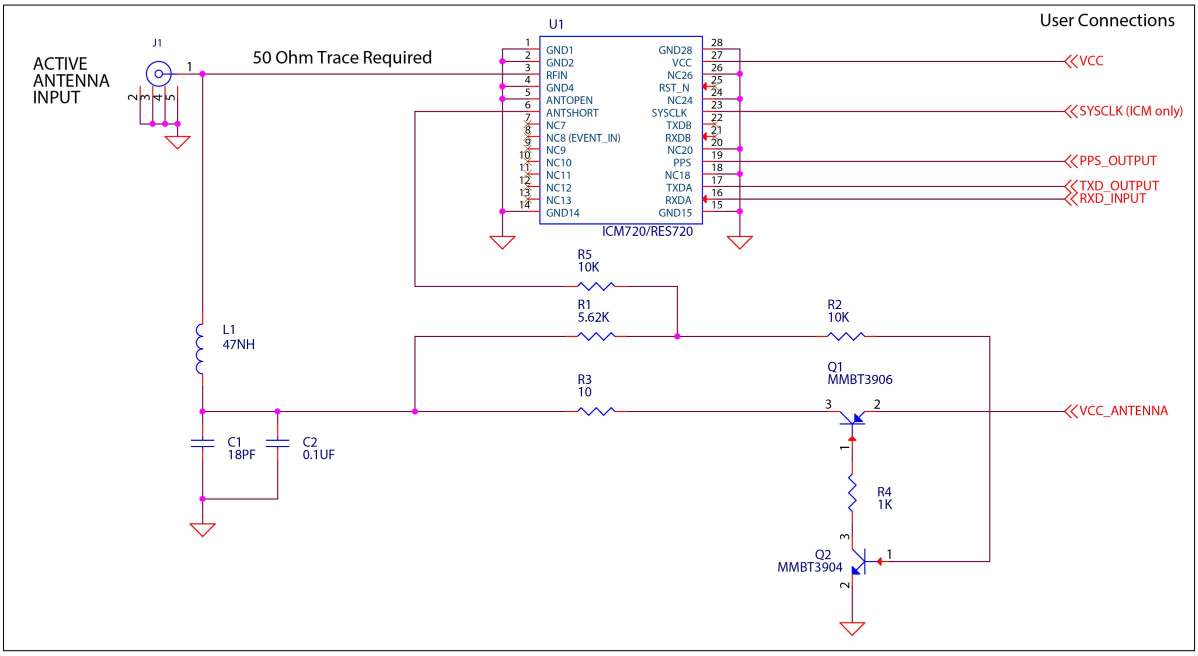
Total LNA Gain: 20 dB (10 dB attenuator added inline)

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



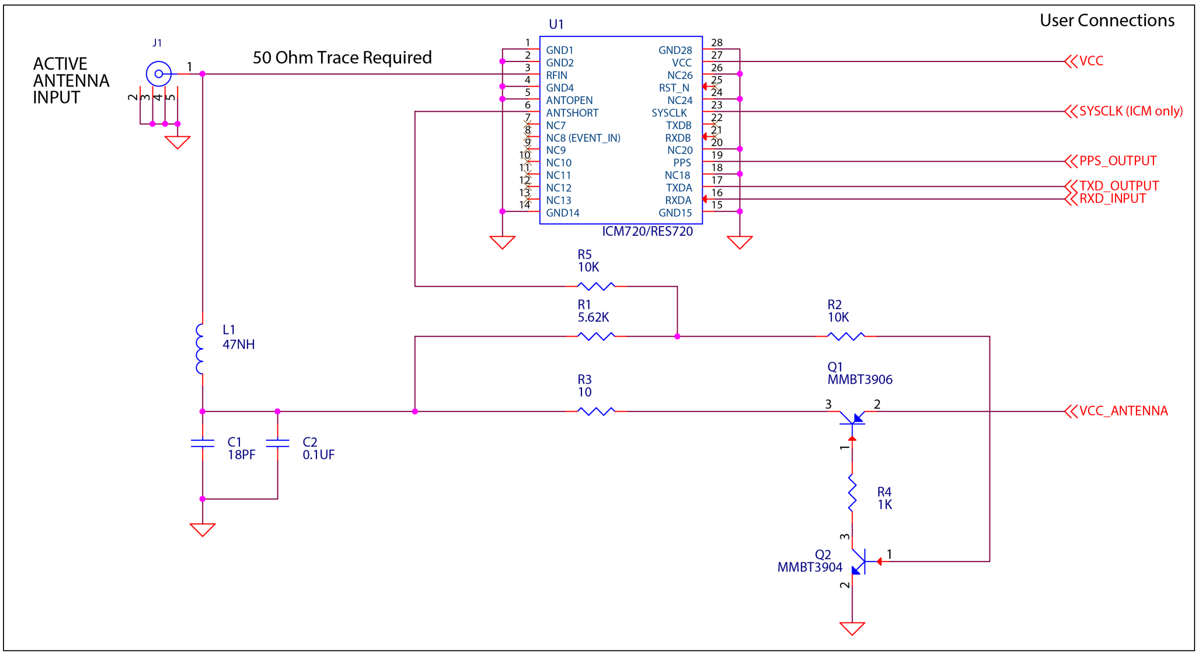
In this schematic without antenna detection:

- An active antenna is used.
- There is no hardware reset ability through the External Reset pin, as this is left disconnected.
- 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 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	47 nH, 0402 inductor, surface	Murata	LQG15HN47NJ02D

Active antenna – antenna short protection



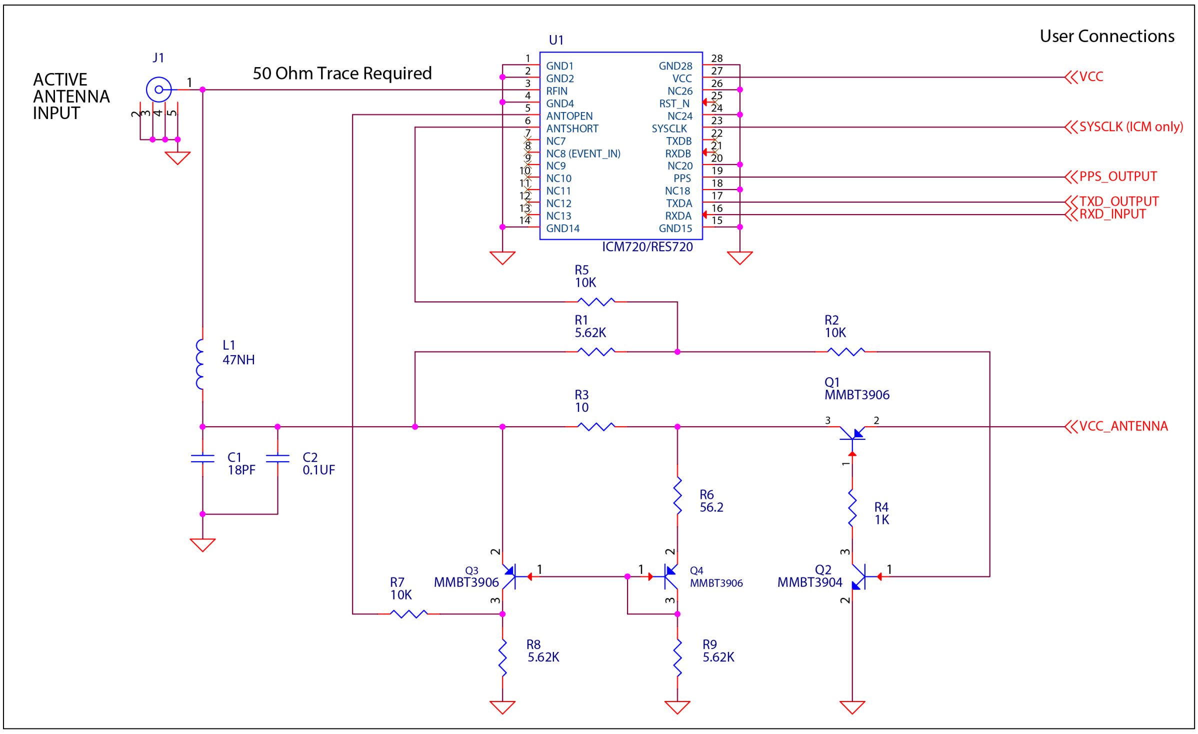
In this schematic with antenna detection:

- An active antenna is used.
- There is no hardware reset ability through the External Reset pin, as this is left disconnected.
- Antenna short detection and protection is provided. The combination of the OPEN and SHORT pins (pins 5 and 6) report the antenna status.

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	47 nH, 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 no hardware reset ability through the External Reset pin, as this is left disconnected.
- Antenna open and short detection and protection is provided. The combination of the OPEN and SHORT pins (pins 5 and 6) report the antenna status.

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	47 nH, 0402 inductor, surface	Murata	LQG15HN47NJ02D
Q1	PNP transistor	Philips	MMBT3906

Component	Description	Manufacturer	Part Number
Q2	NPN transistor	Philips	MMBT3904
Q3	PNP transistor	Philips	MMBT3906
Q4	PNP transistor	Philips	MMBT3906

7

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.

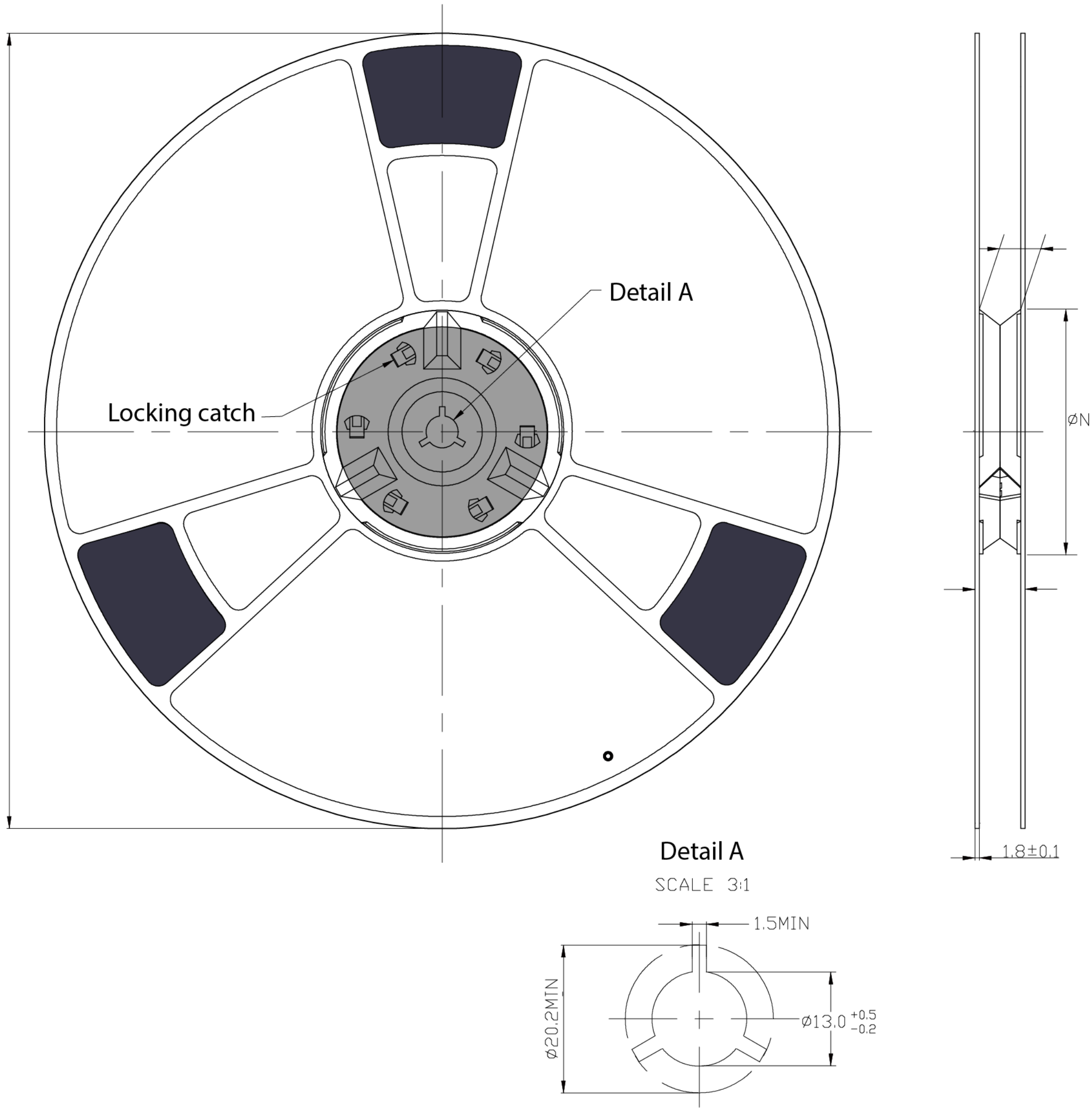
Introduction

The timing modules are packaged in tape and reel for mass production. One reel holds 500 modules. See Label, page 159 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.

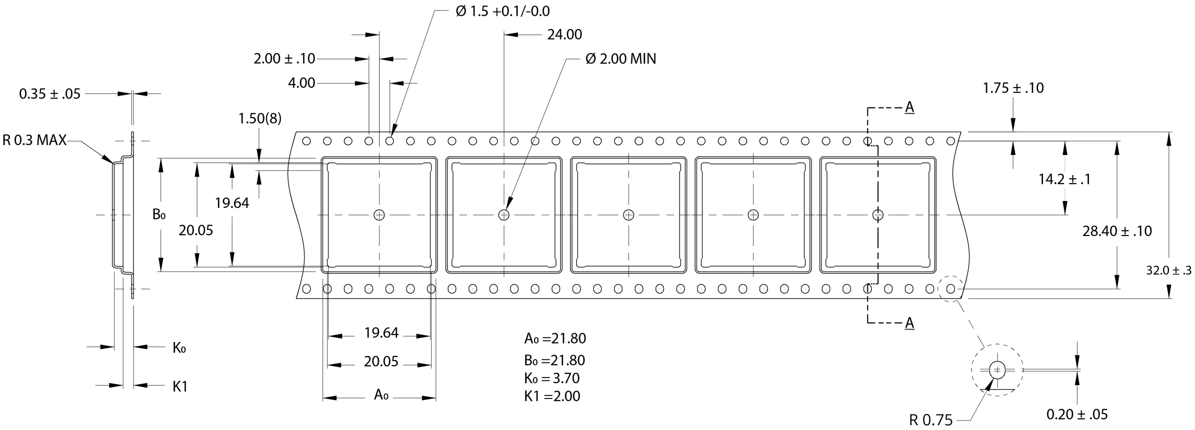


Weight

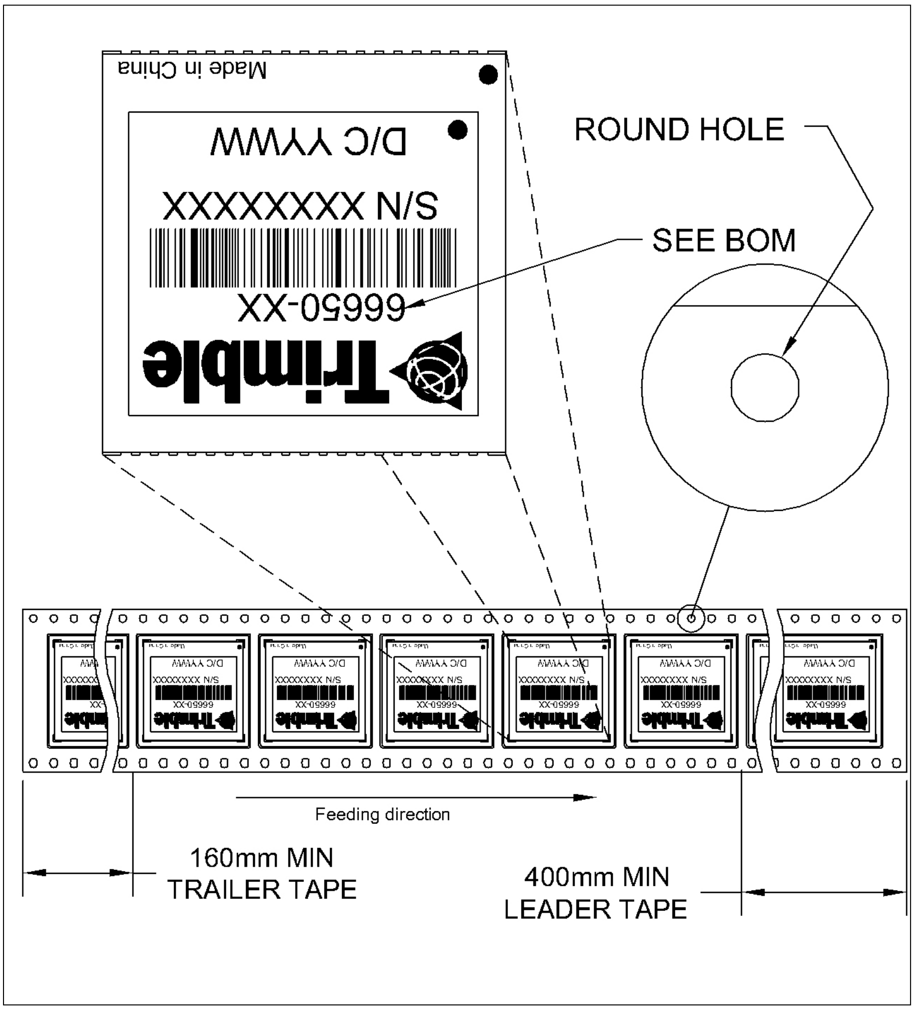
Unit description	Weight (approx.)
500 pieces with reel packaging, desiccant, and humidity indicator	1,380 g
500 pieces with reel packaging, desiccant, humidity indicator and white carton box	1,595 g

Tapes

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

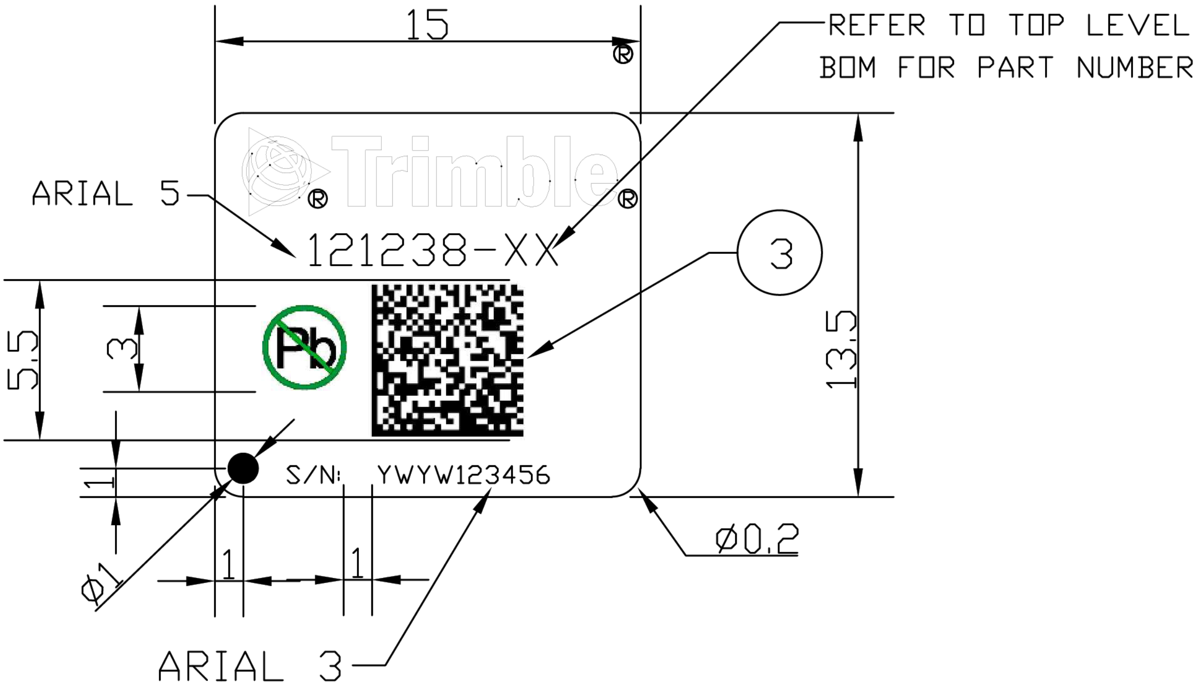


The feeding direction is illustrated below:



Label

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



8

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.