



NEO-F10T

u-blox F10 GNSS timing module

Integration manual



Abstract

This document describes the features and application of the u-blox NEO-F10T module, a low-power receiver for high-performance timing applications.

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Contents

1 System description.....	5
1.1 Overview.....	5
1.2 Architecture.....	5
1.2.1 Block diagram.....	5
1.3 Pin assignment.....	5
2 Receiver functionality.....	8
2.1 Receiver configuration.....	8
2.1.1 Basic receiver configuration.....	8
2.1.2 Navigation configuration.....	10
2.1.3 Timing receiver configuration.....	12
2.1.4 Primary and secondary output.....	13
2.2 Augmentation systems.....	15
2.2.1 SBAS.....	15
2.3 Communication interfaces and PIOs.....	17
2.3.1 UART.....	17
2.3.2 PIOs.....	17
2.4 Forcing receiver reset.....	18
2.5 Security.....	19
2.5.1 Spoofing detection and monitoring.....	19
2.5.2 Jamming and interference detection and monitoring.....	20
2.5.3 Spoofing and jamming indication.....	20
2.5.4 GNSS receiver security.....	20
2.6 Power management.....	21
2.6.1 Continuous mode.....	21
2.6.2 Backup modes.....	21
2.7 Time.....	22
2.7.1 Receiver local time.....	22
2.7.2 GNSS time bases.....	22
2.7.3 Navigation epochs.....	23
2.7.4 iTow timestamps.....	24
2.7.5 Time validity.....	24
2.7.6 UTC representation.....	25
2.7.7 Leap seconds.....	25
2.7.8 Date ambiguity.....	26
2.8 Time mark.....	27
2.9 Time pulse.....	28
2.9.1 Recommendations.....	29
2.9.2 Time pulse configuration.....	30
2.10 Time mark for Common View Time Transfer.....	31
2.11 Time maintenance.....	32
2.11.1 Real-time clock.....	32
2.11.2 Time assistance.....	32
2.11.3 Frequency assistance.....	32
2.11.4 Clock drift assistance.....	33
2.12 Multiple GNSS assistance (MGA).....	33

2.12.1 Authorization.....	33
2.12.2 Preserving MGA and operational data during power-off.....	33
2.13 Save-on-shutdown feature.....	34
2.14 Sky view signal masking.....	34
2.15 Firmware update.....	35
3 Hardware integration.....	36
3.1 Power supply.....	36
3.1.1 VCC.....	36
3.1.2 V_BCKP.....	36
3.2 RF front-end.....	36
3.2.1 Out-of-band blocking immunity.....	37
3.2.2 Out-of-band rejection.....	37
3.3 Antenna requirements.....	37
3.3.1 Antenna power supply.....	38
3.4 RF interference.....	39
3.4.1 In-band interference.....	39
3.4.2 Out-of-band interference.....	39
3.4.3 Spectrum analyzer.....	40
3.5 Layout.....	41
3.5.1 Package footprint, copper and solder mask.....	41
4 External components.....	44
4.1 Standard capacitors.....	44
4.2 Standard resistors.....	44
4.3 Inductors.....	44
5 Product handling.....	45
5.1 Safety.....	45
5.1.1 ESD precautions.....	45
5.1.2 Safety precautions.....	46
5.2 Packaging.....	46
5.2.1 Reels.....	46
5.2.2 Tapes.....	46
5.2.3 Moisture sensitivity level.....	47
5.3 Soldering.....	47
Related documents.....	51
Revision history.....	52

1 System description

This document is an important source of information for all aspects of NEO-F10T software and hardware design. The purpose of this document is to provide guidelines for a successful integration of the receiver with the customer's end product.

1.1 Overview

The NEO-F10T is a multi-band GNSS module offering 5 ns (1-sigma, with jitter removed) timing accuracy with unparalleled low power consumption. The NEO-F10T incorporates the u-blox F10 L1/L5 dual-band platform in a 16 x 12 mm LCC package.

The NEO-F10T offers backwards pin-to-pin compatibility with products from the previous u-blox generations, which saves the designer's effort and reduces costs when upgrading designs.

1.2 Architecture

The NEO-F10T receiver provides all the necessary RF and baseband processing to enable dual-band operation. The block diagram below shows the key functionality.

1.2.1 Block diagram

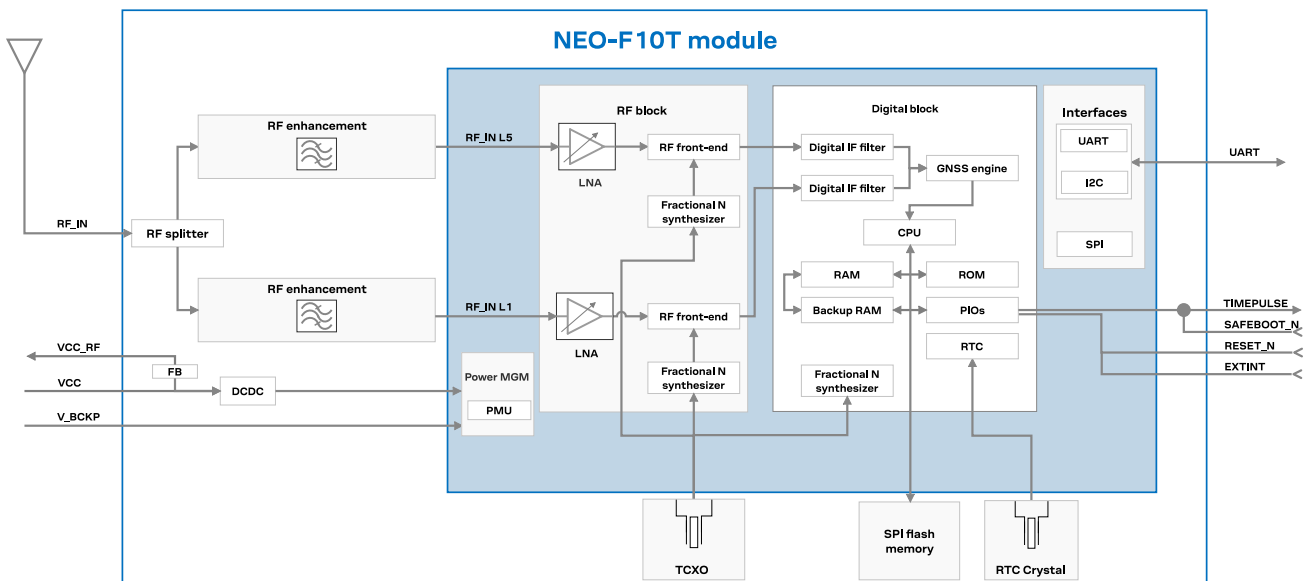
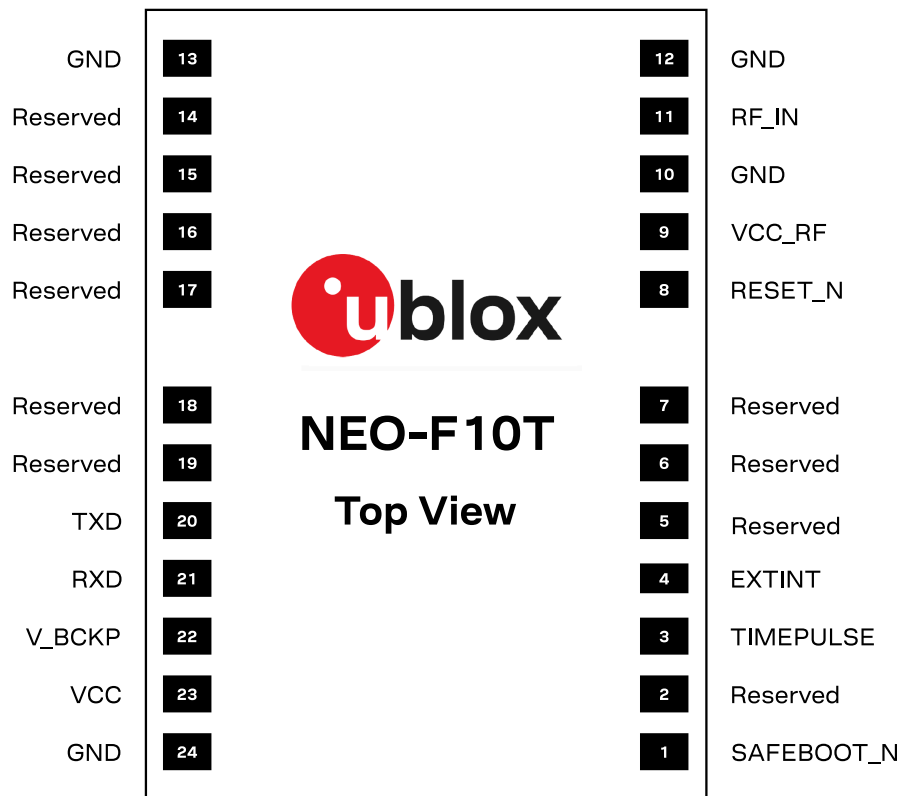


Figure 1: NEO-F10T block diagram

1.3 Pin assignment

The pin assignment of the NEO-F10T module is shown in [Figure 2](#). The defined configuration of the PIOs is listed in [Table 1](#).


Figure 2: NEO-F10T pin assignment

Pin no.	Name	I/O	Description
1	SAFEBOOT_N	I	Safeboot mode. If not used, leave open. ¹
2	Reserved	-	Not connected
3	TIMEPULSE	O	Time pulse signal (1 PPS, Not to be pulled hi/low on start-up) ¹
4	EXTINT	I	External interrupt
5	Reserved	-	Not connected
6	Reserved	-	Not connected
7	Reserved	-	Not connected
8	RESET_N	I	RESET (active low)
9	VCC_RF	O	Output voltage RF section
10	GND	-	Ground
11	RF_IN	I	GNSS signal input
12	GND	-	Ground
13	GND	-	Ground
14	Reserved	-	Not connected
15	Reserved	-	Not connected
16	Reserved	-	Not connected
17	Reserved	-	Not connected
18	Reserved	-	Not connected
19	Reserved	-	Not connected

¹ The receiver enters safeboot mode if SAFEBOOT_N pin is low at start up. The SAFEBOOT_N pin is internally connected to TIMEPULSE pin through a 1 kΩ series resistor.

Pin no.	Name	I/O	Description
20	TXD	O	UART TX
21	RXD	I	UART RX
22	V_BCKP	I	Backup voltage supply
23	VCC	I	Supply voltage
24	GND	-	Ground

Table 1: NEO-F10T pin assignment

2 Receiver functionality

This chapter provides a description of the receiver's functionality.

2.1 Receiver configuration

The configuration determines all aspects of the GNSS receiver operation and therefore, information in this section is essential for the successful integration of NEO-F10T.


NEO-F10T is configured using UBX configuration interface keys. The configuration database in the receiver's RAM holds the current configuration, which is used by the receiver at runtime. It is constructed at the receiver startup from several sources of configuration. For more information on the receiver configuration, see the Interface description [2].

The configuration can be stored in the RAM, battery-backed RAM (BBR), and flash memory. The permanence of the stored configuration and the actions to clear it in each memory are listed in [Table 2](#).

Memory	Permanence of storage	Clearing actions
RAM	Settings remain effective until power-down	<ul style="list-style-type: none"> Activating the RESET_N pin A UBX-CFG-RST message excluding GNSS stop (resetMode 0x08) and GNSS start (resetMode 0x09) Entering software standby mode
BBR	The receiver retains the settings stored as long as the backup power supply remains	<ul style="list-style-type: none"> Activating the RESET_N pin A UBX-CFG-RST message with reset mode set to a hardware reset (resetMode 0x00 and 0x04)
Flash	Permanent storage of the configuration settings	<ul style="list-style-type: none"> A UBX-CFG-CFG message to erase the configuration on the flash layer

Table 2: Permanence of storage and clearing actions for each memory

It is recommended to apply runtime configuration on both RAM and BBR or flash memory layers. For more information about the UBX-CFG-RST message, refer to [Forcing receiver reset](#).

 **CAUTION** The configuration interface has changed from earlier u-blox positioning receivers. Users must adopt the configuration interface described in this document.

The configuration interface settings are stored in a database consisting of separate configuration items. An item is made up of a pair consisting of a key ID and a value. Related items are grouped together and identified under a common group name: CFG-GROUP-*; a convention used in u-center 2 and within this document. Within u-center 2, a configuration group is identified as "Group name" and the configuration item is identified as the "item name" in the "Device configuration" window.

The UBX messages available to change or poll the configurations are the UBX-CFG-VALSET, UBX-CFG-VALGET, and UBX-CFG-VALDEL messages. For more information about these messages and the configuration keys, see the configuration interface section in the Interface description [2].

2.1.1 Basic receiver configuration

This section summarizes the most commonly used, basic receiver configurations.



2.1.1.1 GNSS signal configuration

NEO-F10T supports reception of GPS, Galileo, BeiDou dual-band signals plus NavIC SPS-L5 and GLONASS L1OF. The default configuration is concurrent reception of GPS (L1C/A), Galileo (E1-B/C,E5a) and BeiDou (B1C,B2a) with QZSS (L1C/A, L5) and SBAS enabled.

GNSS constellations and signals can be configured using the CFG-SIGNAL-* configuration group. Each GNSS constellation can be enabled or disabled independently except for QZSS and SBAS, which are functional only with GPS. In addition to the configuration key for each constellation, there is a configuration key for each signal supported by the firmware.

For example, if CFG-SIGNAL-GPS_ENA is set to zero, all signals from the GPS constellation are disabled. Alternatively, if CFG-SIGNAL-GPS_L1CA_ENA is set to zero, only the GPS L1 C/A signal is disabled.

Unsupported combinations are rejected with a UBX-ACK-NAK message, and the warning "inv sig cfg" is sent via UBX-INF and NMEA-TXT messages (if enabled).

-  Any change to the signal configuration items triggers a restart of the GNSS subsystem. During the restart, the host application should wait for message acknowledgement and a margin of 0.5 seconds prior to sending any further commands.
-  It is recommended to enable QZSS L1C/A when GPS L1C/A is enabled to mitigate possible cross-correlation issues between the signals.

For more information on the CFG-SIGNAL-* configuration group, refer to the Interface description [2].

2.1.1.2 Communication interface configuration

Several configuration groups allow configuring the operation mode of the communication interfaces. These include parameters for the data framing, transfer rate and enabled input/output protocols. See [Communication interfaces and PIOs](#) section for details. The configuration groups available for each interface are:

Interface	Configuration groups
UART	CFG-UART1-*, CFG-UART1INPROT-*, CFG-UART1OUTPROT-*

Table 3: Interface configuration

2.1.1.3 Basic hardware configuration

The NEO-F10T receiver is configured with the default settings during the module production. The receiver starts up and is fully operational as soon as proper power supply, communication interfaces and antenna signal from the host application device are connected.

2.1.1.4 Message output configuration

The receiver supports two protocols for output messages: industry-standard NMEA and u-blox UBX. Any message type can be enabled or disabled individually and the output rate is configurable.

The message output rate is related to the frequency of an event. For example, the output message UBX-NAV-PVT (position, velocity, and time solution) is related to the navigation event, which generates a navigation epoch. In this case, the rate for each navigation epoch is defined by the configuration keys CFG-RATE-MEAS and CFG-RATE-NAV. For example, a value of 1000 ms in CFG-RATE-MEAS indicates that a measurement is done every second. If CFG-RATE-NAV is set to one (1), the solution is calculated for every measurement. This means that a navigation epoch is calculated every 1000 ms. If the rate is set to two (2), only the second measurement is used and the navigation epoch is calculated every two seconds. The same result is obtained if CFG-RATE-MEAS is set to 2000 ms, and CFG-RATE-NAV is set to one (1). Every 2000 ms a measurement is done, and in every measurement, a navigation epoch is calculated. However, this second option demands fewer resources and is the correct procedure when the navigation rate is changed. Setting a navigation rate value higher than one (1) is only needed when it is required that the raw measurement data is output at a higher rate than the navigation data.

The output rate for each message is defined in the CFG-MSGOUT-* configuration group. If the output rate of the message is set to one (1) on the UART interface, CFG-MSGOUT-UBX_NAV_PVT_UART1 = 1, the message is output for every navigation epoch. If the rate is set to two (2), the message is output for every other navigation epoch. If the rate is zero (0), then corresponding message is not output. As seen in this example, the rates of the output messages are individually configurable per communication interface.

Some messages, such as UBX-MON-VER, are non-periodic and are only output as an answer to a poll request.

The UBX-INF-* and NMEA-Standard-TXT information messages are non-periodic output messages that do not have a message rate configuration. Instead they can be enabled for each communication interface via the CFG-INFMSG-* configuration group.



All message output is additionally subject to the protocol configuration of the communication interfaces. Messages of a given protocol are not output unless the protocol is enabled for output on the interface. See [Communication interface configuration](#) for details.

2.1.2 Navigation configuration

This section presents various configuration options related to the navigation engine. These options can be configured through CFG-NAVSPG-* configuration keys.

2.1.2.1 Dynamic platform

The dynamic platform model can be configured through the CFG-NAVSPG-DYNMODEL configuration item. For the supported dynamic platform models and their details, see [Table 4](#) and [Table 5](#).

Platform	Description
Portable	Applications with low acceleration, e.g. portable devices. Suitable for most situations.
Stationary (default)	Used in timing applications (antenna must be stationary) or other stationary applications. Velocity restricted to 0 m/s. Zero dynamics assumed.
Pedestrian	Applications with low acceleration and speed, e.g. how a pedestrian would move. Low acceleration assumed.
Automotive	Used for applications with equivalent dynamics to those of a passenger car. Low vertical acceleration assumed.
At sea	Recommended for applications at sea, with zero vertical velocity. Zero vertical velocity assumed. Sea level assumed.
Airborne <1g	Used for applications with a higher dynamic range and greater vertical acceleration than a passenger car. No 2D position fixes supported.
Airborne <2g	Recommended for typical airborne environments. No 2D position fixes supported.
Airborne <4g	Only recommended for extremely dynamic environments. No 2D position fixes supported.
Wrist	Only recommended for wrist-worn applications. Receiver will filter out arm motion.

Table 4: Dynamic platform models

Platform	Max altitude [m]	Max horizontal velocity [m/s]	Max vertical velocity [m/s]	Sanity check type	Max position deviation
Portable	12000	310	50	Altitude and velocity	Medium
Stationary	9000	10	6	Altitude and velocity	Small
Pedestrian	9000	30	20	Altitude and velocity	Small
Automotive	6000	100	15	Altitude and velocity	Medium
At sea	500	25	5	Altitude and velocity	Medium
Airborne <1g	80000	100	6400	Altitude	Large

Platform	Max altitude [m]	Max horizontal velocity [m/s]	Max vertical velocity [m/s]	Sanity check type	Max position deviation
Airborne <2g	80000	250	10000	Altitude	Large
Airborne <4g	80000	500	20000	Altitude	Large
Wrist	9000	30	20	Altitude and velocity	Medium

Table 5: Dynamic platform model details

Applying dynamic platform models designed for high acceleration systems (e.g. airborne <2g) can result in a higher standard deviation in the reported position.

If a sanity check against the limit of the dynamic platform model fails, the position solution becomes invalid. Table 5 shows the types of sanity checks which are applied for a particular dynamic platform model.

2.1.2.2 Navigation input filters

The navigation input filters in the CFG-NAVSPG-* configuration group control how the navigation engine handles the input data that comes from the satellite signal.

Configuration item	Description
CFG-NAVSPG-FIXMODE	By default, the receiver calculates a 3D position fix if possible but it reverts to 2D position if necessary (auto 2D/3D). The receiver can be configured to only calculate 2D (2D only) or 3D (3D only) positions. ²
CFG-NAVSPG-CONSTR_ALT, CFG-NAVSPG-CONSTR_ALTVAR	The fixed altitude is used if fixMode is set to 2D only. A variance greater than zero must also be supplied. ²
CFG-NAVSPG-INFIL_MINELEV	Minimum elevation of a satellite above the horizon to be used in the navigation solution. Low-elevation satellites may provide degraded accuracy, due to the long signal path through the atmosphere.
CFG-NAVSPG-INFIL_MINSVS, CFG-NAVSPG-INFIL_MAXSVS	Minimum and maximum number of satellites to use in the navigation solution. There is an absolute maximum limit of 32 satellites that can be used for navigation.
CFG-NAVSPG-INFIL_NCNOTHRS, CFG-NAVSPG-INFIL_CNOTHRS	A navigation solution will only be attempted if there is at least the given number of satellites with signals at least as strong as the given threshold.

Table 6: Navigation input filter parameters

If the receiver has only three satellites for calculating a position, the navigation algorithm uses a constant altitude to compensate for the missing fourth satellite. This is called a 2D fix. The constant altitude value is taken from the last successful 3D fix using a minimum of four available satellites.

2.1.2.3 Navigation output filters

The result of a navigation solution is initially classified by the fix type (as detailed in the `fixType` field of the UBX-NAV-PVT message). This distinguishes between failures to obtain a fix ("No Fix") and cases where a fix has been achieved, which are further subdivided into specific types of fixes (for example, 2D, 3D, Time).

Where a fix has been achieved, the fix is checked to determine whether it is valid or not. A fix is only valid if it passes the navigation output filters as defined in CFG-NAVSPG-OUTFIL. In particular, both PDOP and accuracy values must be below the respective limits.



Important: Users are recommended to check the `gnssFixOK` flag in the UBX-NAV-PVT or the NMEA valid flag. Fixes not marked as valid should not be used.

² This configuration is ignored when in Time Mode, i.e. after a position survey-in or fixed location parameters have been set

UBX-NAV-STATUS message also reports whether a fix is valid in the `gpsFixOK` flag. These messages have only been retained for backwards compatibility and it is recommended to use the UBX-NAV-PVT message.

2.1.3 Timing receiver configuration

Time mode is a receiver mode specific to timing products where the receiver position is fixed and only time and frequency is estimated using all available satellites. This mode allows for maximum time accuracy and provides operation down to single-SV solutions.

In order to use the time mode, the receiver's position must be known as accurately as possible. Errors in the fixed position will translate into time errors depending on the satellite constellation.

The following procedures can be used to initialize the timing receiver position:

- Using the built-in survey-in procedure to estimate the position.
- Providing coordinates from an independently generated survey or from a known accurate position such as a survey marker.

2.1.3.1 Survey-in

Survey-in is a procedure that is carried out prior to entering the time mode. It estimates the receiver position by building a weighted mean of all valid 3D position solutions.

Two major parameters are required when configuring:

- A **minimum observation** time defines the minimum observation time independent of the actual number of fixes used for the position estimate. Values can range from one day for high accuracy requirements to a few minutes for coarse position determination.
- A **3D position standard deviation** defines a limit on the spread of positions that contribute to the calculated mean.

Survey-in ends when both requirements are successfully met. The Survey-in status can be queried using the UBX-TIM-SVIN message.

To configure a timing receiver into Survey-in mode (CFG-TMODE-MODE=SURVEY_IN), the following items are required:

Configuration item	Description
CFG-TMODE-MODE	Receiver mode (disabled, survey-in or fixed)
CFG-TMODE-SVIN_MIN_DUR	Survey-in minimum duration
CFG-TMODE-SVIN_ACC_LIMIT	Survey-in position accuracy limit. The accuracy of given coordinates in 0.0001 meters (i.e. value 100 equals 1 cm)

Table 7: Configuration items used for setting a timing receiver into Survey-in mode



Set the configuration items shown above into flash memory to perform a survey-in procedure automatically on startup.

2.1.3.2 Fixed position

Here the timing receiver position coordinates are entered manually. Any error in the timing receiver position will directly translate into timing errors.

To configure into Fixed mode (CFG-TMODE-MODE=FIXED), the following items are relevant:


Configuration item	Description
CFG-TMODE-MODE	Receiver mode (disabled or survey-in or fixed)
CFG-TMODE-POS_TYPE	Determines whether the ARP position is given in ECEF or LAT/LON/HEIGHT
CFG-TMODE-ECEF_X	ECEF X coordinate of the ARP position, coordinate in centimeters

Configuration item	Description
CFG-TMODE-ECEF_Y	ECEF Y coordinate of the ARP position, coordinate in centimeters
CFG-TMODE-ECEF_Z	ECEF Z coordinate of the ARP position, coordinate in centimeters
CFG-TMODE-LAT	Latitude of the ARP position, coordinate in 1e-7 degrees
CFG-TMODE-LON	Longitude of the ARP position, coordinate in 1e-7 degrees
CFG-TMODE-HEIGHT	Height of the ARP position, coordinate in centimeters
CFG-TMODE-ECEF_X_HP	High-precision ECEF X coordinate of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-ECEF_Y_HP	High-precision ECEF Y coordinate of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-ECEF_Z_HP	High-precision ECEF Z coordinate of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-LAT_HP	High-precision latitude of the ARP position, coordinate in 1e-9 degrees
CFG-TMODE-LON_HP	High-precision longitude of the ARP position, coordinate in 1e-9 degrees
CFG-TMODE-HEIGHT_HP	High-precision height of the ARP position, coordinate in 0.1 millimeters
CFG-TMODE-FIXED_POS_ACC	Fixed position 3D accuracy estimate

Table 8: Configuration items used for setting a timing receiver into fixed mode

Once the receiver is set in fixed mode, select the position format to use: either LLH or ECEF with optional high precision (mm) coordinates compared to the standard cm value.

For example, with CFG-TMODE-POS_TYPE=ECEF the timing receiver antenna position can be entered to cm precision using CFG-TMODE-ECEF_X, CFG-TMODE-ECEF_Y, CFG-TMODE-ECEF_Z. For high precision (mm) coordinates use CFG-TMODE-ECEF_X_HP, CFG-TMODE-ECEF_Y_HP, CFG-TMODE-ECEF_Z_HP. The same applies with corresponding coordinates used with CFG-TMODE-POS_TYPE=LLH.

-  If the timing receiver is moved during operation then new position coordinates must be configured.

2.1.4 Primary and secondary output


2.1.4.1 Introduction


u-blox GNSS receivers output various navigation results and data calculated as part of the navigation solution. These include results such as position, altitude, velocity, status flags, accuracy estimate figures, satellite/signal information and more.

The NEO-F10T can provide this output in two streams:

- **Primary output:** Reports the results of a full navigation solution using all capabilities of the NEO-F10T, such as, for example, time mode.
- **Secondary output:** Reports the results of a GNSS standalone navigation solution.

Both the primary output and secondary output provide a similar set of information but the two outputs report different results. The primary output is reported in the form of UBX-NAV-* messages, while the secondary output is reported in the form of UBX-NAV2-* messages. Therefore, the UBX message class can be used to distinguish between the primary output and the secondary output. For the specification of the UBX-NAV2-* messages and for a full list of available UBX-NAV2-* messages, see the applicable Interface description [2].

-  The secondary output is also available as NMEA-NAV2-* messages. For simplicity this section refers only to UBX-NAV2-* messages but the same information applies for NMEA-NAV2-* messages.

-  The secondary output is complementary to the primary output. It does not provide the full navigation solution of the primary output. It can be used to expand the applications of the

NEO-F10T to enable using a second navigation solution in parallel with the primary navigation solution.

The rest of this section describes how to configure and use the secondary output, what is the expected output behavior, and provides examples that illustrate potential uses for the secondary output, while highlighting the differences between the primary and the secondary output.

2.1.4.2 Configuration

Configuring the secondary output to the application's needs requires:

- Enabling the secondary output
- Configuring the desired secondary output UBX-NAV2-* messages
- Optionally, configuring the properties of the secondary output navigation solution

The configuration items relevant to the secondary output are in the CFG-NAV2-* configuration group. The configuration items for enabling and configuring the output rate of the UBX-NAV2-* messages are in the CFG-MSGOUT-* group and are of the form CFG-MSGOUT-UBX_NAV2_*. An example set of secondary output configuration items is shown in the table below. For all available configuration items, see the applicable Interface description [2].

Configuration item	Description
CFG-NAV2-OUT_ENABLED	Enables secondary output
CFG-NAV2-SBAS_USE_INTEGRITY	Enables using SBAS integrity information in the secondary output
CFG-MSGOUT-UBX_NAV2_PVT_*	Enables UBX-NAV2-PVT secondary output message
CFG-MSGOUT-UBX_NAV2_TIMEGPS_*	Enables UBX-NAV2-TIMEGPS secondary output message

Table 9: Example secondary output configuration items

Enabling the secondary output: The first necessary step to enable the secondary output is to configure the CFG-NAV2-OUT_ENABLED configuration item appropriately. This will enable the secondary output navigation solution to run in parallel with the primary output navigation solution. By default, the secondary output is disabled. Note that if you do not follow the next step, there will be no secondary output visible in the NEO-F10T communication interfaces in the form of UBX-NAV2-* messages.



Both primary and secondary output report a navigation solution computed at the same navigation rate. Enabling the secondary output may affect the maximum achievable navigation update rate due to the extra computational receiver load.

Configuring the desired secondary output UBX-NAV2-* messages: The second necessary step is to configure the desired CFG-MSGOUT-UBX_NAV2_* configuration items appropriately. These set the message output rates for the UBX-NAV2-* messages that you wish to output. By default, all UBX-NAV2-* message output rates are set to 0 and as such are not being output.



Due to the increased message output, the interface load will be higher while the secondary output messages are enabled. Therefore, the interface baud rate may need to be adapted accordingly. Alternatively, it is possible to configure the UBX-NAV2-* messages with a different output rate from that of their primary output UBX-NAV-* counterparts.

Configuring the properties of the secondary output navigation solution: Optionally, it is possible to configure the properties of the secondary output navigation solution in order to adapt it to the application's needs.

A minimal subset of the primary output navigation solution configuration is available for the secondary output navigation solution configuration. All such available configuration items are in the CFG-NAV2-* configuration group (see applicable Interface description [2]).



Configuring any of the CFG-NAV2-* configuration items changes the behavior of the secondary output navigation solution only and not the primary output one. All such configuration items have a primary output configuration counterpart and have the same default value as their primary output configuration counterpart. Refer [Example use cases](#) section.

2.1.4.3 Expected output behavior

Once the secondary output is enabled and the desired secondary output UBX-NAV2-* messages are configured, the NEO-F10T will output both primary and secondary output data in the form of the enabled UBX-NAV-* and UBX-NAV2-* messages respectively.

In every navigation epoch, a set of UBX-NAV-* messages will be output followed by another set of UBX-NAV2-* messages. Both sets will be referring to the navigation solution of the same navigation epoch.

Each set will be delimited at its end with a UBX-NAV-EOE or a UBX-NAV2-EOE message respectively. In other words, a UBX-NAV-EOE message will be output at the end of the UBX-NAV-* class enabled messages and a UBX-NAV2-EOE message will be output at the end of the UBX-NAV2-* class enabled messages. For example, if only UBX-NAV-PVT, UBX-NAV2-PVT, UBX-NAV-TIMEGPS and UBX-NAV2-TIMEGPS are enabled on the same port with message output rate 1, then every navigation epoch output will be as follows: UBX-NAV-PVT, UBX-NAV-TIMEGPS, UBX-NAV-EOE, UBX-NAV2-PVT, UBX-NAV2-TIMEGPS, UBX-NAV2-EOE.

-  Secondary output messages appear after the primary output messages. This results in a higher latency for the secondary output messages than the primary output messages.
-  Contrary to UBX-NAV2-* messages, secondary output NMEA-NAV2-* messages are not delimited by an NMEA-equivalent to UBX-NAV-EOE.

The specification of the UBX-NAV2-* messages resembles that of the UBX-NAV-* messages. The payload specification of a UBX-NAV2 message is identical to the payload specification of its UBX-NAV counterpart, allowing to easily adapt any existing message parsers. The primary output will contain results and data reflecting the full navigation solution of the NEO-F10T. The secondary output will contain results and data reporting a GNSS standalone navigation solution.

2.1.4.4 Example use cases

As an example, an application using a NEO-F10T that has been configured into time mode can enable the secondary output and monitor a GNSS standalone solution to average the position of the NEO-F10T over time to detect if the antenna position has moved with respect to the surveyed-in location.

2.2 Augmentation systems

2.2.1 SBAS

NEO-F10T is capable of receiving multiple Satellite Based Augmentation System (SBAS) signals concurrently, even from different SBAS systems (WAAS, EGNOS, etc.).

For receiving correction data, NEO-F10T automatically chooses the best SBAS satellite as its primary source. It selects only one satellite since the information received from other SBAS satellites is redundant and could be inconsistent. The selection strategy is determined by the proximity of the satellites, the services offered by the satellite, the configuration of the receiver (test mode allowed/disallowed, integrity enabled/disabled) and the signal link quality to the satellite.

If corrections are available from the chosen SBAS satellite and used in the navigation calculation, the correction status will be indicated in UBX-NAV-SIG message group. The UBX-NAV-SBAS message

provides detailed information about which corrections are available and applied. Refer to the Interface description [2] for a detailed description of the messages.

The most important SBAS feature for timing accuracy improvement is the ionosphere correction parameters. The measured data from regional Ranging and Integrity Monitoring Stations (RIMS) are combined to make a Total Electron Content (TEC) map. This map is transferred to the receiver via SBAS satellites to allow a correction of the ionosphere delays on each received signal. By default, NEO-F10T uses ionospheric corrections from SBAS and will apply them over any dual frequency - derived delay estimates. If SBAS or dual frequency - derived estimates are not available, the receiver will revert to using the broadcast Klobuchar parameters.



Message type	Message content	Source
0(0/2)	Test mode	All
1	PRN mask assignment	Primary
17	Satellite almanac	All
18	Ionosphere grid point assignment	Primary
26	Ionosphere delays	Primary

Table 10: Supported SBAS messages

To configure the SBAS functionality, use the CFG-SBAS-* configuration group.

Parameter	Description
CFG-SBAS-USE_TESTMODE	Allow/disallow SBAS usage from satellites in test mode
CFG-SBAS-USE_IONOONLY	Allow/disallow usage of SBAS ionospheric corrections only(enabled by default)
CFG-SBAS-PRNSCANMASK	Allows selectively enabling/disabling SBAS satellites

Table 11: SBAS configuration parameters

-  Ionospheric correction service is the only SBAS service supported by NEO-F10T. Default SBAS operation mode is CFG-SBAS-USE_IONOONLY enabled.
-  Although u-blox receivers try to select the best available SBAS correction data, it is recommended to configure them to exclude the unwanted SBAS satellites.

Each satellite serves a specific region and its correction signal is only useful within that region. Planning is crucial to determine the best possible configuration, especially in areas where signals from different SBAS systems can be received:

- **Example 1 - SBAS receiver in North America:** In eastern parts of North America, make sure that EGNOS satellites do not take preference over WAAS satellites. The satellite signals from the EGNOS system should be disallowed by using the PRN scan mask (configuration key CFG-SBAS-PRNSCANMASK).
- **Example 2 - SBAS receiver in Europe:** Some WAAS satellite signals can be received in some parts of western Europe as well as GAGAN SBAS satellites in some parts of Europe, therefore it is recommended that the satellites from all but the EGNOS system should be disallowed using the PRN scan mask.

2.3 Communication interfaces and PIOs


NEO-F10T supports communication over UART for communication with a host system. UBX and NMEA protocols can be enabled simultaneously with individual interface settings, e.g. for baud rate, message rates, and so on.

2.3.1 UART

NEO-F10T supports a Universal Asynchronous Receiver/Transmitter (UART) port consisting of an RX and a TX line. The UART can be used as a host interface which supports a configurable baud rate and protocol selection.

 The UART interface does not support handshaking signals or hardware flow control signals.


The UART baud rate can be configured for selected speeds. Different rates than these speeds are not supported for transmission and reception.

 The UART RX interface is disabled when more than 100 frame errors are detected during a one-second period. This can happen if the wrong baud rate is used or the UART RX pin is grounded. An error message appears when the UART RX interface is re-enabled at the end of the one-second period.

Baud rate	Data bits	Parity	Stop bits
4800	8	none	1
9600	8	none	1
19200	8	none	1
38400	8	none	1
57600	8	none	1
115200	8	none	1
230400	8	none	1
460800	8	none	1
921600	8	none	1

Table 12: Possible UART interface configurations

Allow a short time delay of typically 100 ms between sending a baud rate change message and providing input data at the new rate. Otherwise some input characters may be ignored or the port could be disabled until the interface is able to process the new baud rate.

 The default baud rate is 38400 baud. Using a lower baud rate may cause buffering problems.



If there is too much data for the interface's bandwidth, the output buffer will fill up. Once the buffer space is exceeded, new messages to be sent will be dropped. To prevent message loss, the baud rate and the number of enabled messages should be selected carefully.

2.3.2 PIOs

This section describes the PIOs supported by NEO-F10T. All PIO active voltage levels are related to the VCC supply voltage. All the inputs have internal pull-up resistors in normal operation and can be left open if unused.


2.3.2.1 RESET_N

NEO-F10T provides a RESET_N pin to reset the receiver. The RESET_N pin is input-only with an internal pull-up resistor to VCC and should be left open for normal operation. Driving RESET_N low for at least 1 ms will trigger a reset of the receiver. The RESET_N complies with the VCC level and can be actively driven high.

-  Use RESET_N only in critical situations to recover the receiver. RESET_N resets the receiver and clears the BBR content including receiver configuration, real-time clock (RTC), and GNSS orbit data, triggering a cold start.
-  No capacitor should be placed at RESET_N to GND, otherwise it could trigger a reset on every startup.


2.3.2.2 SAFEBOOT_N

The SAFEBOOT_N pin is for future service, updates and reconfiguration.

-  The SAFEBOOT_N pin is internally connected to the TIMEPULSE pin through a 1 kΩ series resistor.

2.3.2.3 TIMEPULSE

The NEO-F10T features one time pulse output at the TIMEPULSE pin. The details about this feature are explained in the section [Time pulse](#).

-  The TIMEPULSE and SAFEBOOT_N functions share the same internal IC function. If this pin is low at receiver startup, the receiver will enter safeboot mode. However, in normal operation the pin outputs the time pulse signal. Make sure this pin has no load that could pull it low at startup.

2.3.2.4 EXTINT

NEO-F10T supports external interrupts at the EXTINT pin. The EXTINT pin has a fixed input voltage threshold with respect to VCC. It can be used for functions such as accurate external [Frequency assistance](#), [Time assistance](#) and [Time mark](#) reporting.

2.4 Forcing receiver reset

GNSS receivers typically make a distinction between cold, warm, and hot start based on the type of valid information the receiver has during the restart.

- **Cold start:** in the cold start mode, the receiver has no information from the last position (e.g. time, velocity, frequency etc.) at startup. Therefore, the receiver must search the full time and frequency space, and all possible satellite numbers. If a satellite signal is found, it is tracked to decode the ephemeris (18–36 seconds under strong signal conditions), while the other channels continue to search satellites. Once there is a sufficient number of satellites with valid ephemeris, the receiver can calculate position and velocity data. Other GNSS receiver manufacturers call this the Factory startup mode.
- **Warm start:** in the warm start mode, the receiver has approximate information for time, position, and coarse satellite position data (Almanac). In this mode, the receiver normally needs to download ephemeris after power-up before it can calculate position and velocity data. As the ephemeris data is usually outdated after 4 hours, the receiver typically starts with a warm start if it has been powered down for more than 4 hours. In this scenario, several augmentations are possible. See [Multiple GNSS assistance](#).
- **Hot start:** in the hot start mode, the receiver has been powered down only for a short time (4 hours or less), so that its ephemeris is still valid. Since the receiver does not need to download ephemeris again, this is the fastest startup method.

Using the UBX-CFG-RST message, you can force the receiver to reset and clear data, in order to see the effects of maintaining/losing such data between restarts. For this purpose, use the `navBbrMask` field in the UBX-CFG-RST message to initiate hot, warm, and cold starts, or a combination of startup modes.

The reset type can also be specified. This is not related to GNSS, but to the way the software restarts the system.

- **Hardware reset** uses the on-chip watchdog to electrically reset the chip. This is an immediate asynchronous reset. No stop events are generated.
- **Controlled software reset** terminates all running processes in an orderly manner. Once the system is idle, restarts the receiver operation, reloads its configuration and starts to acquire and track GNSS satellites.
- **Controlled software reset (GNSS only)** only restarts the GNSS tasks, without reinitializing the full system or reloading any stored configuration.
- **Hardware reset (after shutdown)** uses the on-chip watchdog to reset the receiver after shutdown.
- **Controlled GNSS stop** stops all GNSS tasks. The receiver is not restarted, but stops any GNSS-related processing.
- **Controlled GNSS start** starts all GNSS tasks.

Table 13 below contains an overview of the different reset types and the data that is cleared.

Reset type	Clears RAM	Clears BBR	Clears Flash
0x00 - Hardware reset (immediately), 0x04 - Hardware reset (after shutdown)	Yes	Yes	No
0x01 - Controlled Software reset	Yes	No	No
0x02 - Controlled Software reset (GNSS only), 0x08 - Controlled GNSS stop, 0x09 - Controlled GNSS start	No	No	No
RESET_N pin	Yes	Yes	No

Table 13: Overview of the available reset types

2.5 Security

The security concept of NEO-F10T covers:

- the integrity of the receiver
- communication between the receiver and the GNSS satellites

Some security functions monitor and detect threats and report them to the host system. Other functions mitigate threats and allow the receiver to operate normally.

2.5.1 Spoofing detection and monitoring

Spoofing is the process where a counterfeit GNSS signal is transmitted locally to deceive the receiver/user and produce an erroneous position fix and/or time solution. The detection algorithm monitors GNSS signals for implausible changes or inconsistencies. These are evaluated with regards to spoofing. The known location of the static antenna improves the spoofing detection process built in the receiver.

A detection is successful when a signal is observed to transition from an initially genuine one to a spoofed version. Hence detection is not possible if the receiver is started under spoofing conditions. The detection algorithms also rely on availability of signals from multiple GNSS constellations to improve the spoofing detection capabilities.

In addition, the receiver provides a secondary navigation solution output to aid the detection of spoofing attacks in stationary use cases. To achieve this, the primary output is configured to operate normally in the stationary time mode, whereas the secondary output is operated in 3D navigation mode providing live antenna coordinates. This allows the host system to detect any suspicious

antenna motion which in a stationary application may indicate a spoofing attack. See [Primary and secondary output](#) section for more details

2.5.2 Jamming and interference detection and monitoring

Intentional and/or unintentional jamming of GNSS receivers can degrade the quality of GNSS signals and receiver performance. All u-blox receivers can detect and monitor jamming and report it to the user. The monitoring function is always enabled to inform the user about interference in the GNSS RF bands.



In case of excessive false jamming alerts, the jamming detector sensitivity can be configured with the CFG-SEC-JAMDET_SENSITIVITY_HI configuration.

2.5.3 Spoofing and jamming indication

The UBX-SEC-SIG message provides a direct method for monitoring the current security status at each navigation epoch to alert the host about potential jamming or spoofing events.

The UBX-SEC-SIGLOG message provides a log of past events triggered by jamming or spoofing detection.

Each event is a combination of a detection type and an event type, where the event type 'indication started' and 'indication stopped' and also the event type 'indication triggered' and 'indication timeout' form a pair.

A maximum of 16 events are logged and new events take precedence over the past events in the log. Power cycles and restarts of the receiver reset the log, deleting its content.

See the applicable Interface description [2].

2.5.4 GNSS receiver security

This section describes receiver security features implemented with the NEO-F10T:

- Secure boot
- Secure firmware update
- Receiver configuration lock

2.5.4.1 Secure boot

The NEO-F10T boots only with firmware images that are signed by u-blox. This prevents the execution of non-genuine firmware images on the receiver.


2.5.4.2 Secure firmware update

The firmware image is signed by u-blox. The NEO-F10T verifies the signature during the firmware update.

2.5.4.3 Receiver configuration lock


The receiver configuration lock feature ensures that no configuration changes are possible once the feature is enabled. The configuration lock is enabled by setting the configuration item CFG-SEC-CFG_LOCK to "true".

The configuration lock can be applied to different configuration layers including the RAM, BBR, and flash memory. At startup, the receiver constructs the configuration database from different configuration layers and maintains it in the run-time RAM memory. When the configuration lock is set in the run-time RAM, the receiver configuration cannot be changed on any configuration layer.

 For more information on the configuration layers including the order of priority they are applied in, see the applicable Interface description [2].

The configuration lock set on a configuration layer in volatile memory (RAM, BBR) is removed when the memory is cleared. However, the configuration lock set in non-volatile memory (flash memory) is permanent apart from one exception: during firmware upload to flash memory, the flash is erased during the process causing the configuration lock to be cleared. Refer to [Firmware update to flash](#) for more information on firmware update.

To test the lock functionality, set it on the RAM configuration layer. After a power cycle, the information on RAM layer is cleared and the lock is no longer set.

 It is recommended to apply the configuration lock on the same layer the configuration is stored.

An example of use case is that the host application locks the receiver configuration. A user communicating with the NEO-F10T through any of the available interfaces can poll, enable or send messages, but cannot change the configuration by sending UBX configuration messages.

2.6 Power management

u-blox receivers support different operating modes. These modes represent strategies of controlling the acquisition and tracking engines to achieve either the best possible performance or good performance with reduced power consumption.

2.6.1 Continuous mode

NEO-F10T uses dedicated signal processing engines optimized for signal acquisition and tracking. The acquisition engine actively searches for and acquires signals during cold starts or when insufficient signals are available during navigation. The tracking engine continuously tracks and downloads all the almanac data and acquires new signals as they become available during navigation. The tracking engine consumes less power than the acquisition engine.

The current consumption is lower when a valid position is obtained quickly after the start of the receiver navigation, the entire almanac has been downloaded, and the ephemeris for each satellite in view is valid. If these conditions are not met, the search for the available satellites takes more time and consumes more power.

2.6.2 Backup modes

A backup mode is an inactive state where the power consumption is reduced to a fraction of that in operating modes. The receiver maintains time information and navigation data to speed up the receiver restart after backup or standby mode.

The NEO-F10T supports two backup modes: hardware backup mode and software standby mode.

2.6.2.1 Hardware backup mode

The hardware backup mode allows entering a backup state and resuming operation by switching the main power supply on and off while maintaining a V_BCKP supply via, e.g. a battery.

V_BCKP must be supplied to maintain the backup domain (BBR and RTC) to allow better TTFF, accuracy, availability and power consumption at the next startup compared with a cold start. As VCC is not supplied, the PIOs cannot be driven by an external host processor. If driving of the PIOs cannot be avoided, buffers are required for isolating the PIOs.


2.6.2.2 Software standby mode

Software standby mode is entered using the UBX-RXM-PMREQ message. The VCC supply, which must be maintained during standby is switched internally to supply the battery-backed RAM (BBR), RTC, and PIO sections to save power.

Entering the software standby mode clears the RAM memory including the receiver configuration. To maintain the configuration, store it on RAM and BBR or flash layers. For more information on permanence of the stored configuration, refer to [Receiver configuration](#).

The software standby mode can be set for a specific duration, or until the receiver is woken up by a signal at a wake-up source defined in UBX-RXM-PMREQ. The possible wake-up sources are UART RX and/or EXTINT pin. Refer to the Interface description [2] for more information on the UBX-RXM-PMREQ message. A system reset with the RESET_N signal also terminates the software standby mode, clears the BBR content and restarts the receiver.

As VCC is supplied, the PIOs can be driven by an external host processor. No buffers are required for isolating the PIOs, which reduces cost.

 V_BCKP should be left open if not used.

2.7 Time

Maintaining receiver local time and keeping it synchronized with GNSS time is essential for proper timing and positioning functionality. This section explains how the receiver maintains local time and introduces the supported GNSS time bases.

2.7.1 Receiver local time

The receiver is dependent on a local oscillator for both the operation of its radio parts and also for timing within its signal processing. No matter what nominal frequency the local oscillator has, u-blox receivers subdivide the oscillator signal to provide a 1-kHz reference clock signal, which is used to drive many of the receiver's processes. In particular, the measurement of satellite signals is arranged to be synchronized with the "ticking" of this 1-kHz clock signal.

When the receiver first starts, it has no information about how these clock ticks relate to other time systems; it can only count time in 1 millisecond steps. However, as the receiver derives information from the satellites it is tracking or from aiding messages, it estimates the time that each 1-kHz clock tick takes in the time base of the chosen GNSS system. This estimate of GNSS time based on the local 1-kHz clock is called receiver local time.

As receiver local time is a mapping of the local 1-kHz reference onto a GNSS time base, it may experience occasional discontinuities, especially when the receiver first starts up and the information it has about the time base is changing. Indeed, after a cold start, the receiver local time initially indicates the length of time that the receiver has been running. However, when the receiver obtains some credible timing information from a satellite or an aiding message, it jumps to an estimate of GNSS time.


2.7.2 GNSS time bases


GNSS receivers must handle a variety of different time bases as each GNSS has its own reference system time. What is more, although each GNSS provides a model for converting their system time into UTC, they all support a slightly different variant of UTC. So, for example, GPS supports a variant of UTC as defined by the US National Observatory, while BeiDou uses UTC from the National Time Service Center, China (NTSC). While the different UTC variants are normally closely aligned, they can differ by as much as a few hundreds of nanoseconds.

Although u-blox receivers can combine a variety of different GNSS times internally, the user must choose a single type of GNSS time and, separately, a single type of UTC for input (on EXTINT pins) and output (via the TIMEPULSE pin) and the parameters reported in corresponding messages.

The CFG-TP-TIMEGRID_TP* configuration item allows the user to choose between any of the supported GNSS (GPS, GLONASS, BeiDou, etc.) time bases and UTC. Also, the CFG-NAVSPG-UTCSTANDARD configuration item allows the user to select which variant of UTC the receiver should use. This includes an "automatic" option which causes the receiver to select an appropriate UTC version itself, based on the GNSS configuration, using, in order of preference, USNO if GPS is enabled, SU if GLONASS is enabled, NTSC if BeiDou is enabled, European if Galileo is enabled, finally, NPLI if NAVIC is enabled.

The receiver assumes that an input time pulse uses the same GNSS time base as specified for the time pulse output. So if the user selects GLONASS time for time pulse output, any time pulse input must also be aligned to GLONASS time (or to the separately chosen variant of UTC). Where UTC is selected for time pulse output, any GNSS time pulse input will be assumed to be aligned to GPS time.

 The receiver allows users to independently choose GNSS signals used in the receiver (using CFG-SIGNAL-*) and the input/output time base (using CFG-TP-*). For example it is possible to instruct the receiver to use GPS and GLONASS satellite signals to generate BeiDou time. This practice compromises time pulse accuracy if the receiver cannot measure the timing difference between the constellations directly and is therefore not recommended.

 The information that allows GNSS times to be converted to the associated UTC times is only transmitted by the GNSS at relatively infrequent periods. For example GPS transmits UTC(USNO) information only once every 12.5 minutes. Therefore, if a time pulse is configured to use a variant of UTC time, after a cold start, substantial delays before the receiver has sufficient information to start outputting the time pulse can be expected.

Each GNSS has its own time reference for which detailed and reliable information is provided in the messages listed in the table below.

Time reference	Message
GPS time	UBX-NAV-TIMEGPS
BeiDou time	UBX-NAV-TIMEBDS
GLONASS time	UBX-NAV-TIMEGLO
Galileo time	UBX-NAV-TIMEGAL
NavIC time	UBX-NAV-TIMENAVIC
QZSS time	UBX-NAV-TIMEQZSS
UTC time	UBX-NAV-TIMEUTC

Table 14: GNSS time messages

2.7.3 Navigation epochs

Each navigation solution is triggered by the tick of the 1 kHz clock nearest to the desired navigation solution time. This tick is referred to as a navigation epoch. If the navigation solution attempt is successful, one of the results is an accurate measurement of time in the time base of the chosen GNSS system, called GNSS system time. The difference between the calculated GNSS system time and receiver local time is called the clock bias (and the clock drift is the rate at which this bias is changing).

In practice the receiver's local oscillator is not as stable as the atomic clocks to which GNSS systems are referenced and consequently clock bias tends to accumulate. However, when selecting the next navigation epoch, the receiver always tries to use the 1 kHz clock tick which it estimates to be closest to the desired fix period as measured in GNSS system time. Consequently, the number of 1 kHz clock

ticks between fixes occasionally varies. This means that when producing one fix per second, there are normally 1000 clock ticks between fixes, but sometimes, to correct drift away from the GNSS system time, there are 999 or 1001 ticks.

The GNSS system time calculated in the navigation solution is always converted to a time in both the GPS and UTC time bases for output.

Clearly when the receiver has chosen to use the GPS time base for its GNSS system time, conversion to GPS time requires no work at all, but conversion to UTC requires knowledge of the number of leap seconds since GPS time started (and other minor correction terms). The relevant GPS-to-UTC conversion parameters are transmitted periodically (every 12.5 minutes) by GPS satellites, but can also be supplied to the receiver via the `UBX-MGA-GPS-UTC` aiding message. By contrast, when the receiver has chosen to use the GLONASS time base as its GNSS system time, conversion to GPS time is more difficult as it requires knowledge of the difference between the two time bases, but as GLONASS time is closely linked to UTC, conversion to UTC is easier.

When insufficient information is available for the receiver to perform any of these time base conversions precisely, predefined default offsets are used. Consequently, plausible times are nearly always generated, but they may be wrong by a few seconds (especially shortly after receiver start). Depending on the configuration of the receiver, such "invalid" times may well be output, but with flags indicating their state (e.g. the "valid" flags in `UBX-NAV-PVT`).

2.7.4 iTow timestamps

All the main `UBX-NAV` messages (and some other messages) contain an `iTOW` field which indicates the GPS time at which the navigation epoch occurred. Messages with the same `iTOW` value can be assumed to have come from the same navigation solution.

Note that `iTOW` values may not be valid (i.e. they may have been generated with insufficient conversion data) and therefore it is not recommended to use the `iTOW` field for any other purpose.



The original designers of GPS chose to express time/date as an integer week number (starting with the first full week in January 1980) and a time of week (often abbreviated to `TOW`) expressed in seconds. Manipulating time/date in this form is far easier for digital systems than the more conventional year/month/day, hour/minute/second representation. Consequently, most GNSS receivers use this representation internally, only converting to a more conventional form at external interfaces. The `iTOW` field is the most obvious externally visible consequence of this internal representation.

If reliable absolute time information is required, it is recommended to use the `UBX-NAV-PVT` navigation solution message which also contains additional fields that indicate the validity (and accuracy in `UBX-NAV-PVT`) of the calculated times (see also the GNSS times section below for further messages containing time information).

2.7.5 Time validity

Information about the validity of the time solution is given in the following form:

- **Time validity:** Information about time validity is provided in the `valid` flags (e.g. `validDate` and `validTime` flags in the `UBX-NAV-PVT` message). If these flags are set, the time is known and considered valid for use. These flags are shown in table GNSS times in section GNSS times above as well as in the `UBX-NAV-PVT` message.
- **Time validity confirmation:** Information about confirmed validity is provided in the `confirmedDate` and `confirmedTime` flags in the `UBX-NAV-PVT` message. If these flags are set, the time validity can be confirmed by using an additional independent source, meaning that the probability of the time to be correct is very high. Note that information about time

validity confirmation is only available if the `confirmedAvai` bit in the UBX-NAV-PVT message is set.



`validDate` means that the receiver has knowledge of the current date. However, it must be noted that this date might be wrong for various reasons. Only when the `confirmedDate` flag is set, the probability of the incorrect date information drops significantly.



`validTime` means that the receiver has knowledge of the current time. However, it must be noted that this time might be wrong for various reasons. Only when the `confirmedTime` flag is set, the probability of incorrect time information drops significantly.



`fullyResolved` means that the UTC time is known without full seconds ambiguity. When deriving UTC time from GNSS time the number of leap seconds must be known, with the exception of GLONASS. It might take several minutes to obtain such information from the GNSS payload. When the one second ambiguity has not been resolved, the time accuracy is usually in the range of ~20s.

2.7.6 UTC representation

UTC time is used in many NMEA and UBX messages. In NMEA messages, time is always rounded to the nearest hundredth of a second and it is normally reported with two decimal places (e.g. 124923.52). Although compatibility mode (selected using CFG-NMEA-COMPAT) requires three decimal places, rounding to the nearest hundredth of a second remains, so the extra digit is always 0.

UTC time is also reported within some UBX messages, such as UBX-NAV-TIMEUTC and UBX-NAV-PVT. In these messages date and time are separated into seven distinct integer fields. Six of these (year, month, day, hour, min. and sec.) have fairly obvious meanings and are all guaranteed to match the corresponding values in NMEA messages generated by the same navigation epoch. This facilitates simple synchronization between associated UBX and NMEA messages.

The seventh field is called `nano` and it contains the number of nanoseconds by which the rest of the time and date fields need to be corrected to get the precise time. So, for example, the UTC time 12:49:23.521 would be reported as: hour: 12, min: 49, sec: 23, nano: 521000000.

It is however important to note that the first six fields are the result of rounding to the nearest hundredth of a second. Consequently the `nano` value can range from -5000000 (i.e. -5 ms) to +994999999 (i.e. nearly 995 ms).

When the `nano` field is negative, the number of seconds (and maybe minutes, hours, days, months or even years) have been rounded up. Therefore, some or all of them must be adjusted to get the correct time and date. Thus in an extreme example, the UTC time 23:59:59.9993 on 31st December 2011 would be reported as: year: 2012, month: 1, day: 1, hour: 0, min: 0, sec: 0, nano: -700000.

If a resolution of one hundredth of a second is adequate, negative `nano` values can simply be rounded up to 0 and effectively ignored.

The UBX-NAV-TIMEUTC message gives information about the UTC time reference clock.

The preferred variant of UTC time can be specified using the CFG-NAVSPG-UTCSTANDARD configuration item. The UTC time variant configured must correspond to a GNSS that is currently enabled. Otherwise the reported UTC time is inaccurate.

2.7.7 Leap seconds

Due to the slightly uneven spin rate of the Earth, UTC time gradually moves out of alignment with the mean solar time (that is, the sun no longer appears directly overhead at 0 longitude at midday). Occasionally, a "leap second" is announced to bring UTC back into close alignment with the mean

solar time. Usually this means adding an extra second to the last minute of the year, but this can also happen on 30th June. When this happens, UTC clocks are expected to go from 23:59:59 to 23:59:60, and only then on to 00:00:00.

It is also possible to have a negative leap second, in which case there will only be 59 seconds in a minute and 23:59:58 will be followed by 00:00:00.

u-blox receivers are designed to handle leap seconds in their UTC output and consequently applications processing UTC times from either NMEA or UBX messages should be prepared to handle minutes that are either 59 or 61 seconds long.

Leap second information can be polled from the receiver with the message UBX-NAV-TIMELS.

2.7.8 Date ambiguity

Each navigation satellite transmits information about the current date and time in the data message. The time of week (TOW) indicates the elapsed number of seconds since the start of the week (midnight Saturday/Sunday). The week number (WN) indicates the elapsed number of weeks since the particular GNSS system was started. By combining these two values the current date and time can be known. Modern GPS satellites use a 13-bit value for the week number. As GPS system was started in 1980, it allows the week number to represent dates up to year 2137. Unfortunately, at the time when the commonly used GPS L1C/A data message was designed the signal had only 10 bits available for the week number. The top bits of the full week number had to be left out. The 10 bottom bits of the week number are not sufficient to yield a completely unambiguous date as every 1024 weeks (a bit less than 20 years), the transmitted week number value "rolls over" back to zero. Consequently, the information in GPS L1 message does not differentiate between, for example, 1980, 1999, or 2019. GPS L1 receivers must thus use additional methods to calculate the full week number.

Although BeiDou and Galileo have similar representations of time, they still transmit sufficient bits for the week number to be unambiguous for the foreseeable future (the first ambiguity will be in 2078 for Galileo, and not until 2163 for BeiDou). GLONASS presents the time and date in different way and transmits sufficient information to avoid any ambiguity during the expected lifetime of the system (the first ambiguous date will be in 2124). Therefore, the receiver regards the date information transmitted by GLONASS, BeiDou, and Galileo to be unambiguous and, where necessary, uses this information to resolve any ambiguity in the GPS date.



If the receiver is connected to a simulator, note that GPS time is referenced to 6th January 1980, GLONASS to 1 January 1996, Galileo to 22 August 1999 and BeiDou to 1 January 2006. The receiver doesn't work reliably with signals simulated before these dates.


2.7.8.1 GPS-only date resolution

If only GPS L1C/A signals are available, the receiver establishes the date by assuming that all week numbers must be at least as large as the reference rollover week number. The default value for the reference rollover week number is selected at the compile time of the receiver firmware and is normally set to a value of a few weeks before the software is completed. The value can be overridden by CFG-NAVSPG-WKNROLLOVER configuration item.

The following example illustrates how this works:

Assume that the reference rollover week number set in the firmware at compile time is 2148 (which corresponds to a week in calendar year 2021, but is transmitted by the satellites as 100). In this case, if the receiver sees transmissions containing week numbers in the range of 100 ... 1023, they are interpreted as week numbers 2148 ... 3071 (calendar years 2021 ... 2038), whereas transmissions

with week numbers from 0 to 99 are interpreted as week numbers 3072 ... 3171 (calendar years 2038 ... 2040).

 It is important to set the reference rollover week number correctly when supplying the receiver with simulated signals, especially when the scenarios are in the past.


2.8 Time mark

The receiver can be used to provide an accurate measurement of the time at which a pulse was detected on the external interrupt pin. The reference time can be chosen by setting the time source parameter to UTC, GPS, GLONASS, BeiDou, Galileo, NAVIC or local time in the CFG-TP-* configuration group. The UTC standard can be set in the CFG-NAVSPG-* configuration group. The delay figures defined with CFG-TP-* are also applied to the results output in the UBX-TIM-TM2 message.

A UBX-TIM-TM2 message is output at the next epoch if

- The UBX-TIM-TM2 message is enabled, and
- a rising or falling edge was triggered since last epoch on the EXTINT pin.

The UBX-TIM-TM2 messages includes the time of the last time mark, new rising/falling edge indicator, time source, validity, number of marks and an accuracy estimate.

 Only the last rising and falling edge detected between two epochs is reported since the output rate of the UBX-TIM-TM2 message corresponds to the measurement rate configured with CFG-RATE-MEAS (see [Figure 3](#) below).

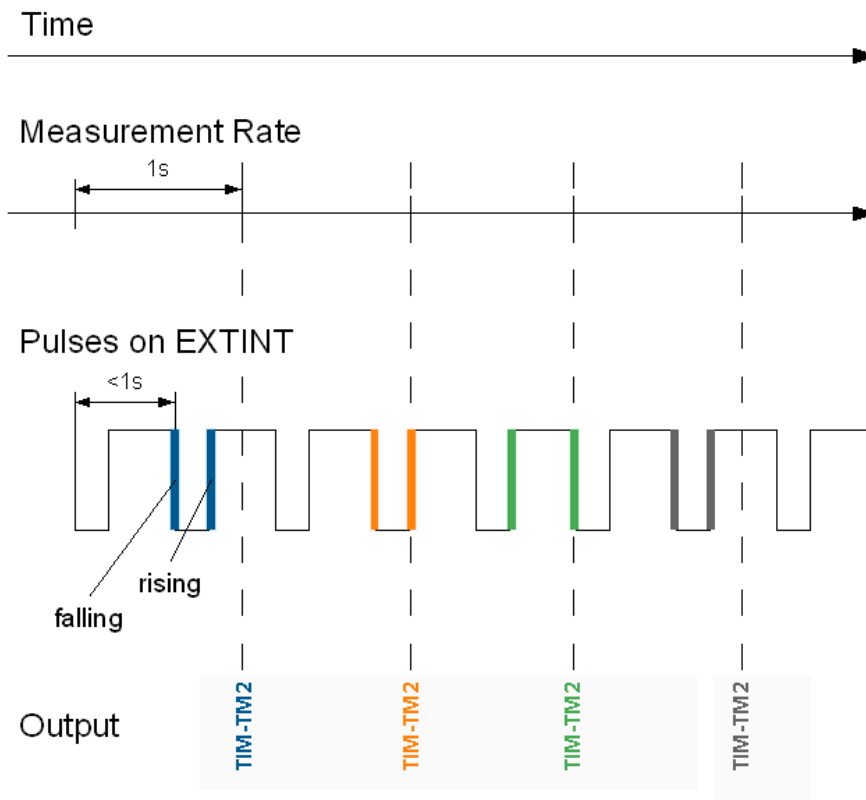
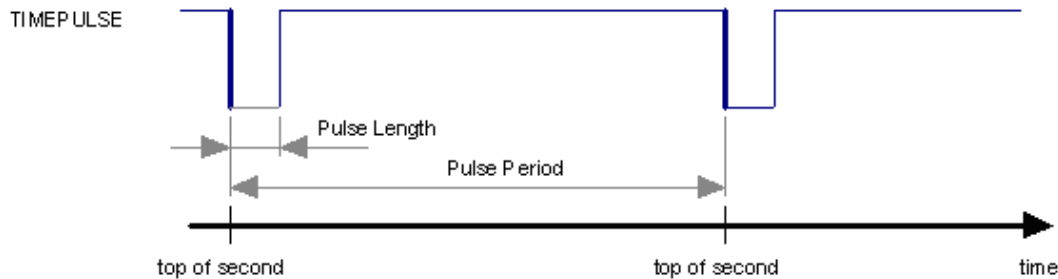


Figure 3: Time mark

2.9 Time pulse

The receiver includes a time pulse feature providing clock pulses with configurable duration and frequency. The time pulse function can be configured using the CFG-TP-* configuration group. The UBX-TIM-TP message provides time information for the next pulse and the time source.

Pulse Mode: Rising

Pulse Mode: Falling

Figure 4: Time pulse

2.9.1 Recommendations

- The time pulse can be aligned to a wide variety of GNSS times or to variants of UTC derived from them. For further information, see [GNSS time bases](#). However, it is strongly recommended that the choice of time base is aligned with the available GNSS signals (for example, to produce GPS time or UTC(USNO), ensure GPS signals are available, and for GLONASS time or UTC(SU) ensure the presence of GLONASS signals etc.). This involves coordinating the setting of CFG-SIGNAL-* configuration group with the choice of time pulse time base.
- When using time pulse for precision timing applications it is recommended to calibrate the antenna cable delay against a reference timing source.
- To get the best timing accuracy with the antenna, a fixed and accurate position is needed.
- If relative time accuracy between multiple receivers is required, do not mix receivers of different product families. If this is required, the receivers must be calibrated accordingly, by setting cable delay and user delay.
- The recommended configuration when using the UBX-TIM-TP message is to set both the measurement rate (CFG-RATE-MEAS) and the time pulse frequency (CFG-TP-*) to 1 Hz.

The sequential order of the signal present at the TIMEPULSE pin and the respective output message for the simple case of 1 pulse per second (1PPS) is shown in the following figure.

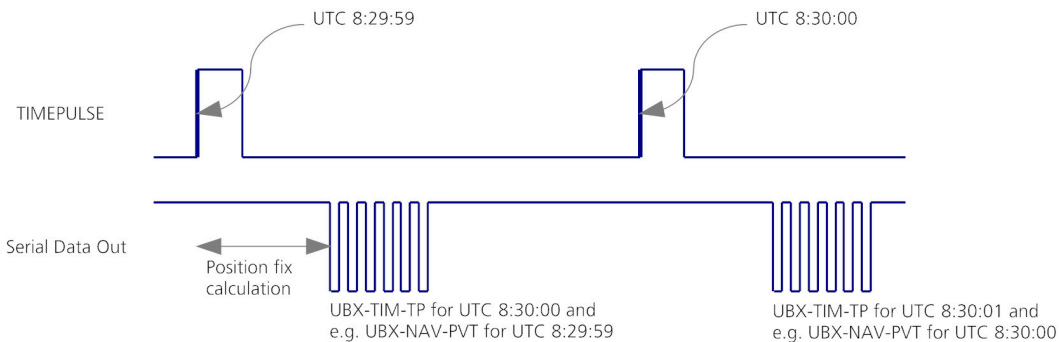


Figure 5: Time pulse and TIM-TP



2.9.2 Time pulse configuration

The time pulse (TIMEPULSE) signal has configurable pulse period, length and polarity (rising or falling edge).

It is possible to define different signal behavior (i.e. output frequency and pulse length) depending on whether or not the receiver is locked to reliable time source.

The configuration group CFG-TP-* can be used to change the time pulse settings, and includes the following parameters defining the pulse:

- **time pulse enable** - If this item is set, the time pulse is active.
- **frequency/period type** - Determines whether the time pulse is interpreted as frequency or period.
- **length/ratio type** - Determines whether the time pulse length is interpreted as length [us] or pulse ratio [%].
- **antenna cable delay** - Signal delay due to the cable between the antenna and the receiver.
- **pulse frequency/period** - Frequency or pulse time period when locked mode is not configured or not active.
- **pulse frequency/period lock** - Frequency or pulse time period for locked mode. In use as soon as the receiver has calculated a valid time from a received signal. Only used if the corresponding item is set to use another setting in locked mode.
- **pulse length/ratio** - Length or duty cycle of the generated pulse, specifies either time or ratio for the pulse to be on/off.
- **pulse length/ratio lock** - Length or duty cycle of the generated pulse for locked mode. In use as soon as the receiver has calculated a valid time from a received signal. Only used if the corresponding item is set to use another setting in locked mode.
- **user delay** - The cable delay from the receiver to the user device plus signal delay of any user application.
- **lock to GNSS freq** - If this item is set, uses the frequency gained from the GNSS signal information rather than the local oscillator's frequency.
- **locked other setting** - If this item is set, the alternative setting is used as soon as the receiver can calculate a valid time. This mode can be used, for example, to disable time pulse if the time is not locked, or to indicate a lock with different duty cycles.
- **align to TOW** - If this item is set, pulses are aligned to the top of a second.
- **polarity** - If set, the first edge of the pulse is a rising edge (pulse polarity: rising).
- **grid UTC/GNSS** - Selection between UTC (0), GPS (1), GLONASS (2), BeiDou (3), (4) Galileo and NAVIC (5) time grid. Also affects the time output by UBX-TIM-TP message.
- **drive strength** - Selection of time pulse drive strength (available options: 2mA, 4mA, 8mA, 12mA)

-  The maximum pulse length cannot exceed the pulse period.
-  The high and the low period of the output cannot be less than 50 ns, otherwise pulses can be lost.

2.9.2.1 Example

The example below shows the 1PPS TIMEPULSE signal generated on the time pulse output according to the specific parameters of the CFG-TP-* configuration group:

- **CFG-TP-TP1_ENA** = 1
- **CFG-TP-PERIOD_TP1** = 1 000 000 μ s
- **CFG-TP-LEN_TP1** = 100 000 μ s
- **CFG-TP-TIMEGRID_TP1** = 1 (GPS)
- **CFG-TP-PULSE_LENGTH_DEF** = 0 (Period)
- **CFG-TP-ALIGN_TO_TOW_TP1** = 1
- **CFG-TP-USE_LOCKED_TP1** = 1
- **CFG-TP-POL_TP1** = 1
- **CFG-TP-PERIOD_LOCK_TP1** = 1 000 000 μ s
- **CFG-TP-LEN_LOCK_TP1** = 100 000 μ s
- **CFG-TP-DRSTR_TP1** = 1 (4 mA drive strength)

The 1 Hz output is maintained whether or not the receiver is locked to GPS time. The alignment to TOW can only be maintained when GPS time is locked.

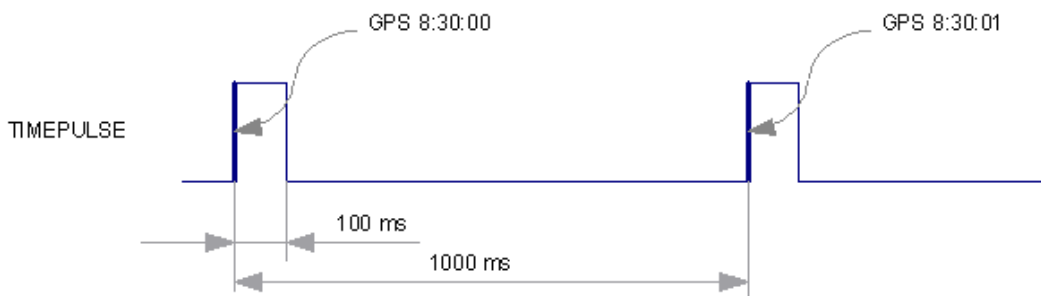


Figure 6: Time pulse signal with the example parameters

2.10 Time mark for Common View Time Transfer

Common view time transfer (CVTT) allows comparison of geographically widely spaced clocks by comparing GNSS signal times observed at each location with respect to a time pulse provided, for example, by a site reference clock. The techniques that can be employed are classical common view signal methods or "all in view" where GNSS time is the common factor. In all cases a mechanism is required to provide an estimate of the received signal time (sigtow) coincident with an external time pulse.

The NEO-F10T makes GNSS signal pseudo-range and doppler measurements at nominally 1 ms intervals set by the receiver local time base (rcvTow) and published at the navigation rate in UBX-RXM-RAWX. The UBX-RXM-TM message records the local receiver time (rcvTow) for a pulse applied to the EXTINT input pins. With this information and that obtained from UBX-RXM-RAWX the user can then estimate the pseudo-range for signals at the input pulse time.

Observations using identical NEO-F10T receivers can then be used to compare the difference between, for example, two reference clock PPS signals for time transfer or comparison purposes.

Note that reasonable estimates of antenna, cable and interconnection delays will have to be taken into account when making accurate timing measurement comparisons.

The UBX-RXM-TM message provides a set of measurements giving the EXTINT channel (0 or 1) and receiver time (rcvTow) for up to 18 pulses (rising and falling edges).

2.11 Time maintenance

Maintaining accurate time can improve the speed and performance of the receiver restart. Estimate of GNSS time can be maintained by a real-time clock, or it can be provided to the receiver by the host. Estimate of the clock drift of the receiver local oscillator or an external reference frequency can also be provided to improve the startup performance.

2.11.1 Real-time clock

The receiver contains a real-time clock (RTC). The RTC section is located in the backup domain and can keep time while the receiver is otherwise powered off. When the receiver powers up, it attempts to use the RTC to initialize receiver local time and in most cases this leads to considerably faster and more accurate first fixes.

2.11.2 Time assistance

The host can deliver time assistance to the receiver using UBX-MGA-INI-TIME_UTC or UBX-MGA-INI-TIME_GNSS for better startup performance.

The current GNSS time can be supplied to the receiver as a coarse value via the standard communication interfaces. This method suffers from communication latency and unpredictable delays so the accuracy of the supplied time is poor. Accuracy of the supplied time can be improved greatly if the host system has a very good sense of the current time and can deliver an exactly timed pulse to the EXTINT pin. This pulse informs the receiver when the supplied time assistance data is to be applied.

UTC time leap seconds and GPS-to-UTC conversion parameters are transmitted periodically by GPS satellites, but that happens only every 12.5 minutes. The receiver can normally calculate the correct leap seconds value from other GNSS systems immediately, but in some situations that is not possible. If the leap seconds information or the difference of time between GPS and UTC system is important for the host application, the information can be supplied to the receiver via the UBX-MGA-GPS-UTC aiding message.

2.11.3 Frequency assistance

To supply hardware frequency assistance, connect a periodic rectangular signal with a frequency of up to 500 kHz to the EXTINT pin. The frequency can have an arbitrary duty cycle but the low/high phase duration must not be shorter than 50 ns. The applied frequency value must be submitted to the receiver using the UBX-MGA-INI-FREQ message.

Frequency assistance can improve the cold start speed in crystal-based designs. For TCXO-based designs, the frequency assistance has only minimal impact as the receiver is quick to acquire accurate frequency from satellite transmissions. A stable external reference frequency can be used

to speed up receiver testing in production test setup. The host system may also be able to provide the reference frequency to improve the cold start speed.

2.11.4 Clock drift assistance

Estimate of the clock drift of the local oscillator can also be fetched from the receiver using the UBX-NAV-CLOCK message. This estimate can then be sent back to the receiver using the UBX-MGA-INI-CLKD message.

2.12 Multiple GNSS assistance (MGA)

The u-blox AssistNow services provide a proprietary implementation of an A-GNSS protocol compatible with u-blox GNSS receivers. The MGA services consist of AssistNow Online and Offline variants delivered by HTTP or HTTPS protocol.

When a client device makes an AssistNow request, the service responds with the requested data using standard UBX protocol MGA messages. These messages are ready for direct transmission from the client to the receiver port without requiring any modification.

AssistNow Online optionally provides immediate satellite ephemerides, health information and time aiding data suitable for GNSS receiver systems with direct internet access.

The AssistNow Offline service benefits u-blox GNSS receivers that only have occasional internet access. Users request data from the service by specifying the time period for which they want coverage (1 to 5 weeks). The data downloaded from the service is organized by date and encoded into a sequence of UBX MGA messages. In addition there is an MGA feature called AssistNow Autonomous which does not need an internet connection and runs entirely on the receiver.

The NEO-F10T supports AssistNow Online only.

Table 15 below contains an overview of the different MGA services u-blox provides. Refer to the NEO-F10T datasheet for the supported GNSS signals by each MGA service [1].

Requirements	AssistNow Online	AssistNow Offline	AssistNow Autonomous
Requires external flash memory	No	Optional	Optional
Requires internet connection	Permanently	Sporadically	No
Amount of internet data	Medium	High	None
Ephemeris in data	Yes	No	No
Almanac in data	Yes	Yes	Yes

Table 15: AssistNow service overview

2.12.1 Authorization

To use the AssistNow services, customers will need to obtain an authorization token from u-blox. Go to <https://www.u-blox.com/en/solution/services/assistnow> or contact your local technical support to get more information and to request access to the service.

2.12.2 Preserving MGA and operational data during power-off

The time-to-fix after a receiver power interruption is dependent on the amount of operational data available at startup. Satellite broadcast information and an estimate of accurate time can be fetched from the AssistNow service. In addition, the following techniques can restore the data that was stored prior to powering down.

- **Battery-backed RAM:** The receiver operational state stored in this RAM can be maintained during power outages by connecting the V_BCKP pin to an independent supply, e.g. a battery.

This is a recommended method as it will maintain all MGA-related information, any user configuration, calibration data, and an estimate of time via the real-time clock. See [V_BCKP](#) for more information.

- **Save-on-shutdown:** The receiver can be instructed to dump its current state to flash memory as part of the shutdown procedure; this data is then automatically retrieved when the receiver is restarted. For more information, see section [Save-on-shutdown feature](#).
- **Database dump:** The receiver can be made to dump the state of its navigation database in the form of a sequence of UBX messages reported to the host; these messages can be stored by the host and then sent back to the receiver when it has been restarted. See the description of the UBX-MGA-DBD messages in the NEO-F10T Interface description [2] for more information.

2.13 Save-on-shutdown feature

The save-on-shutdown feature (SOS) enables the u-blox receiver to store the contents of the battery-backed RAM to an external flash memory and restore it upon startup. This allows the u-blox receiver to preserve some of the features available only with a battery backup (preserving configuration and satellite orbit knowledge) without having a battery backup supply present. However, the receiver does not preserve any kind of time knowledge. Save-on-shutdown must be commanded by the host. Refer to the NEO-F10T Interface description [2] for more information on the required UBX-UPD-SOS messages. The restoring of data on startup is automatically done if the corresponding data is present in the flash. Data expiration is not checked.

The following outlines the suggested shutdown procedure when using the SOS feature:

- With the UBX-CFG-RST message, the host commands the u-blox receiver to stop, specifying reset mode 0x08 ("Controlled GNSS stop") and a BBR mask of 0 ("Hotstart").
- The host commands the saving of the contents of BBR to the flash memory using the UBX-UPD-SOS-BACKUP message.
- For a valid request the u-blox receiver reports on the success of the backup operation with a UBX-UPD-SOS-ACK message.
- The host powers off the u-blox receiver.

The startup procedure is as follows:

- The host powers on the u-blox receiver.
- The u-blox receiver detects the previously stored data in the flash. It restores the corresponding memory and reports the success of the operation with a UBX-UPD-SOS-RESTORED message on the port on which it had received the save command message (if the output protocol filter on that port allows it). It does not report anything if no stored data has been detected.
- Additionally the u-blox receiver outputs a UBX-INF-NOTICE and/or a NMEA-TXT message with the contents `RESTORED` in the boot screen (depends on the configuration of the port and information messages) upon success.
- Optionally the host can deliver coarse time assistance using UBX-MGA-INI-TIME_UTC for better startup performance.



It is recommended to delete the stored data using a UBX-UPD-SOS-CLEAR message once the u-blox receiver has started up. The u-blox receiver responds with a UBX-ACK-ACK / UBX-ACK-NAK message.

2.14 Sky view signal masking

When a stationary receiver's antenna has a poor view of the sky, the resultant performance can be compromised owing to signal distortion produced by processing non-line-of-sight signals. A legacy configuration CFG-NAVSPG-INFIL_MINELEV key can set a common minimum elevation angle below

which satellites will not be used. The default angle is set to 10 deg. The configuration provides a common minimum elevation cut-off for all satellite azimuth angles.

A second method is to use The CFG-NAVMASK-EL_MASK key which allows users to mask individual portions of the sky to prevent receiving signals in a known blocked direction. This is especially useful for timing receivers when surveyed into urban locations with a restricted sky view. Customers can e.g. use local mapping data to predict the sky view and set appropriate masking parameters. The CFG-NAVMASK-EL_MASK configuration allows masking of set parts of the sky in increments of nominally 5 deg. in azimuth and elevation.

Users should take note that satellites may be blocked by the elevation masking message (CFG-NAVSPG-INFIL_MINELEV) described above when used together.

For more information about these messages and the configuration keys see the applicable Interface description [2].

2.15 Firmware update

u-blox may release updated images containing, for example, security fixes, enhancements, bug fixes, etc. Therefore, it is important that customers implement a firmware update mechanism in their system.

Upon start-up the NEO-F10T operating FW image is loaded into the receiver code RAM from the flash memory. The flash memory can be erased and re-programmed with the latest FW image via a host.

Contact u-blox for more information on firmware update.

3 Hardware integration

This chapter explains how the receiver can be integrated into an application design.

3.1 Power supply

The NEO-F10T has the following power supply pins: **VCC** and **V_BCKP**.

A power supply at VCC must be present for normal operation. A supply at V_BCKP is optional. If present, it enables the hardware backup mode when the VCC supply is off.

Refer to the NEO-F10T Data sheet [1] for absolute maximum ratings, operating conditions, and power requirements.

3.1.1 VCC

VCC provides power to the core and RF domains and must be supplied during normal operation. A filtered VCC supply is available on the VCC_RF pin. The VCC_RF output voltage is derived from the VCC supply and is available whenever VCC is supplied.

VCC also supplies all the digital IOs, clock, and the backup domain. The current drawn at VCC depends on the activity and loading of the PIOs and the main oscillator.



Do not add series resistance greater than 0.2 Ω on the supply line to avoid voltage ripple due to the dynamic current conditions.

3.1.2 V_BCKP

Power supply at V_BCKP is optional. If the power supply at VCC is interrupted, but the V_BCKP pin is supplied, the receiver enters the hardware backup mode. In this mode, the RTC time and the GNSS orbit data in the BBR are maintained. Valid time and GNSS orbit data at startup improves positioning performance by enabling hot starts, warm starts, and AssistNow Autonomous. This ensures faster TTFF when VCC is supplied again. To make these features available, connect an independent power supply to V_BCKP to ensure backup domain supply when VCC is not supplied.

Designs using an external battery as a power source at the V_BCKP pin must consider the battery capacity. The GNSS satellite ephemeris data is typically valid for up to 4 hours for hot starts, and up to a few days for warm starts and AssistNow (Offline and Autonomous).



Avoid high resistance on the V_BCKP line. During the switch to V_BCKP supply, a short current adjustment peak may cause a high voltage drop at the pin.



If the hardware backup mode is not used, leave the V_BCKP pin open.

3.2 RF front-end

GNSS receivers operate with very low signal levels, ranging from -130 dBm to approximately -167 dBm. This alone is a challenge for the GNSS application design. Out-of-band sources of interference such as GSM, CDMA, WCDMA, LTE, Wi-Fi, or Bluetooth wireless systems with a much higher signal level require additional specific measures. The goal of the RF front-end design is to receive the in-band signal with minimum loss and added noise while suppressing the out-of-band interference.

Refer to the [Block diagram](#) for an overview of the RF front-end.

3.2.1 Out-of-band blocking immunity

Out-of-band RF interference may degrade the quality and availability of the navigation solution. Out-of-band immunity limit describes the maximum power allowed at the receiver RF input with no degradation in performance. Minor violation of the immunity limit may reduce C/N0 of the received signals but does not necessarily affect the overall receiver performance. However, a significant violation may reduce receiver sensitivity or cause a complete loss of signal reception. The severity of the interference depends on the repetition rate, frequency, signal level, modulation, and bandwidth of the signal.



If the out-of-band immunity limit is exceeded, it is recommended to verify that the receiver performance is not affected or is at an acceptable level in the presence of interference.

3.2.2 Out-of-band rejection

RF interference is typically first coupled into the antenna and subsequently conducted into the receiver input. Typical out-of-band interference sources include transmitting antennas of other radio systems.

Estimation of the RF interference level coupled into the receiver antenna is a starting point for RF front-end design. For designs with other radio systems, the maximum power coupled into the antenna can be estimated from the maximum transmission power and the isolation between the antennas. Practical values for antenna isolation can range from 15 - 20 dB down to 6 - 10 dB for very small devices. RF interference may also couple from external sources such as nearby mobile devices or base stations.



A simplified test board can be used to estimate the isolation between two antennas. The size of the board and the placement of the antennas must match the final design. Connect the RF cables to the antenna inputs and measure S21 over the frequency band of interest with a vector network analyzer (VNA).

The required out-of-band rejection or isolation is the difference of the maximum power coupled into the antenna input terminal and the immunity level of the receiver RF input. The required isolation is realized with appropriate filtering, typically with one or two SAW filters. Amplification on the RF path reduces the out-of-band rejection and needs to be considered in filter selection. The type and number of filters are selected based on the estimated interference level and the immunity of the receiver.

RF interference from other parts of the design is more difficult to estimate. One option is to measure the interference level at the receiver input using a spectrum analyzer. Interference within the design is primarily a problem at the receiver in-band, where it cannot be addressed by filtering on the RF path. Outside the GNSS band, the required filtering is determined by the estimated interference level and the immunity of the receiver.

3.3 Antenna requirements

The NEO-F10T requires an active antenna with integral LNA to ensure good performance under nominal signal reception.

When implementing a custom antenna installation, it is recommended that an OEM active antenna module be used that meets our specification. Implementing a custom active antenna design is an important exercise to meet the required bandwidths and group delay specifications compared to previous L1-only designs.



Location of the antenna is critical to reach the stated performance. For timing receivers locate to provide a good all round sky view.

A set of recommended specifications for a dual band active antenna is given below.

Parameter	Specification	
Active antenna recommendations	Minimum gain ³	15 dB
	Maximum gain ³	40 dB
	Noise figure	<4 dB
Group delay variation in-band ⁴	10 ns max at each GNSS system bandwidth. Note: Inter-signal requirement 50 ns max.	
Out-of-band ⁴ rejection	40 dB typ	
Antenna element specification	L1 band antenna gain ⁵	1559 - 1606 MHz: 3 dBic typ.
	L5/E5a band antenna gain ⁵	1166 - 1186 MHz: 2 dBic typ.
	Polarization	RHCP
	Axial ratio	2 dB max, at Zenith
	Phase center variation	<10 mm over elevation/azimuth
EMI immunity out-of-band ⁶	30 V/m	
ESD circuit protection	15 kV human body model air discharge	

Table 16: Antenna specifications for NEO-F10T modules

The antenna system should include filtering to ensure adequate protection from nearby transmitters. Take care in the selection of antennas placed close to cellular or Wi-Fi transmitting antennas.

3.3.1 Antenna power supply

Figure 7 shows an active antenna supply network to connect the antenna supply to the RF signal line. The inductance L4 connects the antenna power supply to the RF signal line. The capacitance C14 filters out high-frequency interference from the power supply and the resistor R8 limits the short-circuit current.

The type and value of L4 is selected to have a resonance peak at GNSS frequencies. This provides a high series impedance above 500 Ω at GNSS L1 and L5 frequencies, creating an impedance mismatch with respect to the 50 Ω RF signal line. This minimizes the effect of the feed point on the RF signal line, and isolates the antenna supply from the RF signal line at GNSS frequencies. Both R8 and L4 must have sufficient current and power rating to withstand the short-circuit current. Example component values for the antenna supply network are given in [Standard resistors](#), [Standard capacitors](#), and [Inductors](#).

The NEO-F10T VCC_RF pin is provided as a convenient source for the active antenna supply. VCC_RF is a RF filtered source taken from the VCC input voltage. For the VCC_RF output specifications, see the Data sheet[1].

³ Including passive losses (filters, cables, connectors etc.)

⁴ GNSS system bandwidths: B1I 1559... 1563 MHz; L1,E1,B1C 1573... 1578 MHz; L1OF 1598... 1606 MHz; L5,E5a,B2a 1166... 1286 MHz;

⁵ Measured with a ground plane d=150 mm

⁶ Exception L1, L5 bands +/- 200 MHz, emphasis on cellular bands

The NEO-F10T RF_IN pin has a DC blocking capacitor internally. No additional DC blocking capacitor needs to be added. Lightning protection standards may require an additional DC blocking capacitor for EOS protection.

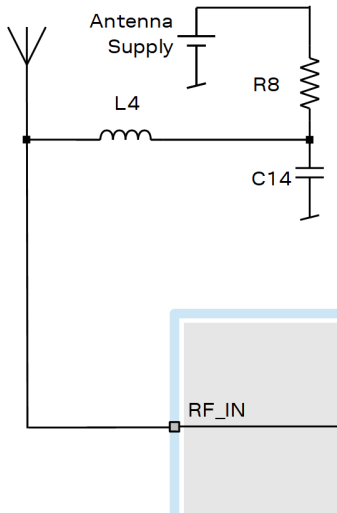


Figure 7: Antenna supply network

3.4 RF interference

The received GNSS signal power at the antenna is very low compared to other wireless communication signals. The nominal -130 dBm received GNSS signal strength is below the thermal noise floor, making a GNSS receiver susceptible to interference from nearby RF sources of any kind.

As an example, cellular applications emit signals with power levels of approximately +30 dBm, while the GNSS signal is less than -128 dBm when reaching the antenna. By simply comparing these numbers it is obvious that interference issues must be seriously considered during the design phase.

3.4.1 In-band interference

Although the radio communications standards prevent intentional RF signal sources from interfering the GNSS frequencies, many devices emit RF power into the GNSS band at levels much higher than the GNSS signal itself.

One reason is that the frequency band above 1 GHz is not well regulated with regards to EMI, and even if permitted, signal levels are much higher than the GNSS signal power. In particular, all types of digital equipment, such as PCs, digital cameras, LCD screens, etc. tend to emit a broad frequency spectrum up to several GHz of frequency. Also wireless transmitters may generate spurious emissions that fall into the GNSS band.



The section defines measures against in-band interference during the design phase of the application.

3.4.2 Out-of-band interference

Out-of-band interference is caused by signal frequencies that are different from the GNSS carrier frequency. The main sources are wireless communication systems such as LTE, GSM, CDMA, WCDMA, Wi-Fi, BT, etc. Typically, these systems may emit their specified maximum transmit power

in close proximity to the GNSS receiving antenna, especially if such a system is integrated with the GNSS receiver. Even at reasonable antenna selectivity, destructive power levels may reach the RF input of the GNSS receiver. In addition, larger signal interferers may generate intermodulation products inside the GNSS receiver front-end that fall into the GNSS band and contribute to in-band interference.

3.4.3 Spectrum analyzer

The UBX-MON-SPAN message can be enabled in u-center2 to provide a low-resolution spectrum analyzer sufficient to identify noise or jammers in the reception band. Once enabled, u-center2 includes a real-time chart that is updated once per second with the message data. See [Figure 8](#) for an example.

The design or device environment can generate interference at the in-band that can be analyzed from the spectrum in the UBX-MON-SPAN message. Hence, the shape of the spectrum as well as visible peaks help to identify in-band interference. Out-of-band interference can also cause peaks that appear in the in-band. However, there can be out-of-band interference that is not visible within the span of the spectrum. The presence of out-of-band interference may be seen as reduction in the PGA value.

The vertical axis compares the power level in dB for each frequency. A good spectrum shape is characterized by an even noise floor along with the GNSS band. For example, if any unwanted interference peak stands out, the vertical axis gives a rough approximation of the power level in dB compared to the noise floor.

Next to the chart, the center frequency, span, and resolution values set for the spectrum, and the PGA value are also displayed. The PGA value represents the internal gain set by the receiver, which depends on the external amplification of the GNSS input signal.

The vertical discontinuous lines in the chart area represent the offset to the center frequency in MHz. This helps to estimate the frequency of any spurious emission seen.

[Figure 8](#) shows the spectrum view in u-center2.

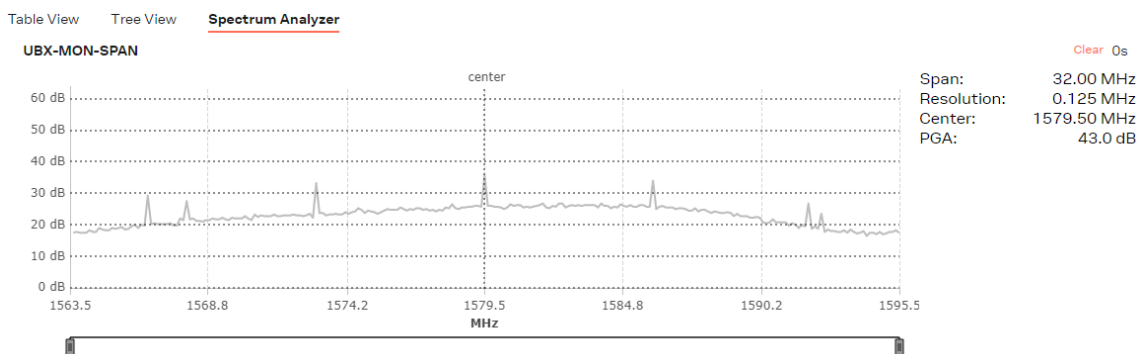


Figure 8: Spectrum analyzer view in u-center2

- By changing the GNSS constellations enabled, the span widens or narrows. This has a direct impact on the spectrum resolution, as the number of measured values is fixed to 256. For further details about this message and how to calculate each frequency, see the Interface description [2].
- A peak may be visible around the center frequency. The signal comes internally from the receiver and it does not cause any degradation in the performance.

3.5 Layout

GNSS signals on the surface of the earth have a very low signal strength and are about 15 dB below the thermal noise floor. When integrating a GNSS receiver into a PCB, the placement of the components, as well as grounding, shielding, and interference from other digital devices are crucial issues that need to be considered very carefully.

An important factor in achieving high GNSS performance is the placement of the receiver with respect to other components on the PCB.

To minimize signal loss on the RF connection from the antenna to the receiver input and to avoid possible coupled interference, the connection to the antenna must be kept short while keeping some distance from the antenna to other electronic components.

The RF section should not be subject to noisy digital supply currents running through its GND plane. Make sure that critical RF circuits are clearly separated from any other digital circuits on the system board. To achieve this, position the receiver digital part towards the digital section of the system PCB and place the RF section and antenna as far away as possible from the other digital circuits on the board. Keep at least a 5 mm distance to any RF component and ensure proper grounding.



For applications using cellular antennas, increase the distance between both antennas as much as possible.

Another very important factor in GNSS applications is the grounding concept. Ensure good ground reference to the host ground by increasing the number of GND vias. The GND vias will improve the GND reference between all the layers, and the pads will serve as thermal relief.


Any stubs at the ground planes must be avoided or ended with a via to the reference ground. Otherwise, they could pick up and propagate interference.

For the RF signal line, it is best to use the co-planar waveguide with ground on the second layer. All the RF parts need a solid GND plane underneath in order to achieve the targeted impedance in the RF signal line.

The length and geometry in the RF signal line must be carefully analyzed. The impedance of the RF signal line must be 50 Ω . Select the stack-up, copper, and dielectric properties of the PCB accordingly to fulfill this condition. The RF signal line should be as short as possible and the ground plane around should be filled with GND vias.

Be careful when placing the receiver in proximity to circuitry that can emit heat. Temperature-sensitive components inside the module, like TCXOs and crystals, are sensitive to sudden changes in ambient temperature which can adversely impact satellite signal tracking. Sources can include co-located power devices, cooling fans or thermal conduction via the PCB.

The GND planes can conduct heat to other elements, but they can act as heat dissipators as well. Increasing the number of GND vias helps to decrease sudden temperature changes.

 High temperature drift and air vents can affect the GNSS performance. For best performance, avoid high temperature drift and air vents near the module.

3.5.1 Package footprint, copper and solder mask

The mechanical specification is available in the Data sheet [1].

Figure 9 and Figure 10 describe the footprint and provide recommendations for the paste mask. Note that the copper and solder masks have the same size and position.

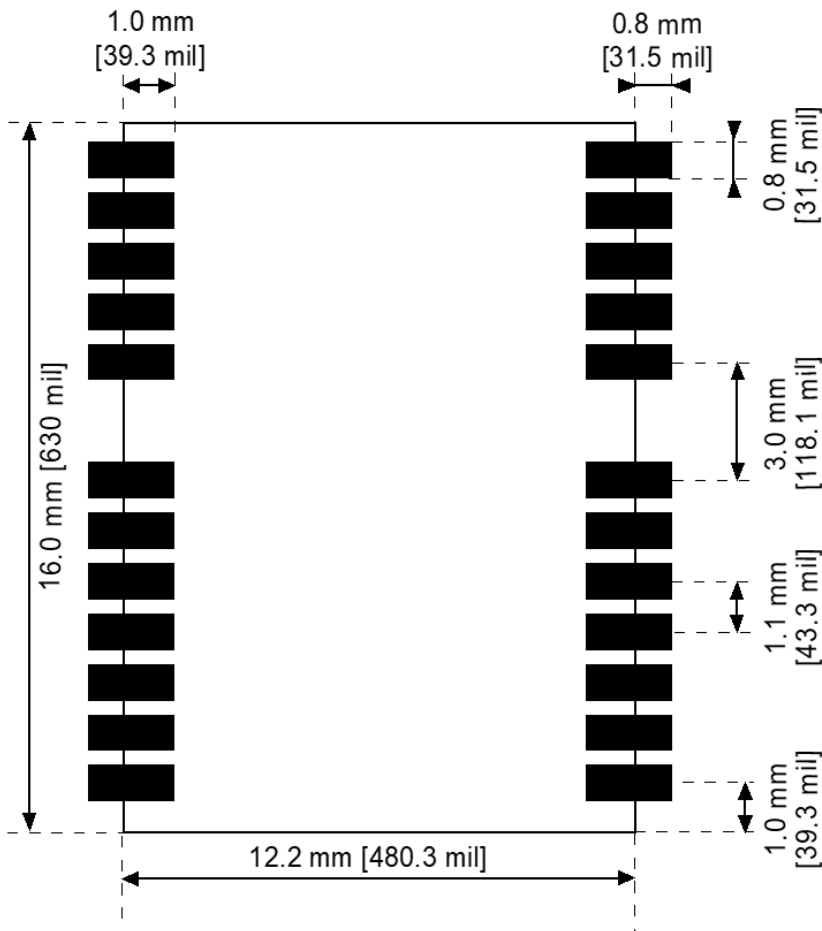


Figure 9: Recommended copper land and solder mask opening for NEO-F10T

To improve the wetting of the half vias, reduce the amount of solder paste under the module and increase it outside of the module by defining the dimensions of the paste mask to form a T-shape (or equivalent) extending beyond the copper mask.

Recommended stencil thickness is 150 μm .

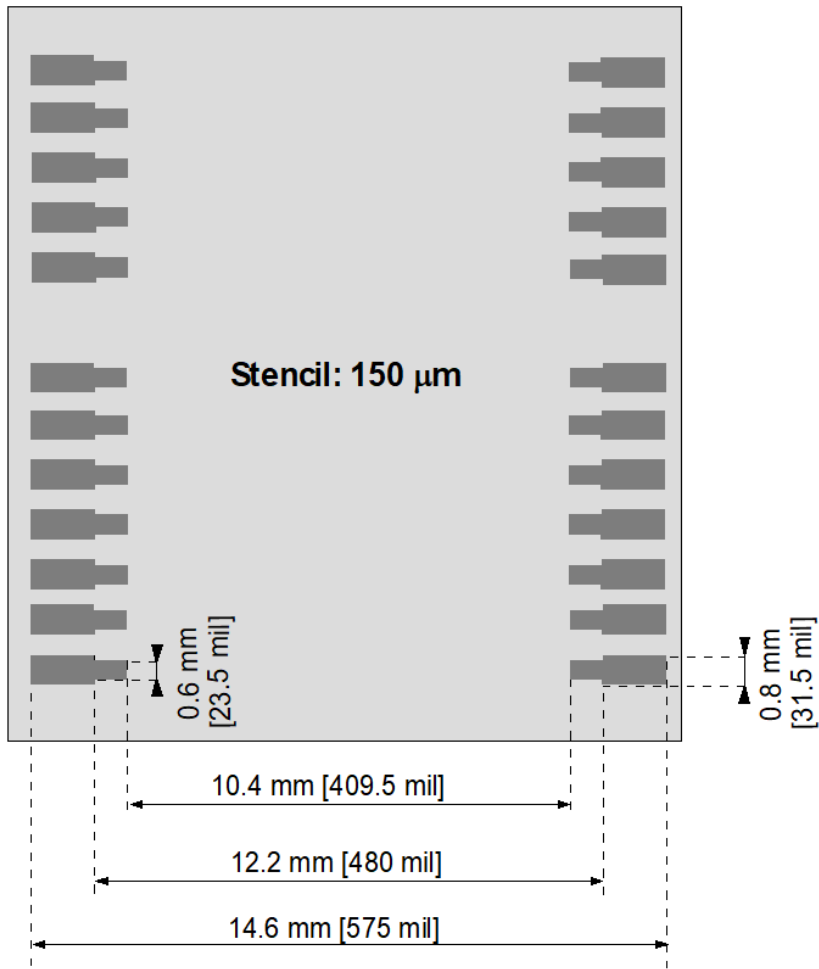


Figure 10: Recommended paste mask pattern for NEO-F10T

4 External components

This section lists the recommended values for the external components in the reference designs.

4.1 Standard capacitors

Table 17 presents the recommended capacitor values for NEO-F10T.

Name	Use	Type / Value
C14	RF Bias-T capacitor	10 nF, 10%, 16 V, X7R

Table 17: Standard capacitors

4.2 Standard resistors

Table 18 presents the recommended resistor values for NEO-F10T.

Name	Use	Type / Value
R8	Antenna supply current limiter/shunt resistor	10 Ω , 5%, 0.25 W

Table 18: Standard resistors

4.3 Inductors

Table 19 presents the recommended inductor values for NEO-F10T.


Name	Use	Type / Value	Recommended component
L4	RF Bias-T inductor	47 nH, 5%	Murata LQG15HS47NJ02 Johanson Technology L-07W series Any other inductor with impedance > 500 Ω at GNSS L1 and L5 frequencies and current rating above 300 mA.

Table 19: Recommended inductors

5 Product handling

5.1 Safety

5.1.1 ESD precautions

-  CAUTION! Risk of electrostatic discharge (ESD) damage. u-blox chips and modules are electrostatic sensitive devices containing highly sensitive electronic circuitry. A discharge of static electricity may damage the device or reduce the life expectancy of the device. To avoid ESD damage, adhere to the standard guidelines for handling ESD devices.

Consider the following:

Preventing electrostatic discharge

- Keep components in their original packages during transport.
- Open the package within an ESD-protected area (EPA), as in [Figure 11](#).
- At a workstation, store components in an EPA.
- Place ESD sensitive devices inside of shielding packaging or containers when transported outside of an EPA.
- Use protective clothing and proper personnel grounding at all necessary points when touching electrostatic sensitive device or assembly. For instance, wear ESD-safe clothing and shoes and wear an ESD wrist strap connected to a grounded workstation. Use heel straps when standing on conductive floors or dissipating floor mats.
- Hold the devices by the edges and avoid touching component contacts, pins, or circuitry

Product handling

- When handling RF transceivers and patch antennas, work in an EPA.
- When connecting test equipment or any other electronics to the module (as a standalone or PCB-mounted device), the first point of contact must always be between the local ground and the PCB ground.
- Before mounting a ceramic patch antenna, connect the device to ground.
- When handling the RF pin, do not touch any charged capacitors. Be especially careful when handling materials like patch antennas (~10 pF), coaxial cables (~50-80 pF/m), soldering irons, or any other materials that can develop charges.
- If there is any risk of touching an exposed antenna area in a non-ESD protected work area, implement proper ESD protection measures in the design.
- When soldering RF connectors and patch antennas to the receiver's RF pin, use an ESD-safe soldering iron (tip)

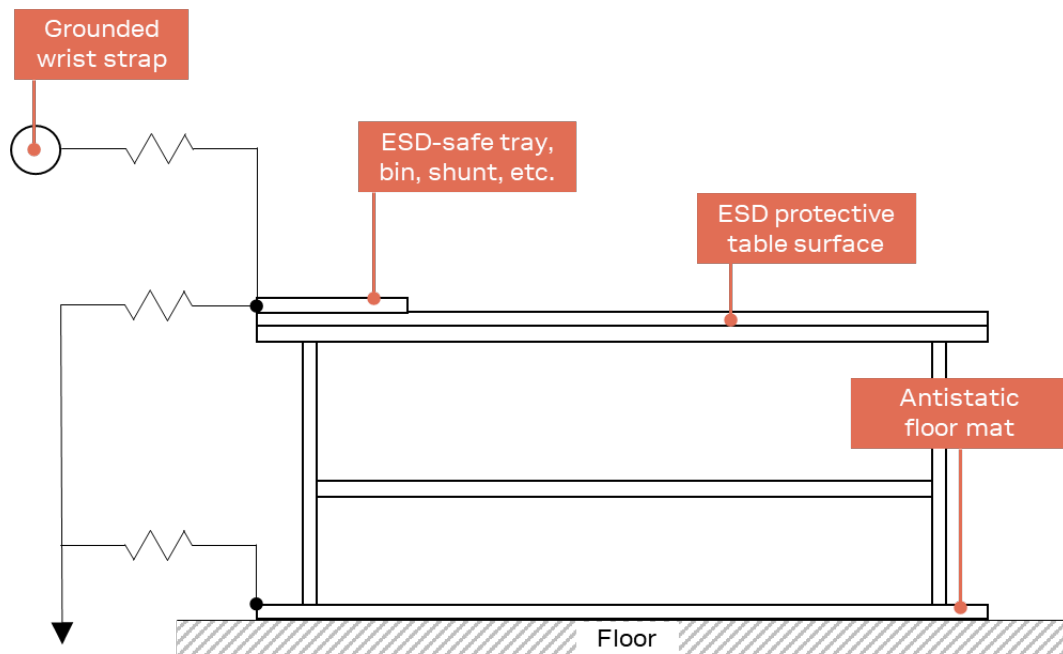



Figure 11: Standard workstation setup for safe handling of ESD-sensitive devices

5.1.2 Safety precautions

The NEO-F10T modules must be supplied by an external limited power source in compliance with the clause 2.5 of the standard IEC 60950-1. In addition to external limited power source, only Separated or Safety Extra-Low Voltage (SELV) circuits are to be connected to the module including interfaces and antennas.

 For more information about SELV circuits see section 2.2 in Safety standard IEC 60950-1.

5.2 Packaging

The NEO-F10T modules are delivered as hermetically sealed, reeled tapes to enable efficient production, production lot set-up and tear-down. For more information, see the u-blox Product packaging reference guide [3].

5.2.1 Reels

NEO-F10T modules are deliverable in quantities of 250 pieces on a reel. They are shipped on reel type B, as specified in the u-blox Product packaging reference guide [3].

5.2.2 Tapes

Figure 12 shows the feed direction and illustrates the orientation of the components on the tape.

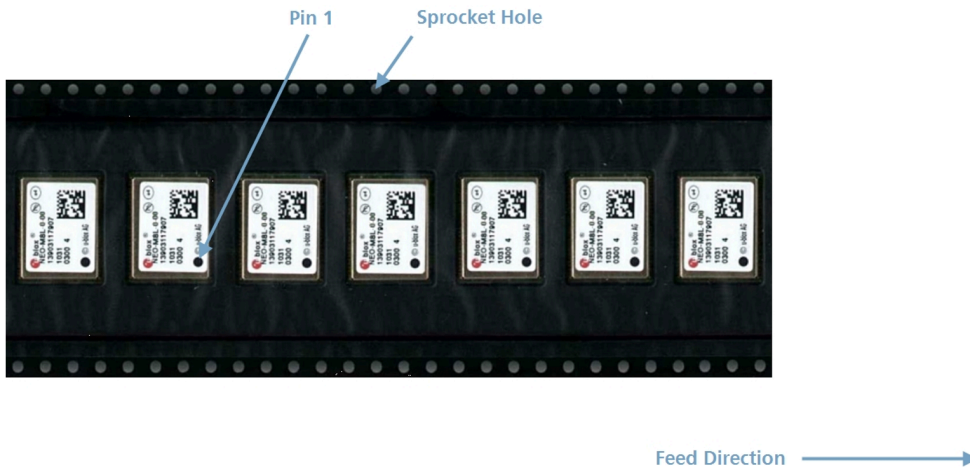


Figure 12: Orientation of the components on the tape

The feed direction into the pick and place pick-up is from the reel (located on the left of the figure) towards right, and the tape is fed to the right.

The dimensions of the tape are specified in [Figure 13](#) (measurements in mm).

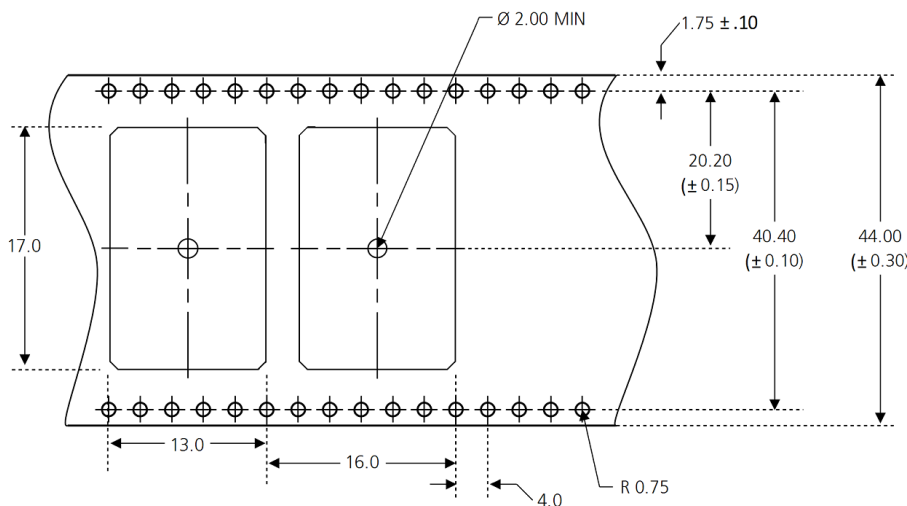


Figure 13: Tape dimensions (mm)

5.2.3 Moisture sensitivity level

The moisture sensitivity level (MSL) for NEO-F10T modules is specified in the table below.


Package	MSL level
LCC (professional grade)	4

Table 20: MSL level

For MSL standard see IPC/JEDEC J-STD-020, and J-STD-033 that can be downloaded from www.jedec.org. For more information regarding moisture sensitivity levels, labeling, storage and drying, see the u-blox Product packaging reference guide[3].

5.3 Soldering

Reflow soldering procedures are described in the IPC/JEDEC J-STD-020 standard.

-  When populating the modules, make sure that the pick and place machine is aligned to the copper pins of the module and not to the module edge.

Soldering paste

Use of “no clean” soldering paste is highly recommended, as it does not require cleaning after the soldering process. The paste in the example below meets these criteria.

- Soldering paste: OM338 SAC405 / Nr.143714 (Cookson Electronics)
- Alloy specification: Sn 95.5/ Ag 4/ Cu 0.5 (95.5% tin/ 4% silver/ 0.5% copper)
- Melting temperature: 217 °C
- Stencil: The exact geometry, distances, stencil thicknesses and solder paste volumes must be adapted to the customer's specific production processes.

Reflow soldering

A convection-type soldering oven is highly recommended over the infrared-type radiation oven. Convection-heated ovens allow precise control of the temperature, and all parts will heat up evenly, regardless of material properties, thickness of components and surface color.

As a reference, see “IPC-7530 Guidelines for temperature profiling for mass soldering (reflow and wave) processes”, published in 2001.

Preheat phase

During the initial heating of component leads and balls, residual humidity will be dried out. Note that the preheat phase does not replace prior baking procedures.

- Temperature rise rate: max 3 °C/s. If the temperature rise is too rapid in the preheat phase, excessive slumping may be caused
- Time: 60 – 120 s. If the preheat is insufficient, rather large solder balls tend to be generated. Conversely, if performed excessively, fine balls and large balls will be generated in clusters
- End temperature: 150 – 200 °C. If the temperature is too low, non-melting tends to be caused in areas containing large heat capacity

Heating - reflow phase

The temperature rises above the liquidus temperature of 217 °C. Avoid a sudden rise in temperature as the slump of the paste could become worse.

- Limit time above 217 °C liquidus temperature: 40 – 60 s
- Peak reflow temperature: 245 °C

Cooling phase

A controlled cooling prevents negative metallurgical effects of the solder (solder becomes more brittle) and possible mechanical tensions in the products. Controlled cooling helps to achieve bright solder fillets with a good shape and low contact angle.

- Temperature fall rate: max 4 °C/s

-  To avoid falling off, the modules should be placed on the topside of the board during soldering.

The final soldering temperature chosen at the factory depends on additional external factors such as the choice of soldering paste, size, thickness and properties of the base board, etc. Exceeding the maximum soldering temperature in the recommended soldering profile may permanently damage the module.

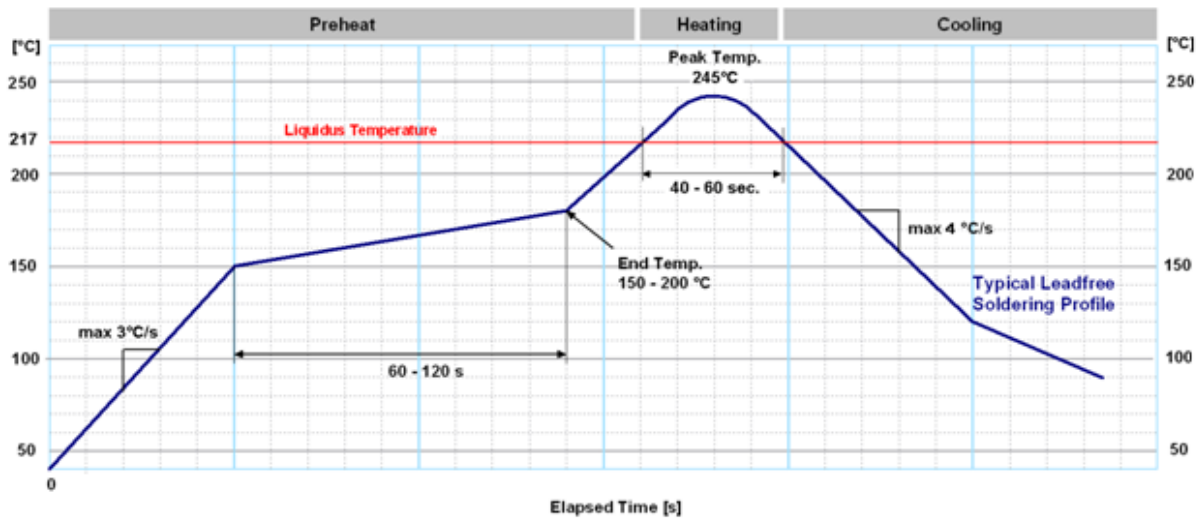


Figure 14: Soldering profile

Modules must not be soldered with a damp heat process.

Optical inspection

After soldering the module, consider optical inspection.

Cleaning

Do not clean with water, solvent, or ultrasonic cleaner:

- Cleaning with water will lead to capillary effects where water is absorbed into the gap between the baseboard and the module. The combination of residues of soldering flux and encapsulated water leads to short circuits or resistor-like interconnections between neighboring pads.
- Cleaning with alcohol or other organic solvents can result in soldering flux residues flowing underneath the module, into areas that are not accessible for post-cleaning inspections. The solvent will also damage the sticker and the printed text.
- Ultrasonic cleaning will permanently damage the module, in particular the quartz oscillators.

The best approach is to use a “no clean” soldering paste to eliminate the cleaning step after the soldering.

Repeated reflow soldering

Repeated reflow soldering processes or soldering the module upside down are not recommended.

A board that is populated with components on both sides may require more than one reflow soldering cycle. In such a case, the process should ensure the module is only placed on the board submitted for a single final upright reflow cycle. A module placed on the underside of the board may detach during a reflow soldering cycle due to lack of adhesion.

The module can also tolerate an additional reflow cycle for rework purposes.

Wave soldering

Base boards with combined through-hole technology (THT) components and surface-mount technology (SMT) devices require wave soldering to solder the THT components. Only a single wave soldering process is encouraged for boards populated with modules.

Rework

We do not recommend using a hot air gun because it is an uncontrolled process and can damage the module.

- ⚠ Use of a hot air gun can lead to overheating and severely damage the module. Always avoid overheating the module.

After the module is removed, clean the pads before reapplying solder paste, placing and reflow soldering a new module.

- ⚠ Never attempt a rework on the module itself, e.g. by replacing individual components. Such actions will immediately void the warranty.

Conformal coating

Certain applications employ a conformal coating of the PCB using HumiSeal® or other related coating products. These materials affect the RF properties of the GNSS module and it is important to prevent them from flowing into the module. The RF shields do not provide 100% protection for the module from coating liquids with low viscosity. Apply the coating carefully.

- 👉 Conformal coating of the module will void the warranty.

Casting

If casting is required, use viscose or another type of silicon pottant. The OEM is strongly advised to qualify such processes in combination with the module before implementing this in the production.

- 👉 Casting will void the warranty.

Grounding metal covers

Attempts to improve grounding by soldering ground cables, wick or other forms of metal strips directly onto the EMI covers is done at the customer's own risk. The numerous ground pins should be sufficient to provide optimum immunity to interferences and noise.

- 👉 u-blox makes no warranty for damages to the module caused by soldering metal cables or any other forms of metal strips directly onto the EMI covers.

Use of ultrasonic processes

Some components on the module are sensitive to ultrasonic waves. Use of any ultrasonic processes (cleaning, welding etc.) may cause damage to the receiver.

- 👉 u-blox offers no warranty against damages to the module caused by ultrasonic processes.

Related documents

- [1] NEO-F10T Data sheet, [UBX-22022576](#)
- [2] u-blox TIM3.01 Interface description, [UBX-23003447](#)
- [3] u-blox Product packaging reference guide, [UBX-14001652](#)



For regular updates to u-blox documentation and to receive product change notifications please register on our homepage <https://www.u-blox.com>.

Revision history

Revision	Date	Status / comments
R01	05-Apr-2023	Product status is available in the product Data sheet [1].
R02	22-Jan-2024	Editorial changes throughout the document. Updated sections: <ul style="list-style-type: none">• Active antenna recommendations in Antenna requirements• Recommended inductors in External components• Deliverable quantities on a reel in Packaging

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