

MAX-F10S

Standard precision GNSS module

Professional grade

Integration manual



Abstract

This document describes the features and application of the u-blox MAX-F10S module, an L1/L5 dual-band GNSS receiver for meter-level accuracy in urban environment.

Note! GPS L5 signals are pre-operational and not used by default. Refer to the Overview section for more information.

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1 System description

This document is an important source of information for all aspects of MAX-F10S 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

MAX-F10S is built on the u-blox F10 dual-band GNSS technology using L1 and L5 band signals. The proprietary dual-band multipath mitigation technology enables the u-blox F10 to use the best signals from the L1 and L5 bands providing a solid meter-level position accuracy in urban environment.

- ⚠ At the time of writing, the GPS L5 signals remain pre-operational and are set as unhealthy until sufficient monitoring capability is established. This is an operational issue concerning the satellites / space segment and not a limitation of u-blox products.
- ⚠ Due to the pre-operational status, the GPS L5 signals are not used for the navigation solution by default. However, it is possible to evaluate the GPS L5 signals before they become fully operational by changing the receiver configuration to override the GPS L5 health status. Refer to the section [GPS L5 signal health status configuration](#) for details.

1.2 Architecture

The MAX-F10S 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

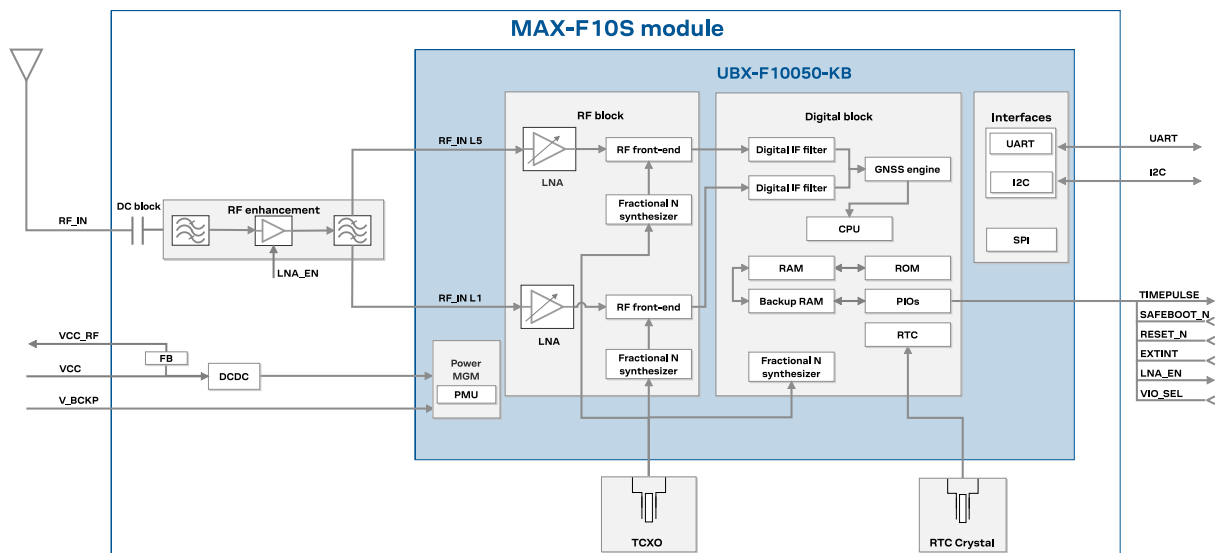


Figure 1: MAX-F10S block diagram

1.3 Pin assignment

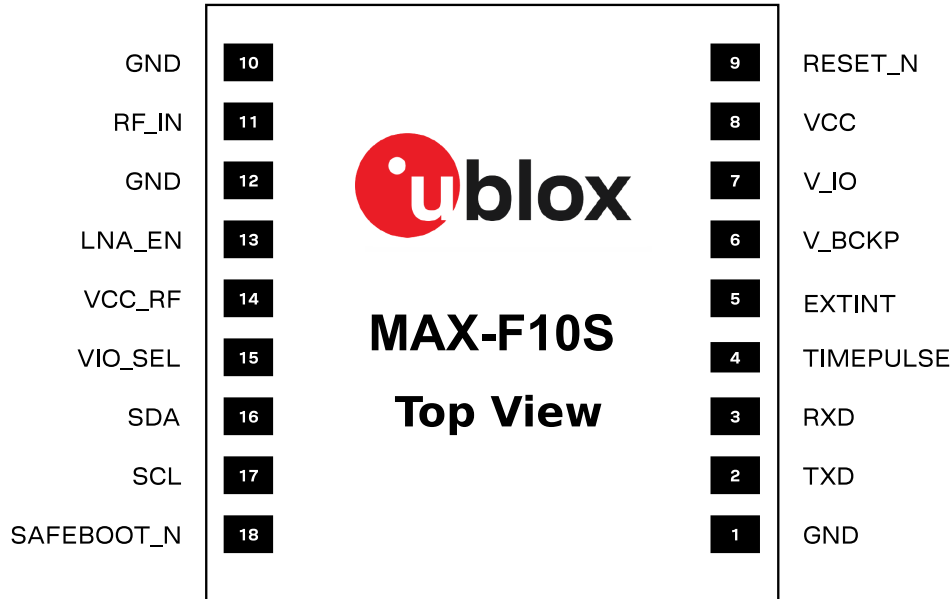


Figure 2: MAX-F10S pin assignment

Pin no.	Name	PIO no.	I/O	Description	Remarks
1	GND	-	-	-	Connect to GND
2	TXD	1	O	UART TX	If not used, leave open. Alternative functions ¹ .
3	RXD	0	I	UART RX	If not used, leave open. Alternative functions ¹ .
4	TIMEPULSE	4	O	Time pulse signal	See section TIMEPULSE for more information. Alternative functions ¹ .
5	EXTINT	5	I	External interrupt	See EXTINT for more information. Alternative functions ¹ .
6	V_BCKP	-	I	Backup voltage supply.	Leave open if no external backup supply. See V_BCKP for more information.
7	V_IO	-	I	IO voltage supply	See V_IO for more information.
8	VCC	-	I	Main voltage supply	See VCC for more information.
9	RESET_N	-	I	System reset (active low)	It has to be low for at least 1 ms to trigger a reset. Leave open if not used. See RESET_N section for more information.
10	GND	-	-	-	Connect to GND
11	RF_IN	-	I	GNSS signal input	The RF signal line is DC blocked internally. The line must match the 50 Ω impedance. See sections RF front-end and Layout for more information about the RF signal considerations.
12	GND	-	-	-	Connect to GND
13	LNA_EN	-	O	On/Off external LNA or active antenna	See LNA_EN for more information.
14	VCC_RF	-	O	Output voltage RF section	This pin supplies a filtered voltage that can be used for optional external active antenna or LNA. This pin is internally connected to VCC through a ferrite bead.

¹ Alternatively, this pin can be used for [ANT_DETECT](#), [ANT_SHORT_N](#), and [TX_READY](#). Care must be taken when the assigned function sets the pin as an output.

Pin no.	Name	PIO no.	I/O	Description	Remarks
15	VIO_SEL	-	I	Voltage selector for V _{IO} supply	Connect to GND for 1.8 V supply, or leave open for 3.3 V supply
16	SDA	2	I/O	I2C data	If not used, leave open. Alternative functions ¹ .
17	SCL	3	I	I2C clock	If not used, leave open. Alternative functions ¹ .
18	SAFEBOOT_N	-	I	Safeboot mode	To enter safeboot mode, set this pin to low at receiver's startup. Otherwise, leave it open. The SAFEBOOT_N pin is internally connected to TIMEPULSE pin through a 1 kΩ series resistor.

Table 1: MAX-F10S pin assignment

2 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 MAX-F10S.

MAX-F10S 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 [3].

The configuration can be stored in the RAM and the battery-backed RAM (BBR) 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	- 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	- Activating the RESET_N pin - A UBX-CFG-RST message with reset mode set to a hardware reset (resetMode 0x00 and 0x04)

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

It is recommended to apply runtime configuration on both RAM and BBR 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 [3].

2.1 Basic receiver configuration

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

2.1.1 Basic hardware configuration

The MAX-F10S receiver is preconfigured in module production and is fully operational after connecting a proper power supply, the communication interfaces with the host application device, and a suitable antenna signal.

2.1.2 Internal LNA mode configuration

u-blox 10 receivers feature an internal low-noise amplifier (LNA) with three operational modes: normal gain, low gain and bypass mode. The MAX-F10S default is the low gain mode. With a high-gain external active antenna, use the bypass mode to save power. The normal gain mode is not recommended for MAX-F10S.

The internal LNA mode can be configured at run time in the BBR and RAM memory using the configuration item CFG-HW-RF_LNA_MODE and applying a suitable software reset by sending a UBX-CFG-RST message. The suitable software reset type depends on the configured memory layer. For more information, refer to [Forcing receiver reset](#).

The internal LNA mode can also be permanently configured in the receiver's one-time programmable (OTP) memory.

The default gain mode is pre-configured in the receiver and does not require configuration in production. The configuration strings for setting the internal LNA mode in the OTP memory is given in [Table 3](#).

Internal LNA mode	Configuration string
Low gain	Default
Bypass	B5 62 06 41 10 00 03 00 05 1F 79 B2 0A E5 28 EF 12 05 9F FF FF FF 62 FB

Table 3: Internal LNA mode configuration in OTP memory

Configuring the internal LNA mode in the OTP memory:

1. Power up the system.
2. Test the communication interface by polling the UBX-MON-VER message.
3. Send the desired configuration string in [Table 3](#).
4. Power cycle the receiver or apply a hardware reset by sending a UBX-CFG-RST message. The configured internal LNA setting is applied at startup.
5. Verify that the configuration item is correctly set by polling CFG-HW-RF_LNA_MODE at RAM layer using the UBX-CFG-VALGET message.

2.1.3 GNSS signal configuration

MAX-F10S supports reception of GPS, Galileo, BeiDou and QZSS L1/L5 dual-band signals plus NavIC L5 and SBAS L1. The default configuration is concurrent reception of GPS (L1C/A, L5), Galileo (E1-B/C, E5a) and BeiDou (B1C, B2a) with SBAS enabled.

Each GNSS constellation can be enabled or disabled independently except for QZSS, which is 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 constellations with dual-band support, it is not possible to disable one of the bands. Both bands must be enabled and disabled at once. Alternatively, the CFG-SIGNAL-* configuration group for that constellation can be enabled and disabled. For example, if CFG-SIGNAL-GPS_ENA is set to zero, the GPS constellation 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.



In Japan and surrounding regions, it is recommended to enable QZSS when GPS 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 [3].

2.1.4 GPS L5 signal health status configuration

MAX-F10S supports both GPS L1 C/A and L5 signals. Broadcasting of Civil Navigation (CNAV) messages on the L5 signal began in April 2014. At the time of writing, GPS L5 signals remain **pre-operational** which are set unhealthy until sufficient monitoring capability is established.

To evaluate GPS L5 signals before they become fully operational, the receiver can be configured to ignore the GPS L5 health status by overriding it with the respective GPS L1 C/A signal status.

 Do not use unhealthy, pre-operational GPS L5 signals for safety-of-life or other critical purposes. This is an operational issue concerning the satellites / space segment and not a limitation or specific configuration of u-blox products.

To ignore the GPS L5 signal health status and override it with the respective GPS L1 signal health status, send the configuration string given in [Table 4](#). The configuration can be stored in RAM, battery-backed RAM (BBR), and flash layers. Stored in the RAM layer, the device returns the UBX-ACK-ACK message if the configuration is sent successfully and it is applied immediately without a configuration reset. To apply the configuration stored in the BBR and flash layers, send the UBX-CFG-RST message with resetMode 0x01.

To revert back to the default configuration, send the configuration string given in [Table 5](#). The device returns the UBX-ACK-ACK message if the configuration is sent successfully and it is applied immediately without a reset in the RAM layer. To apply the configuration stored in the BBR and flash layers, send the UBX-CFG-RST message with resetMode 0x01.

 Customers who choose to ignore the GPS L5 signal health status in their production system do so at their own risk and must be fully aware of the implications. The system should also include a mechanism to revert to the mode where the L5 signal health status is respected.

Configuration layer	Configuration string
RAM	B5 62 06 8A 09 00 01 01 00 00 01 00 32 10 01 DF F6
BBR	B5 62 06 8A 09 00 01 02 00 00 01 00 32 10 01 E0 FE

Table 4: UBX binary string to override GPS L5 signal health status with GPS L1 health status

Configuration layer	Configuration string
RAM	B5 62 06 8A 09 00 01 01 00 00 01 00 32 10 00 DE F5
BBR	B5 62 06 8A 09 00 01 02 00 00 01 00 32 10 00 DF FD

Table 5: UBX binary strings to revert the GPS L5 signal health status monitoring to default

2.1.5 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-*

Interface	Configuration groups
I2C	CFG-I2C-* CFG-I2CINPROT-* CFG-I2COUTPROT-* CFG-TXREADY-*

Table 6: Interface configuration


The UART baudrate in MAX-F10S is configured to 9600 baud which is different to the firmware default. This ensures backwards compatibility with previous generations of u-blox MAX modules.

2.1.6 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.

2.1.7 Antenna supervisor configuration

This section gives an overview of the antenna supervisor configuration keys. The implementation of the antenna supervisor and a detailed description can be found in [Antenna supervisor](#).

The antenna supervisor is used to control an active antenna. The configuration of the antenna supervisor allows the following:

- Control voltage supply to the antenna, which allows the antenna supervisor to cut power to the antenna in the event of a short circuit or optimize power to the antenna in power save modes.
- Detect a short circuit in the antenna and automatically recover the antenna supply after the short circuit is no longer present.
- Detect an open circuit, which can be used to indicate if the antenna has been disconnected.



Using some antenna supervisor features may require disabling the UART or I2C interface and reconfiguring the PIOs as antenna supervisor pins.

Table 7 describes the configuration items.

Configuration item	Description	Comments
CFG-HW-ANT_CFG_VOLTCTRL	Enable active antenna voltage control	
CFG-HW-ANT_CFG_SHORTDET	Enable short circuit detection	
CFG-HW-ANT_CFG_SHORTDET_POL	Short antenna detection polarity	Set to 1 if the required logic polarity is active-low (default).
CFG-HW-ANT_CFG_OPENDET	Enable open circuit detection	
CFG-HW-ANT_CFG_OPENDET_POL	Open antenna detection polarity	Set to 1 if the required logic polarity is active-low (default).
CFG-HW-ANT_CFG_PWRDOWN	Power down antenna supply if short circuit is detected	Requires CFG-HW-ANT_CFG_VOLTCTRL and CFG-HW-ANT_CFG_SHORTDET to be enabled.
CFG-HW-ANT_CFG_PWRDOWN_POL	Power down antenna logic polarity	Set to 1 if the required logic polarity is active-high (default).
CFG-HW-ANT_CFG_RECOVER	Enables auto-recovery in the event of a short circuit	To use this feature, enable short circuit detection and CFG-HW-ANT_CFG_PWRDOWN.
CFG-HW-ANT_SUP_SWITCH_PIN	PIO number of the pin used for switching antenna supply	PIO5 is recommended if available. This pin can be used as an LNA_EN signal to control an external LNA, especially if the software standby mode is used.
CFG-HW-ANT_SUP_SHORT_PIN	PIO number of the pin used for detecting a short circuit in the antenna supply	Unused UART or I2C pins can be reassigned for short circuit detection.
CFG-HW-ANT_SUP_OPEN_PIN	PIO number of the pin used for detecting open/disconnected antenna	Unused UART or I2C pins can be reassigned for open circuit detection.
CFG-HW-ANT_ON_SHORT_US	Time delay between the antenna supply being turned on and the short circuit detection being activated (in microseconds)	Increase the time delay to avoid a short circuit to be detected before the antenna supply voltage has stabilized. Recommended values: 500 us (default) to 5000 us.

Table 7: Antenna supervisor configuration

It is possible to obtain the status of the antenna supervisor from the UBX-MON-RF message. For information about the *antStatus* and *antPower* fields, refer to the Interface description [3]. In addition, any changes in the status of the antenna supervisor are reported to the host interface as ANTSTATUS in NMEA notice messages.

ANTSTATUS	Description
OFF	Antenna is off
ON	Antenna is on
DONTKNOW	Antenna power status is not known

Table 8: Antenna power status

2.2 Navigation configuration

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

2.2.1 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 9](#) and [Table 10](#).

Platform	Description
Portable	Applications with low acceleration, e.g. portable devices. Suitable for most situations.
Stationary	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 9: 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
Airborne <2g	80000	250	10000	Altitude	Large
Airborne <4g	80000	500	20000	Altitude	Large
Wrist	9000	30	20	Altitude and velocity	Medium

Table 10: 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 10](#) shows the types of sanity checks which are applied for a particular dynamic platform model.

2.2.2 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.
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.
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 11: 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.



u-blox receivers do not calculate any navigation solution with fewer than three satellites.

2.2.3 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).

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.

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.

2.2.4 Odometer filters

2.2.4.1 Speed (3D) low-pass filter

The CFG-ODO-OUTLPVEL configuration item activates a speed (3D) low-pass filter. The output of the speed low-pass filter is available in the UBX-NAV-VELNED message (`speed` field). The filtering level can be set via the CFG-ODO-VELLPGAIN configuration item and must be between 0 (heavy low-pass filtering) and 255 (weak low-pass filtering).



The internal filter gain is computed as a function of speed. Therefore, the level defines the nominal filtering level for speeds below 5 m/s, as defined in the CFG-ODO-VELLPGAIN configuration item.

2.2.4.2 Course over ground low-pass filter

The CFG-ODO-OUTLPCOG configuration item activates a course over ground low-pass filter when the speed is below 8 m/s. The output of the course over ground (also named heading of motion 2D) low-pass filter is available in the UBX-NAV-PVT message (`headMot` field), UBX-NAV-VELNED

message (`heading` field), NMEA-RMC message (`cog` field), and NMEA-VTG message (`cogt` field). The filtering level can be set via the CFG-ODO-COGLPGAIN configuration item and must be between 0 (heavy low-pass filtering) and 255 (weak low-pass filtering).



The filtering level defines the filter gain for speeds below 8 m/s, as defined in the CFG-ODO-COGLPGAIN configuration item. If the speed is 8 m/s or higher, no course over ground low-pass filtering is performed.

2.2.4.3 Low-speed course over ground filter

The CFG-ODO-USE_COG configuration item activates this feature and the CFG-ODO-COGMAXSPEED, CFG-ODO-COGMAXPOSACC configuration items are used to configure a low-speed course over ground filter (also named heading of motion 2D). This filter derives the course over ground from position at very low speed. The output of the low-speed course over ground filter is available in the UBX-NAV-PVT message (`headMot` field), UBX-NAV-VELNED message (`heading` field), NMEA-RMC message (`cog` field) and NMEA-VTG message (`cogt` field). If the low-speed course over ground filter is not configured, then the course over ground is computed as described in section [Freezing the course over ground](#).

2.2.5 Static hold

The static hold mode allows the navigation algorithms to decrease the noise in the position output when the velocity is below a predefined "Static Hold Threshold" level. This reduces the position wander caused by environmental factors such as multi-path and improves position accuracy especially in stationary applications. By default, the static hold mode is disabled.

The CFG-MOT-GNSSSPEED_THRS configuration item defines the static hold speed threshold. If the speed drops below the defined "Static Hold Threshold", static hold mode is activated. Once static hold mode is active, the position output is kept static and the velocity is set to zero until there is evidence of movement again. Such evidence can be velocity, acceleration, changes of the valid flag (for example, position accuracy estimate exceeding the position accuracy mask, see also section [Navigation output filters](#)), position displacement, etc.

The CFG-MOT-GNSSDIST_THRS configuration item defines the static hold distance threshold. If the distance between the estimated position and the static hold position exceeds the defined threshold, the static hold mode is suspended or deactivated until there is evidence of no movement.

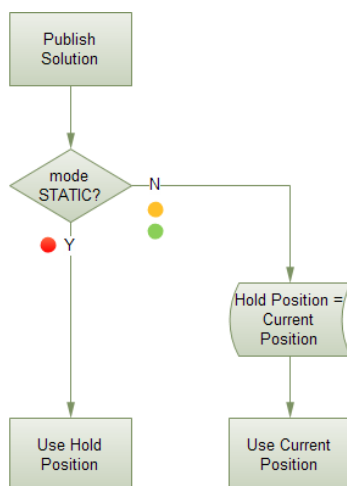


Figure 3: Position output in static hold mode

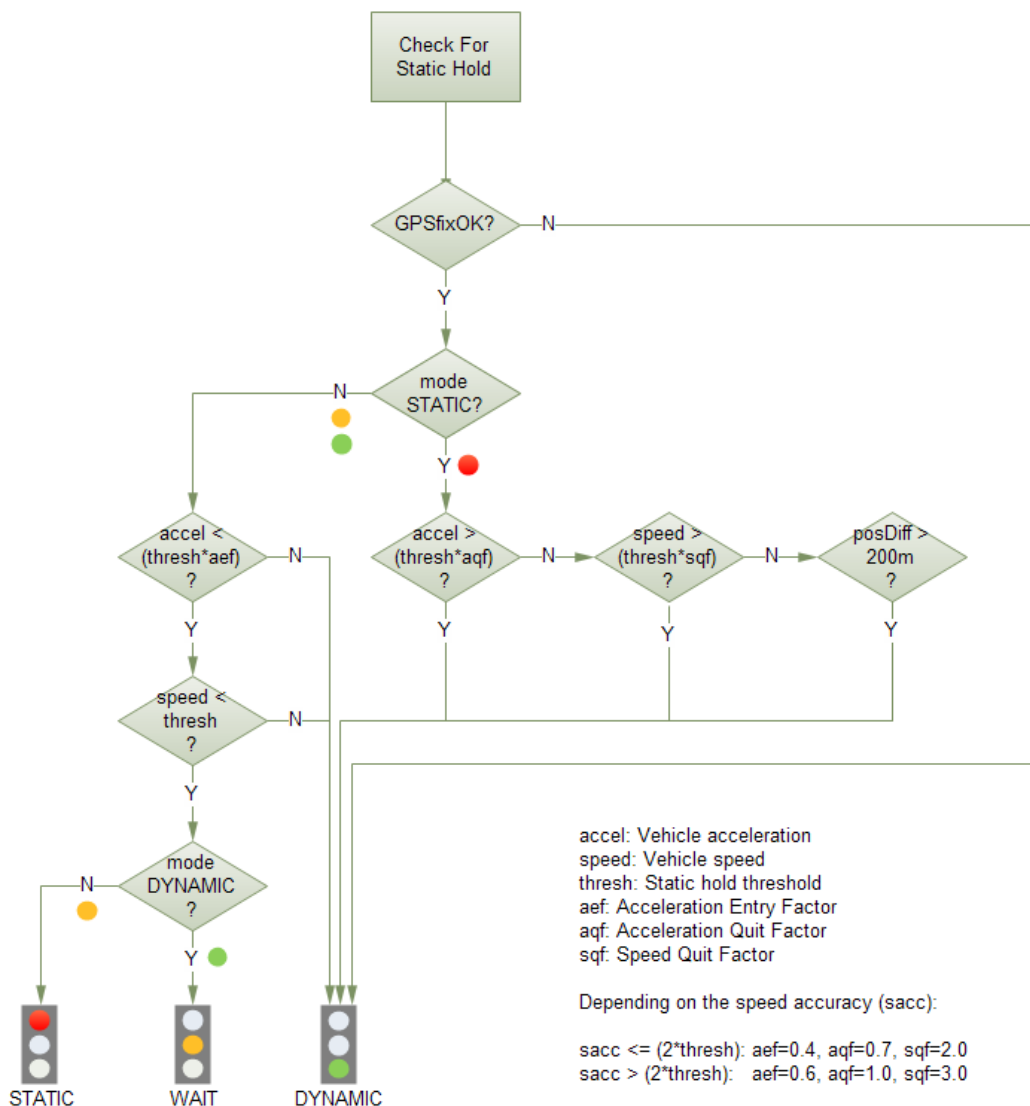


Figure 4: Flowchart of static hold mode

2.2.6 Freezing the course over ground

If the low-speed course over ground filter is deactivated or inactive (see section [Low-speed course over ground filter](#)), the receiver derives the course over ground from the GNSS velocity information. If the velocity cannot be calculated with sufficient accuracy (for example, with bad signals) or if the absolute speed value is very low (under 0.1 m/s), the course over ground value becomes inaccurate too. In this case the course over ground value is frozen, that is, the previous value is kept and its accuracy degrades over time. These frozen values will not be output in the NMEA messages NMEA-RMC and NMEA-VTG unless the NMEA protocol is explicitly configured to do so (see NMEA protocol configuration in the applicable interface description [3]).

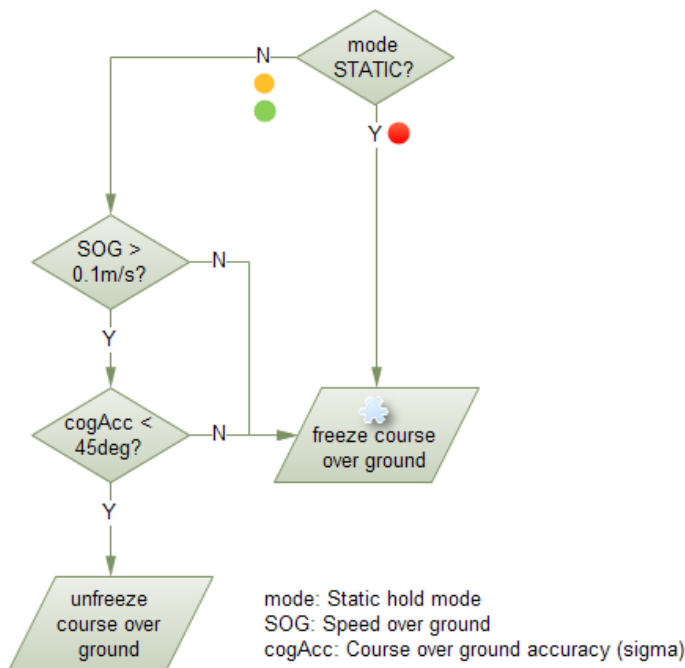


Figure 5: Flowchart of course over ground freezing

2.3 OTP memory configuration

MAX-F10S contains a one-time programmable (OTP) memory. This is a non-volatile memory for storing configuration settings and ROM patches permanently in the device. The stored data cannot be modified after it has been initially programmed. The device applies the settings and ROM patches on the device startup.

As the space in the OTP memory is limited, only essential system configuration settings should be stored. The total space used for device configuration and ROM patches in the OTP memory must not exceed 40 bytes. Other settings can be stored in the BBR or sent from the host to the device on each device startup.



Ensure that the final configuration stored and optional ROM patches do not require more than 40 bytes of OTP memory space.

3 Receiver functionality

This chapter describes the MAX-F10S operational features and their configuration.

3.1 Augmentation systems

3.1.1 SBAS

MAX-F10S is capable of receiving multiple Satellite Based Augmentation System (SBAS) signals concurrently, even from different SBAS systems (WAAS, EGNOS, etc.). SBAS signals are recommended to be used only for correction data. These signals can also be used for navigation, but with their low weighting, they only have a minor impact on the navigation solution.



SBAS is recommended to use, as the accuracy of an L1/L5 receiver is highly affected by ionospheric delays.

For receiving correction data, MAX-F10S 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 solution, the differential correction status is indicated in several output messages such as UBX-NAV-PVT, UBX-NAV-STATUS, UBX-NAV-SAT, UBX-NAV-SIG, NMEA-GGA, NMEA-GLL, NMEA-RMC, and NMEA-GNS. The UBX-NAV-SBAS message provides detailed information about the corrections available and applied. Refer to the Interface description [3] for a detailed description of the messages.

The most important SBAS feature for 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.

Message type	Message content	Source
0(0/2)	Test mode	All
1	PRN mask assignment	Primary
2, 3, 4, 5	Fast corrections	Primary
6	Integrity	Primary
7	Fast correction degradation	Primary
9	Satellite navigation (ephemeris)	All
10	Degradation	Primary
12	Time offset	Primary
17	Satellite almanac	All
18	Ionosphere grid point assignment	Primary
24	Mixed fast / long-term corrections	Primary
25	Long-term corrections	Primary
26	Ionosphere delays	Primary

Table 12: Supported SBAS messages

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

Parameter	Description
CFG-SIGNAL-SBAS_ENA	Enabled/disabled status of the SBAS subsystem
CFG-SBAS-USE_TESTMODE	Allow/disallow SBAS usage from satellites in test mode (enable when BDSBAS is used)
CFG-SBAS-USE_RANGING	Use the SBAS satellites for navigation (ranging)
CFG-SBAS-USE_DIFFCORR	Combined enable/disable switch for fast, long-term, and ionosphere corrections
CFG-SBAS-USE_INTEGRITY	Apply integrity information data
CFG-SBAS-PRNSCANMASK	Allows selectively enabling/disabling SBAS satellites (BDSBAS disabled by default)

Table 13: SBAS configuration parameters

-  When SBAS integrity data is applied, the navigation engine stops using all signals for which no integrity data is available (including all non-GPS signals). It is not recommended to enable SBAS integrity on borders of SBAS service regions in order not to inadvertently restrict the number of available signals.
-  SBAS integrity information is required for at least five GPS satellites. If this condition is not met, SBAS integrity data will not be applied.
-  When the receiver switches from a solution using correction data to a standard position solution, the reference frame of the output position switches as well. For an SBAS solution, the reference frame is aligned within a few centimeters of WGS84 (and modern ITRF realizations).
-  Other SBAS systems (such as KASS) can be enabled by adding the corresponding PRNs to the CFG-SBAS-PRNSCANMASK list.
-  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 and GAGAN SBAS satellites in other parts of Europe. Therefore, it is recommended that satellites from all but the EGNOS system are disallowed using the PRN scan mask.

3.1.1.1 BeiDou SBAS configuration

BeiDou satellite based augmentation system (BDSBAS) provides SBAS services to China and surrounding regions. BDSBAS is integrated in the BeiDou system and uses BDS-3 type satellites to broadcast SBAS L1/L5 signal, providing augmentation for BeiDou and GPS systems.

BeiDou SBAS is in testing mode and it is not enabled by default. Enabling Beidou SBAS may improve navigation solution by its correction data. To enable the BeiDou SBAS functionality, configure the following configuration items.

Configuration item	Value
CFG-SBAS-ACCEPT_NOT_IN_PRNMASK	BDSBAS
CFG-SBAS-PRNSCANMASK	0x0000000001800400
CFG-SBAS-USE_DIFFCORR	TRUE (default)
CFG-SBAS-USE_INTEGRITY	FALSE (default)

Configuration item	Value
CFG-SBAS-USE_IONOONLY	FALSE (default)
CFG-SBAS-USE_RANGING	FALSE
CFG-SBAS-USE_TESTMODE	TRUE

Table 14: BeiDou SBAS configuration item

-  BeiDou SBAS is still in testing mode and it has not been officially released for operational use. Do not use it for safety related applications.
-  The CFG-SBAS-PRNSCANMASK in [Table 14](#) includes only BeiDou SBAS PRNs. Alternatively, the BeiDou SBAS PRNs can be added to the default list of PRNs enabled in the firmware or modified list of PRNs that is configured. This allows other SBAS systems to be used if BeiDou SBAS is not available.

3.1.2 QZSS SLAS

QZSS SLAS (Sub-meter Level Augmentation Service) is an augmentation technology, which provides correction data for pseudoranges of GPS, QZSS, and other major GNSS satellites. The correction stream is transmitted on the L1S signal at the L1 frequency (1575.42 MHz).

For more information on QZSS SLAS, visit qzss.go.jp/en/.

Multiple QZSS SLAS signals can be received simultaneously. When receiving QZSS SLAS correction data, MAX-F10S will autonomously select the best QZSS satellite. The selection strategy is determined by the quality of the QZSS L1S signals, the receiver configuration (test mode allowed or not), and the location of the receiver with respect to the QZSS SLAS coverage area. When outside of this coverage area, the receiver will likely fall back to using SBAS corrections.

If QZSS SLAS corrections are used in the navigation solution, the differential status will be indicated in several output messages such as UBX-NAV-PVT, UBX-NAV-STATUS, UBX-NAV-SAT, NMEA-GGA, NMEA-GLL, NMEA-RMC, and NMEA-GNS. The UBX-NAV-SLAS message provides detailed information about which corrections are available and applied. Refer to the interface description [\[3\]](#) for a detailed description of the messages.

Message type	Message content
0	Test mode
47	Monitoring station information
48	PRN mask
49	Data issue number
50	DGPS correction
51	Satellite health

Table 15: Supported QZSS L1S SLAS messages for navigation enhancement

Use the configuration key CFG-SIGNAL-QZSS_L1S_ENA to enable QZSS L1S signal. For further QZSS SLAS functionality, use the CFG-QZSS-USE_SLAS* configuration keys.

Parameter	Description
CFG-QZSS-USE_SLAS_DGNSS	Apply QZSS SLAS corrections
CFG-QZSS-USE_SLAS_TESTMODE	Allow the correction provided by QZSS satellites that are in test mode
CFG-QZSS-USE_SLAS_RAIM_UNCORR	If this configuration is set, the receiver will try to estimate the position by using only corrected measurements; if all corrected measurements are not available, it will not use any corrections. If this configuration is not set, the receiver will mix corrected and uncorrected measurements for the navigation solution.

Table 16: QZSS SLAS configuration parameters

 If the RAIM option is set, QZSS is the only GNSS time system that measurements can observe.

3.2 Communication interfaces and PIOs

MAX-F10S 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.

3.2.1 UART

MAX-F10S 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
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 17: 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 9600 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.

3.2.2 I2C

An I2C interface is available for communication with an external host CPU in the I2C Fast-mode. Backwards compatibility with the Standard-mode I2C bus operation is not supported. The interface can be operated only in the peripheral mode with the maximum bit rate of 320 kbit/s. The interface can make use of clock stretching by holding the SCL line LOW to pause a transaction. In this case, the bit transfer rate is reduced. The maximum clock stretching time is 20 ms.

The SCL and SDA pins have internal pull-up resistors which should be sufficient for most applications. However, depending on the clock speed of the host and the capacitive load on the

I2C lines, additional external pull-up resistors may be necessary. The higher the speed and the capacitance load, the lower the pull-up resistor needs to be.

To poll or set the I2C address, use the CFG-I2C-ADDRESS configuration item. Refer to Interface description [3] for details. The CFG-I2C-ADDRESS configuration item is an 8-bit value containing the I2C address in the 7 most significant bits plus a 0 as the least significant bit. Thus, the default address becomes 0x84(1000 0100).



In designs where the host uses the same I2C bus to communicate with more than one u-blox receiver, each receiver's I2C address must be configured with a different value.

3.2.2.1 I2C register layout

As shown in Figure 6, there are 256 registers. The data registers 0 to 252, at addresses 0x00 to 0xFC, contain reserved information and must not be used. Hence, only the last three registers are left for communication. The registers 0xFD and 0xFE contain the currently available number of bytes to be read, while the register 0xFF buffers the message stream. The 0xFF address delivers a 0xFF byte value if there is no data awaiting for transmission, or all the bytes have been read.

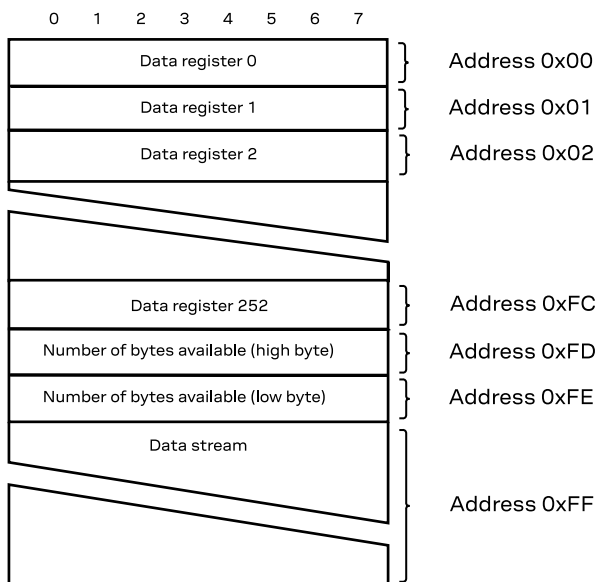


Figure 6: I2C register layout

3.2.2.2 Read access types

The host can choose one of the following two modes:

- Random read access: the controller first reads the number of available bytes at the 0xFD and 0xFE before accessing the data at 0xFF.
- Current address read access: the controller directly reads the data at the register 0xFF, without knowing first if there is any data waiting. If there is no data, the read result is a 0xFF byte value. This mode basically skips the first step of the "random read access", as it does not address to any particular register.

Figure 7 shows the format of the "random access" form of the request.

Following the start condition from the controller, the 7-bit device address and the RW bit (which is a logic low for write access) are clocked onto the bus by the controller transmitter. The receiver answers with an acknowledge (logic low) to indicate that it recognizes the address.

Next, the 8-bit address of the register to be read must be written to the bus (0xFD for u-blox receivers). Following the receiver's acknowledgment, the controller again triggers a start condition and writes the device address, but this time the RW bit is a logic high to initiate the read access. Now, the controller can read 1 to N bytes from the receiver. The receiver will first deliver the byte value at 0xFD, followed by the value at 0xFE. At this point the controller knows the number of bytes waiting at the 0xFF register, and by acknowledging again, the data stream follows. The data transfer will stop once the controller emits a not-acknowledge response or a stop condition is triggered after the last byte has been read.

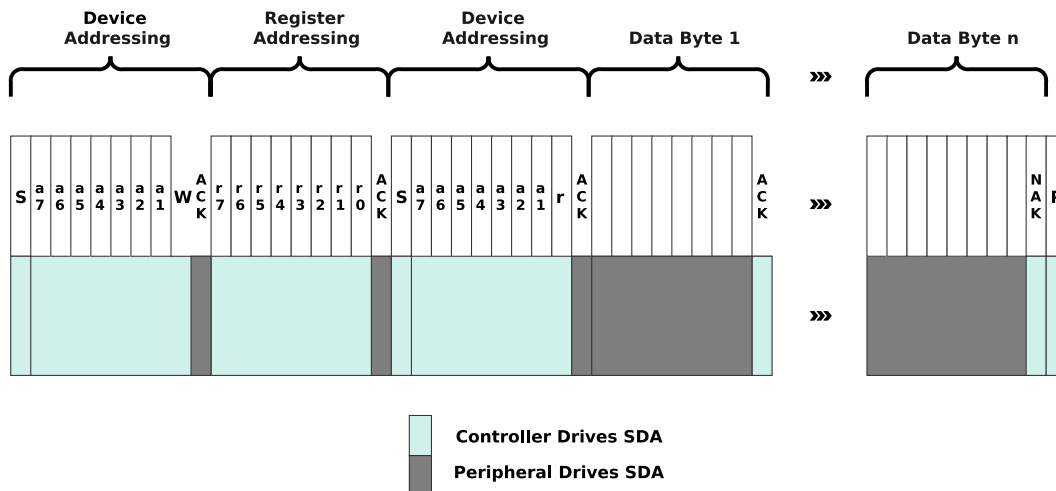


Figure 7: I2C random read access

If "current address" is used, an address pointer in the receiver is used to determine which register to read. This address pointer will increment after each read operation unless it is already pointing at register 0xFF, the highest addressable register, in which case it remains unaltered.

The initial value of this address pointer at startup is 0xFF, so by default all current address read operations will repeatedly read register 0xFF and receive the next byte of message data (or 0xFF value if no message data is waiting).

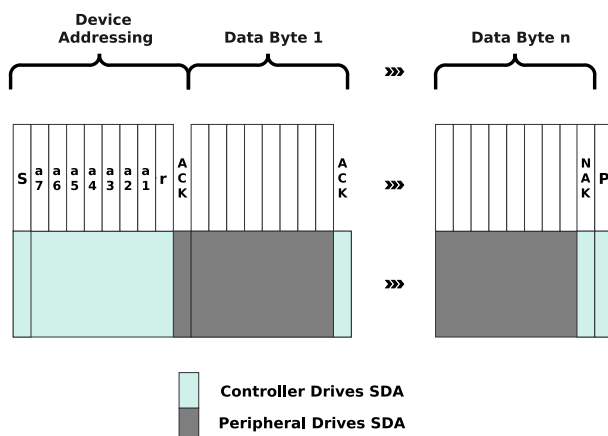


Figure 8: I2C current address read access

Only after addressing the peripheral, the receiver starts the data stream. If the controller does not read data from the receiver for a certain timeout, the receiver assumes that the communication is broken and stops the data stream, preventing an overflow of the output buffer. This timeout is

1.5 seconds by default. However, it can be extended by setting the CFG-I2C-EXTENDEDTIMEOUT configuration item to true. Refer to the Interface description [3] for details. By disabling the timeout, the receiver will only interrupt the data stream when the buffer is full. The buffer can store up to 4 kB and the time for an overflow event depends on the number of messages enabled.

3.2.2.3 Write access

The receiver does not provide any write access except for writing UBX and NMEA messages to the receiver, such as configuration or aiding data. Therefore, the register set mentioned in section [I2C register layout](#) is not writeable.

Following the start condition from the controller, the 7-bit device address and the RW bit (which is a logic low for write access) are clocked onto the bus by the controller. The receiver answers with an acknowledge (logic low) response to indicate that it is responsible for the given address.

The controller can write 2 to N bytes to the receiver, generating a stop condition after the last byte being written. To properly distinguish from the write access to set the address counter in random read accesses, the number of data bytes must be at least 2.

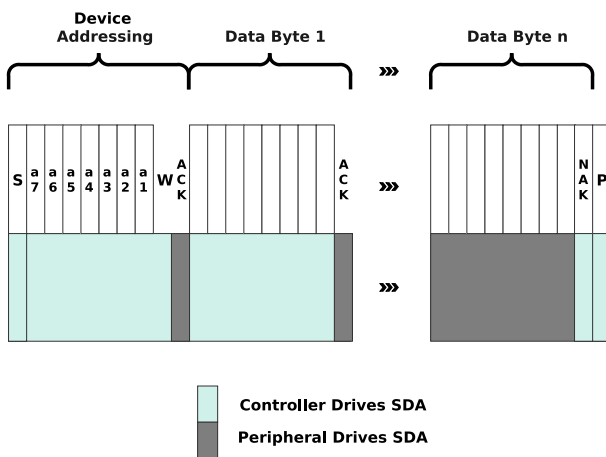


Figure 9: I2C write access

3.2.3 PIOs

This section describes the PIOs supported by MAX-F10S. All PIO active voltage levels are related to the V_{IO} supply voltage. All the inputs have internal pull-up resistors in normal operation and can be left open if unused.



When assigning a different function to a PIO, ensure that the default function is disabled where applicable. For example, disable the I2C interface with the CFG-I2C-ENABLED configuration key if I2C pins are used for antenna supervisor functions.

3.2.3.1 RESET_N

MAX-F10S provides a RESET_N pin to reset the receiver. The RESET_N pin is input-only with an internal pull-up resistor to V_{IO} and should be left open for normal operation. Driving RESET_N low for at least 1 ms triggers a receiver reset. The RESET_N complies with the V_{IO} 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.

3.2.3.2 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.

3.2.3.3 TIMEPULSE

The MAX-F10S features one time pulse output at the TIMEPULSE pin. This can only be configured in PIO4. 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.

3.2.3.4 LNA_EN

The LNA_EN signal can be used to turn on and off an optional external LNA and an active antenna supply to optimize the power consumption in the backup modes and the power save mode on/off operation (PSMOO). The LNA and the active antenna supply are turned on when the LNA_EN signal is "high".

The LNA_EN signal is also used internally in MAX-F10S to control the integrated LNA. The polarity cannot be changed.

The LNA_EN signal can also be used as a part of antenna supervisor circuit to control an active antenna power supply.

3.2.3.5 EXTINT

MAX-F10S supports external interrupts at the EXTINT pin. The EXTINT pin has a fixed input voltage threshold with respect to V_{IO}. It can be used for functions such as accurate external [Frequency assistance](#), [Time assistance](#) and [Time mark](#) reporting.

The EXTINT pin enables [External control](#) for host-controlled on/off operation of the receiver, and as a wake-up source for power save mode on/off operation (PSMOO). If configured for host-controlled on/off operation, the internal pull-up is disabled. Make sure the EXTINT input is always driven within the defined voltage level by the host.

The EXTINT pin can also be configured for another functionality.



EXTINT functionality is only available at the EXTINT pin.

3.2.3.6 TX_READY

The receiver has an internal message buffer for storing bytes to be sent to the host application. TX-ready feature in TX_READY pin enables I2C to have an associated signal to indicate that the buffer has bytes to be transmitted. The host application can wait on the signal instead of polling the interface.

The TX-ready signal is enabled and assigned to a selected pin with CFG-TXREADY configuration items. The polarity of the signal (active-low or active-high) and the threshold for amount of bytes in the buffer must also be configured. When the number of bytes in the buffer reaches the threshold, the TX-ready signal becomes active. The signal stays active until all of the bytes in the buffer have been transferred. The receiver has additional small transmit buffer for each interface. Up to 16 bytes may still need to be transferred to the host after the TX-ready signal has become inactive.

The TX-ready signal can be assigned to any pin. Old function on the pin must be disabled before the assignment. Pin assignment can be verified with the UBX-MON-HW3 message.

The threshold value of the CFG-TXREADY-THRESHOLD is presented as 8-byte (64 bit) chunks. Divide the desired threshold value by 8. E.g., value of 128 sets the TX-ready signal activation threshold to 1024 bytes. The threshold should not be set above 2048 bytes (256 8-byte chunks). Otherwise, the TX-ready signal may not be activated in time, and some messages may get discarded.

3.2.3.6.1 Extended TX timeout

If the host does not communicate over I2C for more than 1.5 seconds, the receiver assumes that the host is no longer using this interface and no more packets are scheduled for this interface. This mechanism can be changed by enabling "extended TX timeouts" (configuration key CFG-I2C-EXTENDEDTIMEOUT). When enabled, the receiver delays idling the interface until the allocated and undelivered bytes for this interface reach 4 kB. This feature is especially useful when using the TX-ready feature with a message output rate of less than once per second, and fetching data only when available, determined by the TX_READY pin becoming active.

3.3 Antenna

This section explains the antenna supervisor feature and the available implementation options.

3.3.1 Antenna supervisor

An active antenna supervisor provides the means to check the antenna for open and short circuits and to shut off the antenna supply if a short circuit is detected. Once enabled, the active antenna supervisor produces status messages that are reported in NMEA and/or UBX protocols. MAX-F10S supports two antenna supervisor variants: three-pin and two-pin implementations.

The three-pin antenna supervisor is able to detect short and open circuits and control the antenna supply. The two-pin antenna supervisor is a reduced version which is able to control the antenna supply and detect short circuits.



The MAX-F10S can make use of the two pin antenna supervisor if only the UART or I2C port is used. The three pin version can be used if the EXTINT PIO pin input is not required.



Antenna supervisor functions are not available when a Flash memory is connected to the MAX-F10S owing to the use of the available PIOs for a host interface (UART or I2C) and Flash memory SPI interface.

An overview of the two antenna supervisor variants is given in [Table 18](#).

The antenna supervisor can be configured through the CFG-HW-ANT_* configuration items. This includes enabling and disabling as well as changing the polarity of each signal. The current configuration of the active antenna supervisor can also be checked by polling the related CFG-HW-ANT_* configuration items.

The active antenna status can be determined by polling the UBX-MON-RF message or checking the NMEA notice messages. If an antenna is connected, the initial state after power-up is reported in the UBX-MON-RF message in *antStatus* and *antPower* fields. For more information, refer to Interface description [3]

Features	Three-pin	Two-pin
Short detection	Yes	Yes
Open detection	Yes	No
External components	Discrete and IC	Discrete and IC

Features	Three-pin	Two-pin
Number of PIOs needed	Three	Two

Table 18: Antenna supervisor overview

3.3.1.1 Three-pin antenna supervisor

An active antenna supervisor circuit uses the ANT_DETECT, ANT_OFF_N, and ANT_SHORT_N signals. The ANT_OFF_N signal is already enabled and assigned to the LNA_EN pin in MAX-F10S. The ANT_DETECT and ANT_SHORT_N signals can be assigned to any unused PIOs, which may require disabling the previous function of the PIOs. For example, the open circuit detection uses the ANT_DETECT signal, "high" = Antenna detected (antenna consumes current); "low" = Antenna not detected (no current drawn). To enable the three-pin antenna supervisor, the ANT_DETECT and ANT_SHORT_N signals must be enabled in the receiver configuration. The polarity of the ANT_DETECT and ANT_SHORT_N signals must also be defined in the receiver configuration based on the design use case.

The antenna can be supplied by VCC_RF or an external supply. Note that the supply voltage must be clean, as any noise could directly couple into the RF part of the GNSS receiver which affecting the overall GNSS performance.

Refer to [Reference designs](#) for antenna supervisor examples and the required configuration.

Figure 10 presents the required three-pin antenna supervisor circuit and subsequent sections describe how to enable and monitor each feature.

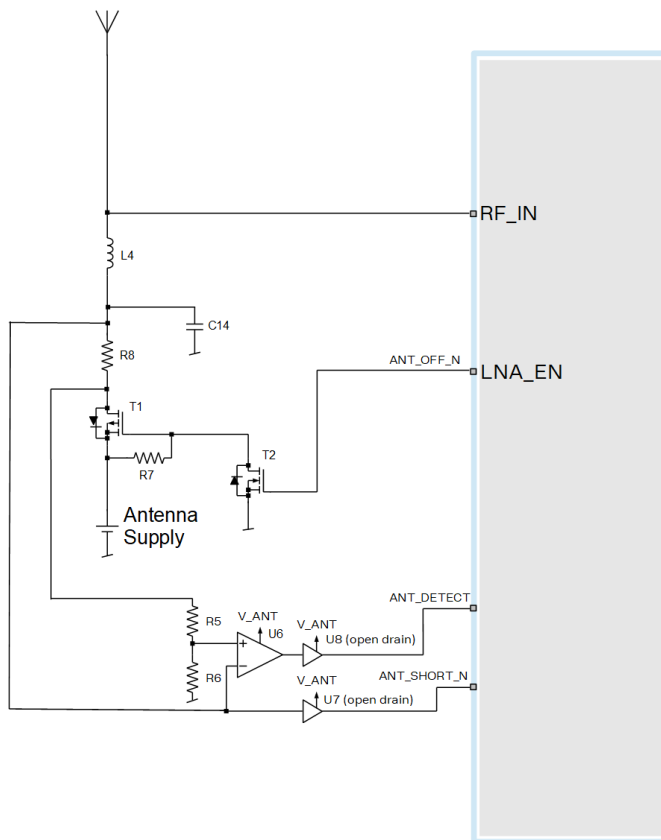

Figure 10: MAX-F10S three-pin antenna supervisor

Table 19 presents a list of the external components required for implementing the three-pin antenna supervisor design in Figure 10. Refer to External components for the recommended parts and specification.

Part	Description
C14	Filtering capacitor
L4	RF Bias-T inductor for L1 and L5
T1, T2	p-channel, n-channel MOSFET acting as a switch to control the antenna supply
U6	Comparator (op-amp)
U7, U8	Open drain buffers to shift voltage levels
R7	Passive pull-up to control T1
R8	Current limiter in the event of a short circuit
R5	Defines the threshold of the comparator
R6	Defines the threshold of the comparator

Table 19: Components in antenna supervisor

The threshold voltage (V_{REF}) of the comparator is defined by R5 and R6. It can be calculated as:
 $V_{REF} = R6/(R6+R5)*V_{ANT}$.



The open drain buffers shown in Figure 10 are not needed if V_{ANT} has the same voltage level as V_{IO} .

3.3.1.2 Two-pin antenna supervisor

The reduced functionality antenna supervisor circuit is connected to two signals: antenna control (ANT_OFF_N) and antenna status detection (ANT_SHORT_N). The ANT_OFF_N signal is already enabled and assigned to the LNA_EN pin in MAX-F10S and the ANT_SHORT_N signal can be assigned to any unused PIO, which may require disabling the previous function of the PIO. To enable the reduced antenna supervisor, the ANT_SHORT_N signal must be enabled in the receiver configuration. The polarity of the ANT_SHORT_N signal must also be defined in the receiver configuration based on the design use case.

The antenna can be supplied by VCC_RF or an external supply. Note that the supply voltage must be clean, as any noise could directly couple into the RF part of the GNSS receiver affecting the overall GNSS performance.

Refer to Reference designs for antenna supervisor examples and the required configuration.

Figure 11 presents the required two-pin antenna supervisor circuit and subsequent sections describe how to enable and monitor each feature.

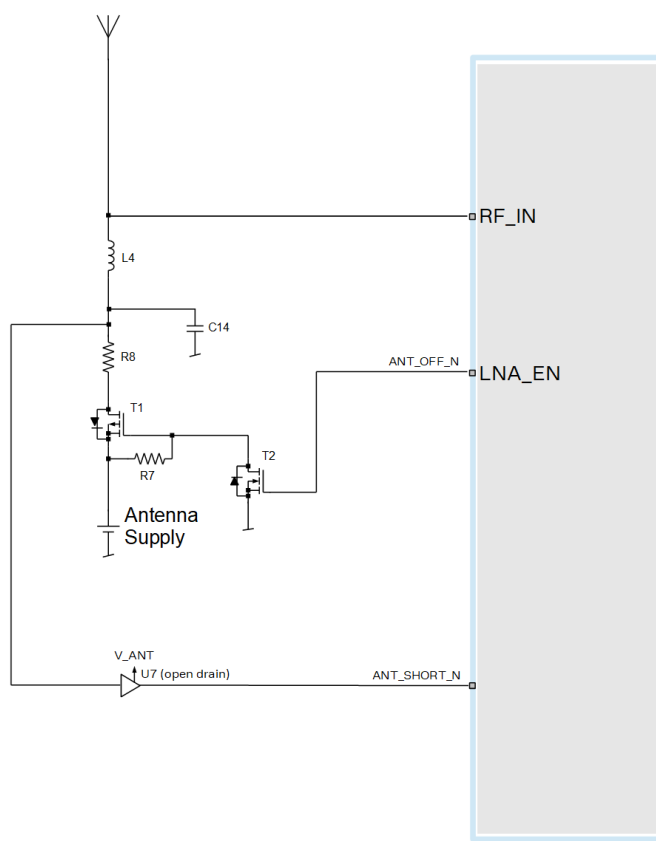


Figure 11: MAX-F10S two-pin antenna supervisor

Table 20 presents a list of the external components required for implementing the two-pin antenna supervisor design in Figure 11. Refer to External components for the recommended parts and specification.

Part	Description
C14	Filtering capacitor
L4	RF Bias-T inductor for L1 and L5
T1, T2	p-channel, n-channel MOSFET acting as a switch to control the antenna supply
U7	Open drain buffers to shift voltage levels
R7	Passive pull-up to control T1
R8	Current limiter in the event of a short circuit

Table 20: Components in two-pin antenna supervisor

The open drain buffer shown in Figure 11 is not needed if V_ANT is the same voltage level as V_IO.

3.3.1.3 Antenna voltage control - ANT_OFF_N

The antenna voltage control is enabled by default in MAX-F10S with the configuration item CFG-HW-ANT_CFG_VOLTCTRL set to true (1).

The antenna status (as reported in UBX-MON-RF and UBX-INF-NOTICE messages) is not reported unless the antenna voltage control has been enabled.

Result:

- UBX-MON-RF: Antenna status = OK. Antenna power status = ON.
- ANT_OFF_N = active low. The pin is pulled high to enable an external antenna or LNA.

Startup message at power-up if the configuration is stored:

```
$GNTXT,01,01,02,ANTSUPERV=AC *00
```

```
$GNTXT,01,01,02,ANTSTATUS=INIT*3B
```

```
$GNTXT,01,01,02,ANTSTATUS=OK*25
```

ANTSUPERV=AC indicates that antenna control is activated.

3.3.1.4 Antenna short detection - ANT_SHORT_N

Enable the antenna short detection by setting the configuration item CFG-HW-ANT_CFG_SHORTDET to true (1).

Result:

- UBX-MON-RF: Antenna status = OK. Antenna power status = ON.
- ANT_OFF_N = active low to disable an external antenna. Therefore, the pin is pulled high to enable an external antenna.
- ANT_SHORT_N = active low to report a short circuit. The pin is default high (PIO pull-up enabled).

Startup message at power-up if the configuration is stored:

```
$GNTXT,01,01,02,ANTSUPERV=AC SD *37
```

```
$GNTXT,01,01,02,ANTSTATUS=INIT*3B
```

```
$GNTXT,01,01,02,ANTSTATUS=OK*25
```

ANTSUPERV=AC SD indicates that antenna control and short detection are activated.

If a short circuit is detected in the antenna (ANT_SHORT_N pulled low):

```
$GNTXT,01,01,02,ANTSTATUS=SHORT*73
```

- UBX-MON-RF: Antenna status = SHORT. Antenna power status = ON (automatic power-down is not enabled, CFG-HW-ANT_CFG_PWRDOWN or powerDown field in OTP memory file 0x37 is off by default).
- ANT_OFF_N = high (external antenna enabled).



If CFG-HW-ANT_CFG_PWRDOWN is already enabled (set to true), the polarity of the ANT_OFF_N signal changes to power down (disable) the antenna supply when a short is detected.



After a detected antenna short, the reported antenna status continues to be reported as a SHORT. If auto-recovery is enabled for the antenna short detection, the antenna status can recover after a timeout of 60 seconds. Recovering the antenna status immediately requires either a power cycle or switching the antenna short detection off and on again.

3.3.1.5 Antenna short detection auto-recovery

Enable the antenna short detection auto-recovery by setting the configuration item CFG-HW-ANT_CFG_RECOVER to true (1).



To use the auto-recovery feature, enable CFG-HW-ANT_CFG_PWRDOWN which requires CFG-HW-ANT_CFG_SHORTDET and CFG-HW-ANT_CFG_VOLTCTRL to be enabled.

Result:

- UBX-MON-RF: Antenna status = OK. Antenna power status = ON.
- ANT_OFF_N = active low. The pin is pulled high to enable an external antenna.
- ANT_SHORT_N = active low. The pin is default high (PIO pull-up enabled, to be pulled low if a SHORT is detected).

Startup message at power-up if the configuration is stored:

```
$GNTXT,01,01,02,ANTSUPERV=AC SD PDoS SR*3E
```

```
$GNTXT,01,01,02,ANTSTATUS=INIT*3B
```

```
$GNTXT,01,01,02,ANTSTATUS=OK*25
```

ANTSUPERV=AC SD PDoS SR (indicates short circuit recovery added - SR)

If short circuit is detected (ANT_SHORT_N pulled low):

```
$GNTXT,01,01,02,ANTSTATUS=SHORT*73
```

- UBX-MON-RF: Antenna status = SHORT. Antenna power status = OFF (automatic power-down is enabled).
- ANT_OFF_N = low (external antenna disabled).

After a timeout period of 60 seconds, the receiver retests the short circuit condition by enabling the antenna (i.e. pulling ANT_OFF_N high).

If a short is not present, the receiver reports antenna condition is OK:

```
$GNTXT,01,01,02,ANTSTATUS=OK*25
```

UBX-MON-RF: Antenna status = OK. Antenna power status = ON.

3.3.1.6 Antenna open circuit detection - ANT_DETECT

Enable the antenna open circuit detection by setting the configuration item CFG-HW-ANT_CFG_OPENDET to true (1).

Result:

- UBX-MON-RF: Antenna status = OK. Antenna power status = ON.
- ANT_OFF_N = active low. The pin is pulled high to enable an external antenna.
- ANT_SHORT_N = active low. The pin is default high (PIO pull-up enabled, to be pulled low if a SHORT is detected).
- ANT_DETECT = active high. The pin is default high (PIO pull-up enabled, to be pulled low if the antenna is not detected).

Startup message at power-up if the configuration is stored:

```
$GNTXT,01,01,02,ANTSUPERV=AC SD OD PDoS SR*15
```

```
$GNTXT,01,01,02,ANTSTATUS=INIT*3B
```

```
$GNTXT,01,01,02,ANTSTATUS=OK*25
```

ANTSUPERV=AC SD OD PDoS SR (indicates open circuit detection added - OD)

If ANT_DETECT is pulled low to indicate no antenna connected:

```
$GNTXT,01,01,02,ANTSTATUS=OPEN*35
```

If ANT_DETECT is left floating or pulled high to indicate antenna connected:

```
$GNTXT,01,01,02,ANTSTATUS=OK*25
```

3.3.1.7 Antenna status reporting

The antenna detection and antenna power status that is available in UBX-MON-RF and NMEA notice messages, is based on the antenna's physical state. The required antenna supervisor configuration keys depend on the selected antenna supervisor implementation (three-pin or two-pin).

Table 21 and Table 22 present a summary of the antenna status that is available in the *antStatus* and *antPower* fields of the UBX-MON-RF message. Refer to the Interface description [3] for more information.

Status	Description
DON'T KNOW	Antenna status is unknown.
INIT	Antenna power control feature is initialized (if CFG-HW-ANT_VOLTCTRL is enabled).
SHORT	A short is detected from the antenna input. That is, a lot of current is drawn from the active antenna.
OPEN	Antenna is not detected. That is, little or no current is drawn from the active antenna.
OK	Antenna is detected and no short is detected.

Table 21: Available antenna detection status

Status	Description
DON'T KNOW	CFG-HW-ANT_VOLTCTRL not configured.
OFF	GNSS OFF or a short is detected and CFG-HW-ANT_PWRDOWN is enabled. Note that this status also applies when the GNSS is restarted with the CFG-RST or implicitly with the CFG-GNSS messages, when the GNSS selection is reconfigured, or when the GNSS is stopped in the software standby mode.
ON	GNSS ON and no short/open is detected from the antenna input. Similarly, when there is a short and CFG-HW-ANT_PWRDOWN is not enabled or auto-recovery is enabled.

Table 22: Available antenna power status

Table 23 shows some possible combinations of the antenna supervisor configuration and the expected antenna status based on the physical state of the antenna. Note that the short detection takes priority over the open detection and "X" in Table 23 implies an unconfigured or undetected physical state. In addition, CFG-HW-ANT_PWRDOWN requires that CFG-HW-ANT_CFG_VOLTCTRL and CFG-HW-ANT_CFG_SHORTDET are enabled. Likewise, CFG-HW-ANT_RECOVER requires CFG-HW-ANT_PWRDOWN to be enabled.



The antenna supervisor is re-initialized after issuing a reset with RESET_N pin or changing any of the antenna supervisor configuration keys. Therefore, if the default configuration has changed, it is recommended to save the antenna supervisor configuration to BBR to ensure that the updated configuration is applied after a reset.

Configuration keys					Physical antenna state		Reported antenna status	
VOLTCTRL	SHORTDET	OPENDET	PWRDOWN	RECOVER	Short circuit	Open circuit	antPower	antStatus
TRUE	X	X	X	X	NO	NO	ON	OK
TRUE	FALSE	X	X	X	X	NO	ON	OPEN
TRUE	X	FALSE	X	X	NO	X		
TRUE	FALSE	FALSE	X	X	X	X		
TRUE	FALSE	TRUE	X	X	X	YES		
TRUE	X	TRUE	X	X	NO	YES	ON	SHORT
TRUE	TRUE	X	FALSE	X	YES	X		
TRUE	TRUE	X	TRUE	X	YES	X	OFF	SHORT
FALSE	TRUE	X	X	X	YES	X	UNKNOWN	SHORT
FALSE	FALSE	TRUE	X	X	X	YES	UNKNOWN	OPEN

Configuration keys					Physical antenna state		Reported antenna status	
VOLTCTRL	SHORTDET	OPENDET	PWRDOWN	RECOVER	Short circuit	Open circuit	antPower	antStatus
FALSE	X	TRUE	X	X	NO	YES	UNKNOWN	OPEN

Table 23: Antenna supervisor configuration and antenna states

3.4 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 24 below contains an overview of the different reset types and the data that is cleared.

Reset type	Clears RAM	Clears BBR
0x00 - Hardware reset (immediately), 0x04 - Hardware reset (after shutdown)	Yes	Yes
0x01 - Controlled Software reset	Yes	No

Reset type	Clears RAM	Clears BBR
0x02 - Controlled Software reset (GNSS only), 0x08 - Controlled GNSS stop, 0x09 - Controlled GNSS start	No	No
RESET_N pin	Yes	Yes

Table 24: Overview of the available reset types


The TTFF after using any reset type that clears the BBR is similar to performing a cold start.

3.5 Security

The security concept of MAX-F10S 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.

3.5.1 Jamming and spoofing detection

3.5.1.1 Jamming and interference detection and monitoring

Intentional and/or unintentional jamming and interference of GNSS receivers can degrade the quality of GNSS signals and receiver performance.

Configuring jamming/interference detection and monitoring

The jamming detection algorithm is configured with the CFG-ITFM-* configuration group. The configuration keys are summarized in [Table 25](#).

Configuration key	Description
CFG-ITFM-ENABLE	Set to 1 to enable ITFM
CFG-ITFM-BBTHRESHOLD	The threshold level for broadband interference detection. The value is given in decibels (dB) above the level of the reference spectrum.
CFG-ITFM-CWTHRESHOLD	The threshold level for continuous wave interference detection. The value is given in decibels (dB) above the level of the reference spectrum.
CFG-ITFM-ANTSETTING	The type of antenna (active or passive) used in the design.

Table 25: CFG-ITFM-* group configuration keys

Once the jamming detection and monitoring is configured, the receiver measures the reference spectrum at the start-up after obtaining a good fix. Until then, the monitor reports "Unknown". Once the reference spectrum is available, the receiver measures the signal spectrum and compares it to the reference while applying the detection thresholds. To determine the jamming state, the receiver also internally monitors other factors including changes in the average C/N0 level. The reported monitor states are summarized in section [Messages related to jamming and spoofing detection and monitoring](#).



It is advised not to restart the receiver while it's indicating jamming.

Evaluation

The detection of jamming and interference depends both on the type of jamming signal and the signal environment. It may not be always possible to detect jamming or interference signals. If the GNSS performance is degraded or the fix is completely lost, jamming or interference reported in `jammingState` field of message `UBX-SEC-SIG` is a likely cause.

RF interference generated by the device itself or coupled from external sources is common and may be reported by the receiver. If jamming is reported but the C/N0 level and GNSS performance are not affected, the receiver may be able to mitigate the impact of jamming.

The jamming and interference detection can be evaluated by applying jamming signals relevant for the application and signal environment and observing the receiver behaviour.

3.5.1.2 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.

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.



It is advised not to restart the receiver while it's indicating spoofing.

3.5.1.3 Messages related to jamming and spoofing detection and monitoring

MAX-F10S have the capability to both detect and monitor jamming/interference and spoofing and to report it to the user.

The information about jamming/interference and spoofing detection are reported in two messages: UBX-SEC-SIG and UBX-SEC-SIGLOG. See the interface description [3].

Signal security status (UBX-SEC-SIG)

The UBX-SEC-SIG message provides information related to the security, i.e. availability and integrity, of the signals. It also provides high-level jamming/interference and spoofing detector information, a direct method for detecting the current security status at each navigation epoch to alert the host about potential jamming/interference or spoofing events.

Fields related to jamming and spoofing states of UBX-SEC-SIG message are described in [Table 26](#).

Message fields	Jamming/spoofing state	Description
jamDetEnabled	0/1	Flag indicates whether jamming/interference detection is enabled or not. If 0, it is disabled and if 1, it is enabled.
jammingState	0: Unknown	Monitor is not enabled, monitor is uninitialized, or the antenna is disconnected
	1: No jamming indicated	No jamming or interference is detected
	2: Warning; jamming indicated but fix OK	Position OK but jamming or interference is visible (above the thresholds)
	3: Critical; jamming indicated and no fix	No reliable position fix and jamming or interference is visible (above the thresholds); interference is a probable reason for no position fix
spfDetEnabled	0/1	Flag indicates whether spoofing detection is enabled or not. If 0, it is disabled and if 1, it is enabled.
spoofingState	0: Unknown	Monitor is not enabled, monitor is uninitialized, or the antenna is disconnected
	1: No spoofing indicated	No spoofing detectors indicate spoofing
	2: Spoofing indicated	Spoofing detectors indicate spoofing
	3: Spoofing affirmed	The indicated spoofing is confirmed

Table 26: Fields related to jamming and spoofing states of UBX-SEC-SIG message



Note that the spoofing state value only reflects the detector state for the current navigation epoch. I.e. a value of 1: No spoofing indicated does not mean that the receiver is not spoofed, it simply states that the detector was not triggered in this epoch.

Signal security logfile (UBX-SEC-SIGLOG)

The UBX-SEC-SIGLOG message provides a log of past events triggered by jamming/interference 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.

Fields related to jamming and spoofing detection states of UBX-SEC-SIGLOG message are described in [Table 27](#).

Message fields	Signal security log state	Description
ttag		Shows the time tag in millisecond.
detectionType	Type of the spoofing or jamming detection: 0 = simulated signal	Signal from simulator with changed navigation data
	1 = abnormal signal	Not supported
	2 = INS/GNSS mismatch	Not supported
	3 = abrupt changes in GNSS signal	Abrupt changes in GNSS signal level and time offset
eventType	Type of the event: 0 = indication started	
	1 = indication stopped	
	2 = indication triggered	
	3 = indication timed-out	

Table 27: Fields related to jamming and spoofing detection states of UBX-SEC-SIGLOG message



Single epoch events, caused by abrupt changes due to switching from the real to the spoofing signal or vice versa are handled as time-out events. This means that the time-out event is reported after a certain cool off period which is not related to any observations in the signal. The other detection types make use of 'start' and 'stop' event types.

3.5.2 GNSS receiver integrity

This section describes receiver security features implemented with the MAX-F10S:

- Secure boot
- Receiver configuration lock

3.5.2.1 Secure boot

The MAX-F10S boots only with firmware images that are signed by u-blox. This prevents the execution of non-genuine firmware images on the receiver.

3.5.2.2 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 and BBR. 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 [3].

The configuration lock set on the RAM or BBR configuration layer is removed when the memory is cleared.

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 MAX-F10S through any of the available interfaces can poll, enable or send messages, but cannot change the configuration by sending UBX configuration messages.

3.6 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.

3.6.1 Continuous mode

MAX-F10S 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.

3.6.2 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 MAX-F10S supports two backup modes: hardware backup mode and software standby mode.

3.6.2.1 Hardware backup mode

The hardware backup mode allows entering a backup state and resuming operation by switching the main power supplies 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 V_IO 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.

3.6.2.2 Software standby mode

Software standby mode is entered using the UBX-RXM-PMREQ message. V_{IO} and VCC must be supplied, however VCC supply is internally disabled to save power. The V_{IO} supply maintains the battery-backed RAM (BBR), RTC, and PIOs.

Entering the software standby mode clears the RAM memory including the receiver configuration. To maintain the configuration, store it on BBR 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 [3] 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 is supplied, the PIOs can be driven by an external host processor. No buffers are required for isolating the PIOs, which reduces cost.

-  The LNA_EN signal is set to the "LOW" state during the software standby mode.
-  V_BCKP should be left open if not used.

3.7 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.

3.7.1 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.

3.7.2 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, 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, NTSC if BeiDou is enabled, NPLI if NAVIC is enabled, NICT when QZSS is enabled, finally, European if Galileo is enabled.

The receiver assumes that an input time pulse uses the same GNSS time base as specified for the time pulse output. 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 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
Galileo time	UBX-NAV-TIMEGAL
NavIC time	UBX-NAV-TIMENAVIC
QZSS time	UBX-NAV-TIMEQZSS
UTC time	UBX-NAV-TIMEUTC

Table 28: GNSS time messages

3.7.3 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.

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).



To support multiple GNSS systems concurrently, u-blox receivers employ multiple GNSS system times and/or receiver local times. For reporting GNSS system time or the receiver local time, users are recommended to use messages that report UTC time instead of using UBX messages. Other messages are retained only to support backwards compatibility.

3.7.4 iTow timestamps

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 (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. Therefore, most GNSS receivers use this time representation internally, and convert it to a more conventional form at external interfaces. In many UBX messages, the iTOW field provides an externally visible example of the internal time representation.

All the main UBX-NAV messages (and some other messages) contain an iTOW field to indicate the GPS time when the navigation epoch occurred. Messages with the same iTOW value can be assumed to have come from the same navigation solution, and therefore, iTOW can be used to synchronize between these UBX messages. However, the iTOW values may not be valid (i.e., they may have been generated with insufficient conversion data). Therefore, it is not recommended to use the iTOW field for any other purpose.

If reliable absolute time information is required, use the UTC time related fields in the UBX-NAV-PVT message. Additionally, the UBX-NAV-PVT message contains information about the validity and the accuracy of the provided UTC time. See the section [Time validity](#) for further information.



iTOW is always referenced to GPS time, and it should not be confused with the [UTC representation](#).



The iTOW timestamps are not compensated for the [Leap seconds](#).

3.7.5 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.

- **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. 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.

3.7.6 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.

3.7.7 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-TIMECLS.

3.7.8 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). Therefore, the receiver regards the date information transmitted by 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, Galileo to 22 August 1999 and BeiDou to 1 January 2006. The receiver doesn't work reliably with signals simulated before these dates.

3.7.8.1 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.



The GPS L5 signal contains the full 13-bit week number. Ambiguity in rollover week number is resolved once GPS L5 signals are acquired.

3.8 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 12](#) below).

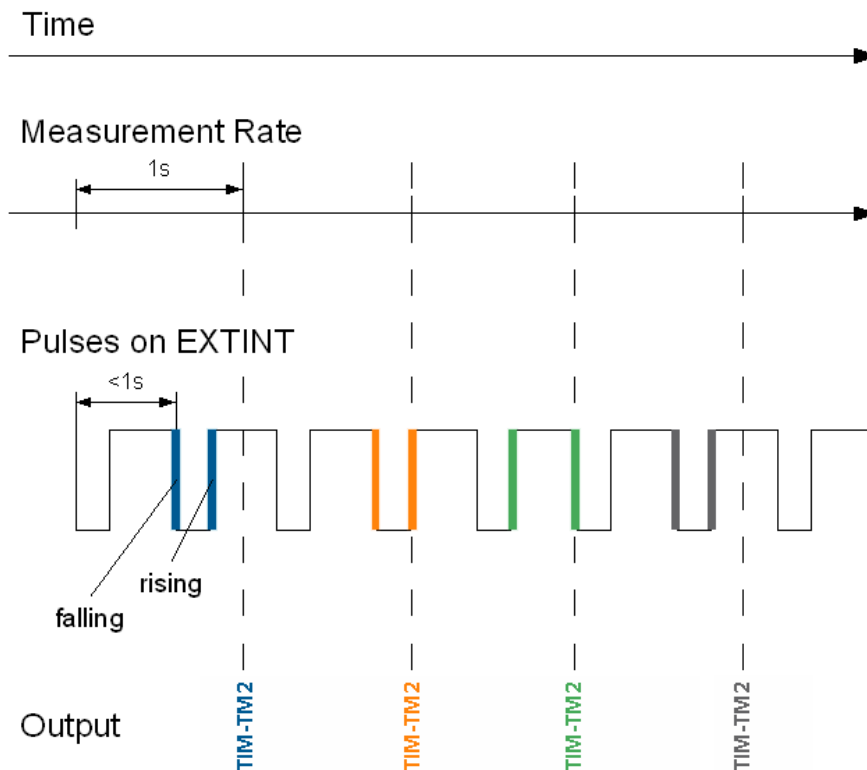


Figure 12: Time mark

3.9 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.

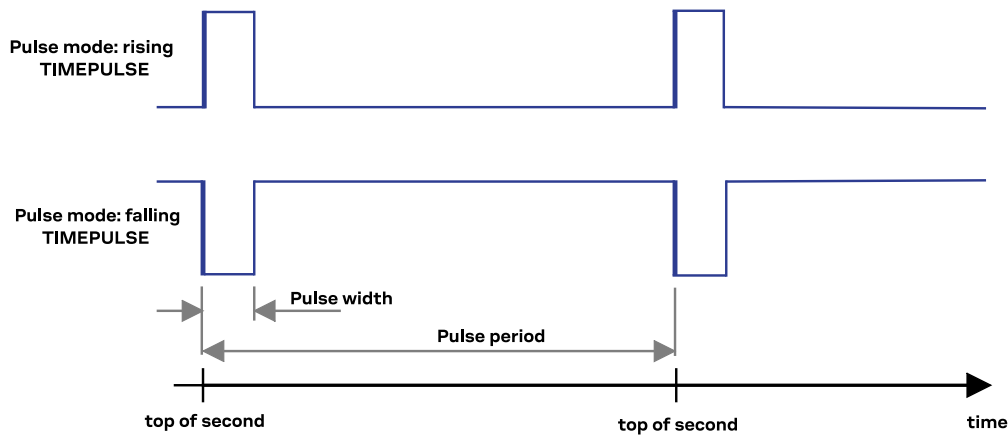


Figure 13: Time pulse

3.9.1 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.

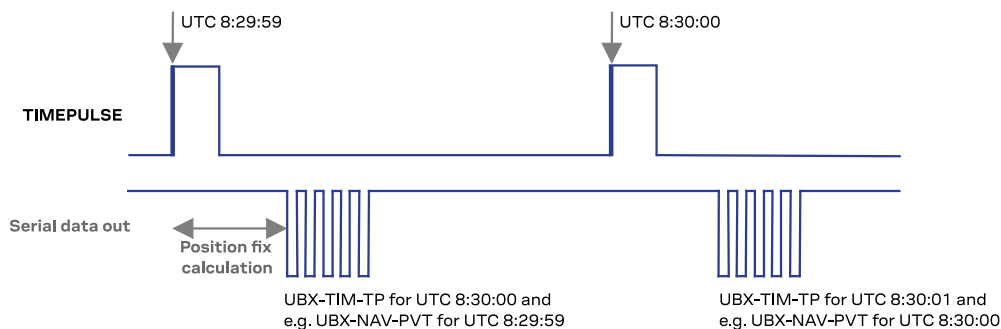


Figure 14: Time pulse and TIM-TP

3.9.2 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.

3.9.2.1 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-PULSE_DEF** = 0 (PERIOD)
- **CFG-TP-PULSE_LENGTH_DEF** = 1 (LENGTH)
- **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-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.

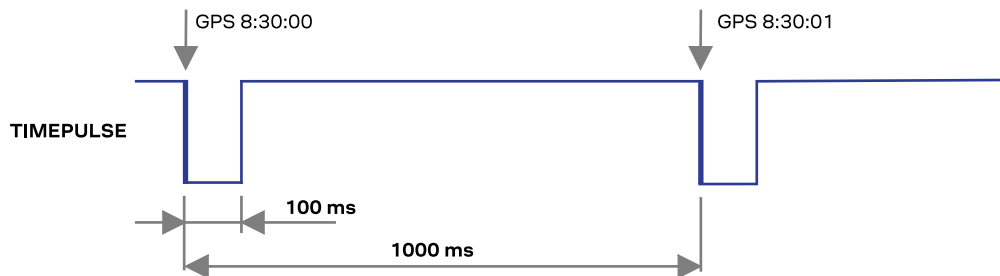


Figure 15: Time pulse signal with the example parameters

3.10 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.

3.10.1 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.

MAX-F10S also provides improved time to first fix (TTFF) when RTC is not available and backup domain is supplied. The receiver uses the time of the last position that is stored in the BBR before the receiver is powered off to estimate the current time at the next startup.

3.10.2 Time assistance

The host can deliver time assistance to the receiver using UBX-MGA-INITIME-UTC or UBX-MGA-INITIME-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.

3.10.3 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-INIT-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.

3.10.4 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-INIT-CLKD message.

3.11 Protection level

3.11.1 Introduction

Critical applications need to know how much trust they can place in their GNSS receiver's output at any given moment. Computed by the GNSS receiver in real time, the protection level (PL) quantifies the reliability of the position information to allow systems to change their mode of operation and improve the efficiency and quality of the tasks being performed.

The GNSS receiver's protection level describes the maximum likely position error to a specified degree of confidence. For example, if a GNSS receiver determines its position with a 95% protection level of one meter, there is only a 5% chance that the reported position is more than one meter away from its true position. Like the accuracy estimate of the GNSS receiver, the protection level constantly fluctuates, influenced by all the common error sources that affect GNSS solutions. Unlike the accuracy estimate, the confidence level of the protection level is much higher and is validated against specific operating scenarios to ensure that the output bounds the true error.



The maximum navigation update rate for protection level is limited to 1 Hz. Higher baud rate (>38400 baud) is required if UBX messages are enabled in addition to the default NMEA messages.



The protection level feature is disabled by default.

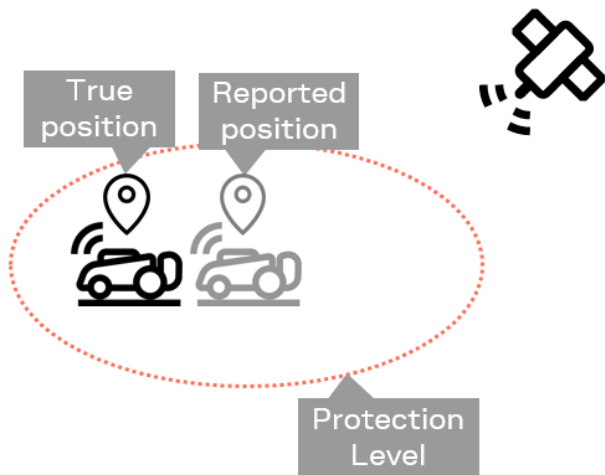


Figure 16: PL bounding true position error

3.11.2 Interface

The protection level bounds the true position error with a target misleading information risk (TMIR), for example 5% [MI/epoch] (read: 5% probability of having an MI per epoch). The target misleading information risk describes the probability per epoch of having misleading information (MI), meaning that it is not possible to bound the true position error because it is larger than the protection level (see [Figure 17](#)).

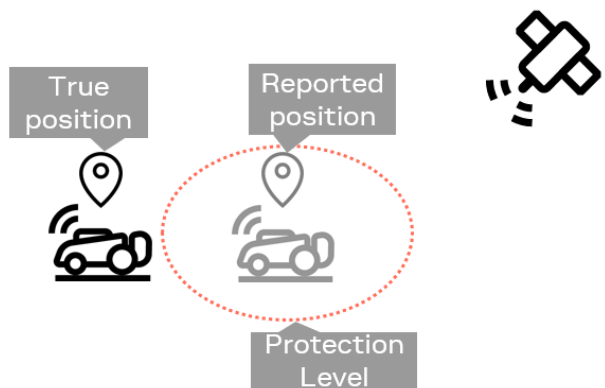


Figure 17: Misleading information

The output of the protection level is published through the UBX-NAV-PL message.

-  TMIR is specified in one dimension for PL. It is not specified as a horizontal 2D or 3D value.
-  The protection level values (UBX-NAV-PL.plPos1/2/3) are confidence intervals around the reported position (for example, UBX-NAV-PVT or UBX-NAV-HPPOSLLH).
-  The target misleading information risk is provided in exponential notation (UBX-NAV-PL.tmirCoeff and UBX-NAV-PL.tmirExp), for example UBX-NAV-PL.tmirCoeff = 5 and UBX-NAV-PL.tmirExp = 0 results in $5e0 (= 5)$.
-  The true position error is generally unknown, unless a very accurate and reliable truth positioning system is reporting an estimate for the true position.

When the GNSS environment deviates significantly from the normal mode of operation as compared to scenarios where the PL has been validated, a validity flag is set to false to indicate these

conditions. These conditions tend to be binary in nature, such as jamming has been detected, or the minimum number of satellites is being observed. UBX-NAV-PL reports a PL validity flag (see UBX-NAV-PL.pIPosValid), which indicates whether the PL is usable.

3.1.1.3 Validity requirements

The protection level performance depends on many external and internal factors. Some external factors such as a harsh GNSS environment may lead to degraded PL performance.

PL validity values	Description
UBX-NAV-PL.pIPosValid = 1	PL values are valid and can be used
UBX-NAV-PL.pIPosValid = 0	PL values are invalid and shall not be used

Table 29: PL validity



The protection level validity flag and the misleading information are two separate, non-related parameters.

The required receiver configuration for using the PL feature is shown in [Table 30](#).

Parameter	Details or required configuration key value
GPS system is enabled and used for navigation	CFG-SIGNAL-GPS_ENA = 1
Minimum 2 GNSS systems are enabled ²	Galileo and/or BeiDou is enabled in addition to GPS CFG-SIGNAL-GAL_ENA = 1 and/or CFG-SIGNAL-BDS_ENA = 1
Automotive and portable dynamic models	CFG-NAVSPG-DYNMODEL = 0 or 4
Continuous mode	CFG-PM-OPERATEMODE = 0
Static hold is disabled (optional)	CFG-MOT-GNSSSPEED_THRS = 0, CFG-MOT-GNSSSPEED_THRS = 0. Optional, disabling ensures that the static hold mode is not activated.
AssistNow Autonomous or AssistNow Offline are not used (optional)	CFG-ANA-USE_ANA = 0, AssistNow Offline data is not used. Optional, disabling ensures that the predicted orbits are not used for the navigation solution. This typically occurs during start-up before the ephemerides are decoded.

Table 30: Required configuration for using the PL feature



If the configuration requirements are not met, the PL values are invalid and shall not be used.

The PL values are valid and can be used provided the conditions in [Table 31](#) are met.

Parameter	Condition
3D position fix	fixType = 3 in UBX-NAV-PVT message
Valid position fix flag	gnssfixOK = 1 UBX-NAV-PVT message
No jamming reported	jammingState flag in UBX-SEC-SIG
No spoofing reported	spoofingState flag in UBX-SEC-SIG
Valid and resolved time and date	validTime = 1, validDate = 1, and fullyResolved = 1 in UBX-NAV-PVT
Static hold mode is not activated	The static hold flag is not raised

² Refer to the data sheet [1] for the supported GNSS combinations.

Parameter	Condition
Orbit prediction algorithm	AssistNow Autonomous or AssistNow Offline are not used for the navigation solution.

Table 31: Navigation solution requirements

3.11.4 Expected behavior

For each navigation epoch and for each coordinate axis, a PL value is provided. For example, if the coordinate frame reported is North/East/Down, then the UBX-NAV-PL contents can be interpreted as follows:

PL values	Description
UBX-NAV-PL.plPos1	1 stands for the north axis
UBX-NAV-PL.plPos2	2 stands for the east axis
UBX-NAV-PL.plPos3	3 stands for the down axis

Table 32: Position PL values

If the PL coordinate frame is set to invalid (UBX-NAV-PL.plPosFrame = 0), then the PL values shall not be used. If the PL validity flag is cleared (UBX-NAV-PL.plValid = 0), the PL values shall not be used. Both of these cases must be checked.

Only if the PL is set to valid (UBX-NAV-PL.plPosValid), the PL values (UBX-NAV-PL.plPos1/2/3) can be used and are reliable with respect to the target misleading information risk.

3.12 Multiple GNSS assistance (MGA)

u-blox AssistNow is a multiple GNSS assistance (MGA) service. It provides a proprietary implementation of an assisted GNSS (A-GNSS) protocol compatible with the u-blox GNSS receivers. The MGA services consist of AssistNow Online and Offline variants delivered by the HTTP or HTTPS protocols.

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.



Do not use more than 1 week old AssistNow Offline data when high navigation rate (i.e. more than 1 Hz) is used.



Do not use BeiDou AssistNow aiding data because MAX-F10S does not support B1I. Using BeiDou aiding data can force the receiver to search for B1I satellites (B1-B18) that do not transmit B1C signals, potentially degrading the receiver performance.

Table 33 below contains an overview of the different MGA services u-blox provides. Refer to the MAX-F10S 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

Requirements	AssistNow Online	AssistNow Offline	AssistNow Autonomous
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 33: AssistNow service overview

3.12.1 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/assistenow> or contact your local technical support to get more information and to request access to the service.

3.12.2 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.
- **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 sent back to the receiver when it has been restarted. See the description of the UBX-MGA-DBD messages in the MAX-F10S Interface description [3] for more information.

3.12.3 AssistNow offline

AssistNow Offline is a feature that combines special firmware in u-blox receivers and a proprietary service run by u-blox. It is targeted at receivers that only have occasional internet access and so cannot use AssistNow Online. AssistNow Offline speeds up time to first fix (TTFF), typically to considerably less than 10 s.



AssistNow Offline currently supports GPS, Galileo, and QZSS. u-blox intends to expand the AssistNow Offline Service to support other GNSS (such as BeiDou) in due course.

The AssistNow Offline Service uses a simple, stateless, HTTP interface. Therefore, it works on all standard mobile communication networks that support internet access, including GPRS, UMTS and Wireless LAN. No special arrangements need to be made with mobile network operators to enable AssistNow Offline.

Users of AssistNow Offline are expected to download data from the AssistNow Offline Service, specifying the time period they want covered (1 day to 5 weeks) and the types of GNSS. This data must be uploaded to a u-blox receiver, so that it can estimate the positions of the satellites when no better data is available. Using these estimates will not provide as accurate a position fix as if current ephemeris data is used, but it will allow a much faster TTFF in nearly all cases.



Do not use more than 1 week old AssistNow Offline data when high navigation rate (i.e. more than 1 Hz) is used.

The data obtained from the AssistNow Offline Service is organized by date, normally a day at a time. Consequently, the longer the requested coverage time, the more data there is to handle. Similarly,

each different GNSS requires its own data and in extreme cases, several hundred kilobytes of data will be provided by the service. This amount can be reduced by requesting lower resolution, but this will have a small negative impact on both position accuracy and TTFF. See the section on [Offline Service Parameters](#) for details of how to specify these options.

The downloaded AssistNow Offline data is encoded in a sequence of UBX-MGA-ANO messages, one for every satellite for every day of the period covered. For example, collecting data from all GPS satellites over a four-week period would result in more than 900 distinct messages, occupying approximately 70 kilobytes, which would not fit into the available BBR memory in the receiver.

If the receiver has no flash storage, either a smaller amount of data must be requested, or the host system must store the AssistNow Offline data until the receiver needs it and then upload only the appropriate part for immediate use. See the section on [host-based AssistNow Offline](#) for further details.

3.12.3.1 Service parameters

The information exchange with the AssistNow Offline Service is based on the HTTP protocol. Upon reception of an HTTP GET request, the server will respond with the required messages in binary format or with an error string in text format. After delivery of all data, the server will terminate the connection.

The HTTP GET request from the client to the server should contain a standard HTTP query string in the request URL. The query string consists of a set of "key=value" parameters in the following form:

key=value;key=value;key=value;

The following rules apply:

- The order of keys is not important.
- Keys and values are case-sensitive.
- Keys and values must be separated by an equals character ('=').
- Key-value pairs must be separated by semicolons(';').
- If a value contains a list, each item in the list must be separated by a comma(',').

The following table describes the keys that are supported.

Key name	Unit/range	Necessity	Description
token	String	Mandatory	The authorization token supplied by u-blox when a client registers to use the service.
gnss	String	Mandatory	A comma-separated list of the GNSS for which data should be returned. The currently supported GNSS are: gps and glo.
period	Numeric [weeks]	Optional	The number of weeks into the future the data should be valid for. Data can be requested for up to 5 weeks into the future. If this value is not provided, the server assumes a period of 4 weeks.
days	Numeric [days]	Optional	The number of days into the future the data should be valid for. Can be used instead of the period parameter when data for less than one week is desired.
resolution	Numeric [days]	Optional	The resolution of the data: 1=every day, 2=every other day, 3=every third day. If this value is not provided, the server assumes a resolution of 1 day.

Table 34: AssistNow Offline parameter keys

Thus, as an example, a valid parameter string would be:

token=XXXXXXXXXXXXXXXXXXXXXXX;gnss=gps,glo;

3.12.3.2 Time, position and almanac

While AssistNow Offline can be used on its own, it is expected that the user will provide estimates of the receiver's current position, the current time and ensure that a reasonably up-to-date almanac is available. In most cases this information is likely to be available without the user needing to do anything. For example, where the receiver is connected to a battery backup power supply and has a functioning real-time clock (RTC), the receiver will keep its own sense of time and will retain the last known position and any almanac. However, should the receiver be completely without power before startup, then it will greatly improve TTFF if time, position and almanac can be supplied in some form.

Almanac data has a validity period of several weeks, so it can be downloaded from the AssistNow Online service at roughly the same time the AssistNow Offline data is obtained. It can then be stored in the host for uploading on receiver startup, or it can be transferred to the receiver straight away and preserved there (provided suitable non-volatile storage is available).

Where a receiver has a functioning RTC, it should be able to keep its own sense of time, but where no RTC is fitted (or power is completely turned off), providing a time estimate via the UBX-MGA-INI-TIME_UTC message will be beneficial to lower the time to first fix and make use of the AssistNow Offline data.

Similarly, where a receiver has effective non-volatile storage, the last known position will be recalled, but if this is not the case, then providing a position estimate via one of the UBX-MGA-INI-POS_XYZ or UBX-MGA-INI-POS_LLH messages will improve the TTFF (details can be found in the MAX-F10S interface description [3]).

Where circumstances prevent providing all three of these pieces of data, providing some is likely to be better than none at all, as this helps to lower the TTFF.

3.12.3.3 Host-based AssistNow Offline

Host-based AssistNow Offline involves AssistNow Offline data being stored until it is needed by the host system in whatever memory it has available.

The host system must download the data from the AssistNow Offline service when an internet connection is available, but retain it until the time the u-blox receiver needs it. At this point, the host must upload just the relevant portion of the data to the receiver, so that the receiver can start using it. This is achieved by parsing all the data and uploading to the receiver only those UBX-MGA-ANO messages with a timestamp nearest to the current time. As each item is a complete UBX message, it can be sent directly to the receiver with no extra packaging. The host can control the message flow if required, but in most cases this is likely to prove unnecessary.

When parsing the data obtained from the AssistNow Offline service, the following points should be noted:

- The data is made up of a sequence of UBX-MGA-ANO messages.
- Customers should not rely on the messages all being of fixed size, but should read their length from the UBX header to work out where the message ends (and where the next begins).
- Each message indicates the satellite for which it is applicable through the svld and gnssld fields.
- Each message contains a timestamp within the year, month and day fields.
- Midday (UTC) on the day indicated should be considered to be the point at which the data is most applicable.
- The messages will be ordered chronologically, earliest first.
- Messages with the same timestamp will be ordered by ascending gnssld and then ascending svld.

3.12.3.3.1 Host-based procedure

The typical sequence for host-based AssistNow Offline is as follows:

- The host downloads a copy of the latest data from the AssistNow Offline service and stores it locally.
- Optionally it may also download a current set of almanac data from the AssistNow Online service.
- The host wants to use the u-blox receiver.
- If necessary it uploads any almanac, position estimate and/or time estimate to the receiver.
- It scans through AssistNow Offline data looking for entries with a timestamp that most closely matches the current (UTC) date and time.
- The host sends each such UBX-MGA-ANO message to the receiver.

Note that when data has been downloaded from the AssistNow Offline service with the (default) resolution of one day, the means for selecting the closest matching timestamp is simply to look for messages with the current (UTC) date.

3.12.4 AssistNow autonomous

The assistance scenarios covered by *AssistNow Online* and *AssistNow Offline* require an online connection and a host that can use this connection to download aiding data and provide this to the receiver when required.

The *AssistNow Autonomous* feature provides a functionality similar to *AssistNow Offline* without the need for a host and a connection. Based on a broadcast ephemeris downloaded from the satellite (or obtained by *AssistNow Online*), the receiver can autonomously (i.e. without any host interaction or online connection) generate an accurate satellite orbit representation ("AssistNow Autonomous data") that is usable for navigation much longer than the underlying broadcast ephemeris was intended for. This makes downloading new ephemeris or aiding data for the first fix unnecessary for subsequent startups of the receiver.



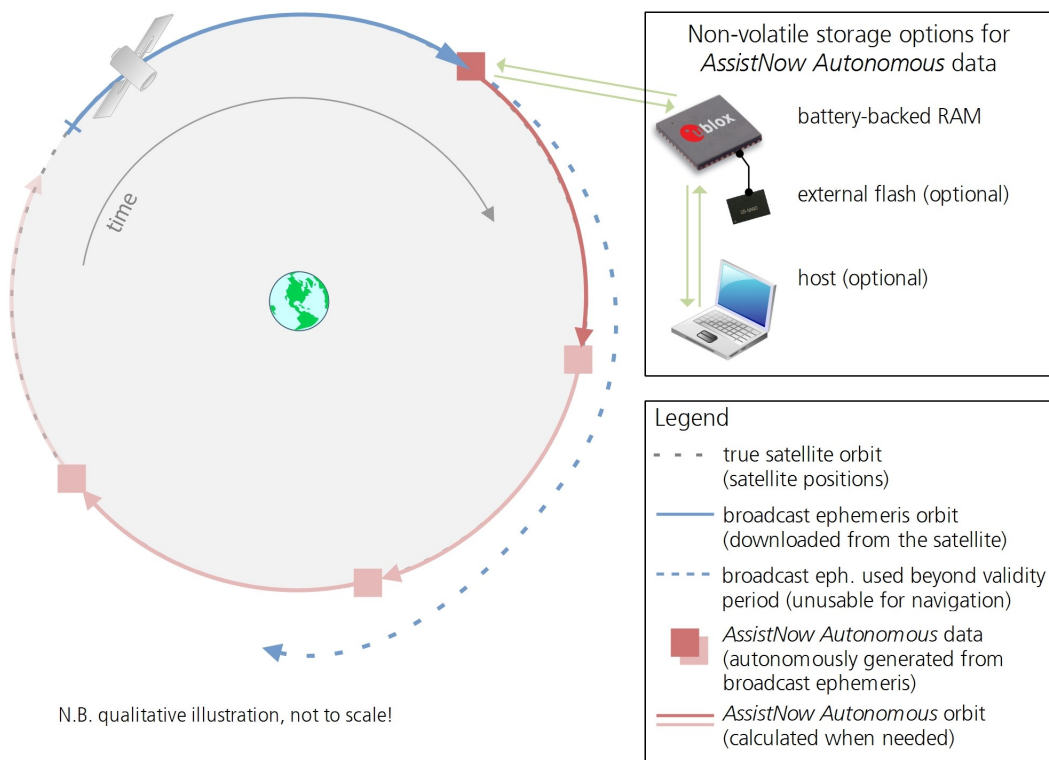
The *AssistNow Autonomous* feature is disabled by default. It can be enabled using the CFG-ANA-USE_ANA configuration item.

3.12.4.1 Concept

The figure below illustrates the *AssistNow Autonomous* concept in a graphical way. Note that the figure is a qualitative illustration and is not to scale.

- A broadcast ephemeris downloaded from the satellite is a precise representation of a part (for GPS nominally four hours) of the satellite's true orbit (trajectory). It is not usable for positioning beyond this validity period because it diverges dramatically from the true orbit afterwards.
- The *AssistNow Autonomous orbit* is an extension of one or more broadcast ephemerides. It provides a long-term orbit for the satellite for several revolutions. Although this orbit is not perfectly precise, it is a sufficiently accurate representation of the true orbit to be used for navigation.
- The *AssistNow Autonomous data* is automatically and autonomously generated from downloaded (or assisted) ephemerides. The data is stored automatically in the on-chip battery-backed memory (BBR). Optionally, the data can be backed up in external flash memory or on the host. The number of satellites for which data can be stored depends on the receiver configuration and may change during operation.
- If no broadcast ephemeris is available for navigation, *AssistNow Autonomous* automatically generates the required parts of the orbits suitable for navigation from the stored data. The data is also automatically kept current in order to minimize the calculation time once the navigation engine needs orbits.

- The operation of the *AssistNow Autonomous* feature is transparent to the user and the operation of the receiver. All calculations are done in the background and do not affect the normal operation of the receiver.
- The *AssistNow Autonomous* subsystem automatically invalidates data that has become too old and that would introduce unacceptable positioning errors. This threshold is configurable.
- The prediction quality will be automatically improved if the satellite has been observed multiple times. However, this requires the availability of a suitable flash memory. Improved prediction quality also extends the maximum usability period of the data.
- *AssistNow Autonomous* considers GPS, GLONASS, Galileo and BeiDou satellites only. It will not consider satellites on orbits with an eccentricity of >0.05 (e.g., Galileo E18). For GLONASS support, a suitable flash memory is mandatory because a single GLONASS broadcast ephemeris contains information only for approximately 30 minutes. This is not long enough to extend it in a usable way. Orbit information of each GLONASS satellite must be collected at least for four hours to generate data.



3.12.4.2 Interface

Several UBX protocol messages provide interfaces to the *AssistNow Autonomous* feature:

- The CFG-ANA-USE_ANA item is used to enable or disable the *AssistNow Autonomous* feature. When enabled, the receiver will automatically produce *AssistNow Autonomous* data for newly received broadcast ephemerides and, if that data is available, automatically provide the navigation subsystem with orbits when necessary and adequate.
- The CFG-ANA-* configuration group also allows for a configuration of the maximum acceptable orbit error. See the next section for an explanation of this feature. It is recommended to use the firmware default value that corresponds to a default orbit data validity of approximately three days (for GPS satellites observed once) and up to six days (for GPS and GLONASS satellites observed multiple times over a period of at least half a day).



If the receiver uses flash memory, disabling the *AssistNow Autonomous* feature will delete all previously collected satellite observation data from the flash memory.

- The UBX-NAV-AOPSTATUS message provides information on the current state of the *AssistNow Autonomous* subsystem. The status indicates whether the *AssistNow Autonomous* subsystem is currently idle (or not enabled) or busy generating data or orbits. Hosts should monitor this information and only power off the receiver when the subsystem is idle (that is, when the `status` field shows a steady zero).
- The UBX-NAV-SAT message indicates the use of *AssistNow Autonomous* orbits for individual satellites.
- The UBX-NAV-ORB message indicates the availability of *AssistNow Autonomous* orbits for individual satellites.
- The UBX-MGA-DBD message provides a means to retrieve the *AssistNow Autonomous* data from the receiver in order to preserve the data in power-off mode where no battery backup is available. Note that the receiver requires the absolute time (i.e. full date and time) to calculate *AssistNow Autonomous* orbits. For the best performance, it is therefore recommended to supply this information to the receiver using the UBX-MGA-INI-TIME_UTC message in this scenario.

3.12.4.3 Benefits and drawbacks

AssistNow Autonomous can provide quicker startup times by lowering the TTFF, provided that data is available for enough visible satellites. This is particularly true under weak signal conditions where it might not be possible to download broadcast ephemerides at all and therefore, no fix would be possible without *AssistNow Autonomous* (or A-GNSS). It is however required that the receiver roughly knows the absolute time, either from an RTC or from time-aiding (see the [Interface](#) section), and that it knows which satellites are visible, either from the almanac or from tracking the respective signals.

The *AssistNow Autonomous* orbit (satellite position) accuracy depends on various factors, such as the particular type of satellite, the accuracy of the underlying broadcast ephemeris, or the orbital phase of the satellite and Earth, and the age of the data (errors add up over time).

AssistNow Autonomous will typically extend a broadcast ephemeris from three up to six days. The CFG-ANA-ORBMAXERR item allows changing this threshold by setting the «maximum acceptable modeled orbit error» (in meters). Note that this number does not reflect the true orbit error introduced by extending the ephemeris. It is a statistical value that represents a certain expected upper limit based on a number of parameters. A rough approximation that relates the maximum extension time to this setting is: $maxError [m] = maxAge [d] * f$, where the factor f is 30 for data derived from satellites seen once and 16 for data derived for satellites seen multiple times during a long enough time period (see the [Concept](#) section).

There is no direct relation between (true and statistical) orbit accuracy and positioning accuracy. The positioning accuracy depends on various factors, such as the satellite position accuracy, the number of visible satellites, and the geometry (DOP) of the visible satellites. Position fixes that include *AssistNow Autonomous* orbit information may be significantly worse than fixes using only broadcast ephemerides. Therefore, it might be necessary to adjust the limits of the navigation output filters (CFG-NAVSPG-OUTFIL_XXXX).

Unknown future events form a fundamental deficiency of any system and can prevent precise satellite orbit predictions. Hence, the receiver will not be able to know about satellites that will have become unhealthy, have undergone a clock swap, or have had a maneuver. This means that the navigation engine might rarely mistake a wrong satellite position as the true satellite position. However, provided that there are enough other good satellites, the navigation algorithms will eventually eliminate a defective orbit from the navigation solution.

The repeatability of the satellite constellation is a potential pitfall for the use of the *AssistNow Autonomous* feature. For a given location on Earth, the (GPS) constellation (geometry of visible

satellites) repeats every 24 hours. Hence, when the receiver «learned» about a number of satellites at some point in time, the same satellites will in most places *not* be visible 12 hours later, and the available *AssistNow Autonomous* data will not be of any help. However, after another 12 hours, usable data would be available because it was generated 24 hours ago.

The longer a receiver observes the sky, the more satellites it will have seen. At the equator, and with full sky view, approximately ten (GPS) satellites will show up in a one-hour window. After four hours of observation approx. 16 satellites (i.e. half the constellation), after 10 hours approx. 24 satellites (2/3rd of the constellation), and after approx. 16 hours the full constellation will have been observed (and *AssistNow Autonomous* data generated). Lower sky visibility reduces these figures (i.e. the number of satellites seen). Further away from the equator, the numbers improve because the satellites can be seen twice a day. For example, at 47 degrees north the full constellation can be observed in approx. 12 hours with full sky view.

The calculations required for *AssistNow Autonomous* are carried out on the receiver. This requires energy and users may therefore occasionally see increased power consumption during short periods (several seconds, rarely more than 60 seconds) when such calculations are running. Ongoing calculations will automatically prevent the power save mode from entering the power-off state. The power-down will be delayed until all calculations are done.



AssistNow Autonomous should be enabled if the system has sporadic access to the *AssistNow Offline* service. In this case, the receiver will intelligently choose the more reliable orbit predictions for each satellite. This way the autonomous prediction can provide performance improvements if the offline data becomes old or gets outdated.

3.13 Sky view signal masking

When a stationary receiver's antenna has a poor view of the sky, the receiver performance can be compromised due to signal distortion produced by processing non-line-of-sight or reflected signals. The position accuracy can be improved by using mainly satellites in the line of sight of the receiver. The CFG-NAVSPG-INFIL_MINELEV configuration key can be used to set a common minimum elevation angle below which applicable satellites are not used. That is, the configuration provides a common minimum elevation cut-off for all satellite azimuth angles.

MAX-F10S also provides CFG-NAVMASK-SV_MASK_* configuration keys for excluding certain satellites from navigation that are known to introduce signal distortions and performance degradation due to multi-path effects. There is a separate satellite mask for each GNSS system. This satellite masking feature is recommended to be used for receivers that are stationary to block non-line-of-sight signals. Refer to the interface description [3] for more information about the CFG-NAVMASK-SV_MASK_* messages.

4 Hardware integration

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

4.1 Power supply

The MAX-F10S has the following power supply pins: [VCC](#), [V_IO](#) and [V_BCKP](#).

Power supply at VCC and V_IO must be present for normal operation. These two pins can either be connected together or supplied independently by the application. Power supply at V_BCKP is optional. If present, it enables the hardware backup mode when V_IO and VCC supplies are off.

The 3.3 V and 1.8 V operating voltages allow different combinations for the power supply design. These are listed in [Supply design examples](#).

Refer to the MAX-F10S Data sheet [1] for absolute maximum ratings, operating conditions, and power requirements.

4.1.1 VCC

VCC provides power to the core and RF domains and must be supplied during normal operation. The VCC pin supplies power to the core via an internal DCDC converter for efficient power consumption. 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.



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

4.1.2 V_IO

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

A power interruption at V_IO will erase the battery-backed RAM (BBR) unless there is an external supply connected to V_BCKP.

V_IO allows two voltage ranges, 1.8 V or 3.3 V operation. For 1.8 V designs, the VIO_SEL pin must be connected to GND. For 3.3 V designs, it must be left open.



V_IO supply voltage must not be higher than VCC + 0.3 V.

4.1.3 V_BCKP

Power supply at V_BCKP is optional. If the power supply at V_IO 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 V_IO is supplied again. To make these features available, connect an independent power supply to V_BCKP to ensure backup domain supply when V_IO is not supplied.

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



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.

4.1.4 Supply design examples

The two voltage ranges for V_IO allow several combinations when designing the receiver power supply. Depending on the chosen combination, there are certain requirements to be considered. These are summarized in [Table 35](#).

Option	Nominal supply (V)		Design case / Requirements
	V_IO	VCC	
1	3.3	3.3	3.3 V design where VCC and V_IO are connected together. See Figure 18 for designs using the hardware backup mode, and Figure 19 for designs without backup supply. - VIO_SEL pin left open. - Voltage at VCC_RF pin = VCC - 0.1 V.
2	1.8	1.8	1.8 V design with VCC and V_IO connected together. This design requires an accurate supply. See Figure 18 for designs using the hardware backup mode, and Figure 19 for designs without backup supply. - VIO_SEL is grounded. - Note that the voltage output at VCC_RF = VCC - 0.1 V. - Note that the maximum supply tolerance is 1.8 V $\pm$ 2 %. To enter hardware backup mode, set the receiver to software standby mode with the UBX-RXM-PMREQ message before switching off V_IO and VCC.
3	1.8	1.8 / 3.3	VCC and V_IO are supplied independently. V_IO is supplied with an accurate 1.8 V supply. VCC can be either supplied with 1.8 V or 3.3 V. See Figure 20 for designs using the hardware backup mode, and Figure 21 for designs without backup supply. - VIO_SEL pin is grounded. - Note that the maximum supply tolerance is 1.8 V $\pm$ 2 %. - Voltage at VCC_RF pin = VCC - 0.1 V. To enter hardware backup mode, switch off V_IO 100 ms before VCC. Alternatively, the receiver can be set to software standby mode with the UBX-RXM-PMREQ message before switching off V_IO and VCC.

Table 35: Voltage supply options

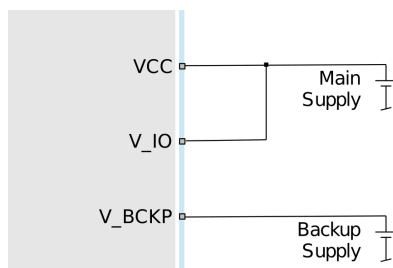


Figure 18: VCC and V_IO connected to the main supply, and external power supply at V_BCKP

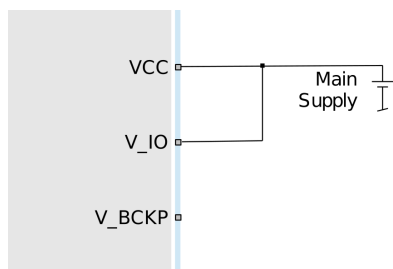


Figure 19: VCC and V_IO connected to the main supply. No external power supply at V_BCKP.

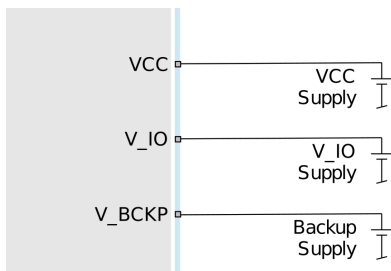


Figure 20: VCC and V_IO supplied by separate supplies, and external power supply at V_BCKP

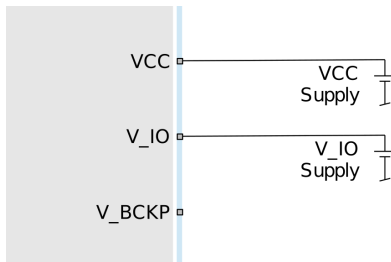


Figure 21: VCC and V_IO supplied by separate supplies. No external power supply at V_BCKP.

4.2 RF interference

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

As an example, cellular applications emit signals with power levels of approximately $+30$ dBm, while the GNSS signal is less than -130 dBm when reaching the antenna. By simply comparing these numbers, it is obvious that interference issues must be seriously considered during the design phase.

4.2.1 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 [Layout](#) section defines measures against in-band interference during the design phase of the application.

4.2.2 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.

Measures against out-of-band interference include maintaining a good grounding concept in the design and adding a GNSS band-pass filter into the antenna input line to the receiver.



The sections [Out-of-band blocking immunity](#) and [Out-of-band rejection](#) provide more information about the RF immunity of the MAX-F10S module and mitigating out-of-band interference.

4.2.3 Spectrum analyzer

The UBX-MON-SPAN message can be enabled in u-center 2 to provide a low-resolution spectrum analyzer sufficient to identify noise or jammers in the reception band. Once enabled, u-center 2 includes a real-time chart that is updated once per second with the message data. See [Figure 22](#) 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.

In addition, u-center 2 includes three functions commonly found in any spectrum analyzer. These features support the RF front-end design and help to spot out any jammer present during the application operation.

- **Hold:** if selected, the current spectrum shape freezes in a colored line. This allows for a comparison between the time the spectrum was frozen and the real-time spectrum. This is particularly helpful in assessing the impact of running other onboard components.
- **Average:** if selected, a colored line shows the averaged spectrum for each frequency. This supports the analysis over time and obtaining a less noisy shape.
- **Max hold:** if selected, a colored line shows the maximum amplitude measured at each frequency. This option helps to spot out any jammer over a period of time.

[Figure 22](#) shows the spectrum view in u-center 2 with the hold, average and max hold options selected. The green, yellow and red lines represent the frozen hold, average and max hold spectrums, while the blue line represents the current continuous spectrum.



Figure 22: Spectrum analyzer view in u-center 2



By changing the enabled GNSS constellations, 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 [3].



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.

4.3 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.

The MAX-F10S RF front-end is designed for high immunity against RF interference and is suitable for designs with a cellular transmitter. The integrated RF circuit includes an L1, L5 dual-band SAW filter followed by a wide-band low-noise amplifier (LNA) and a L1, L5 diplexer SAW filter stage. The dual-band SAW-LNA-SAW circuit efficiently rejects out-of-band blocking signals and amplifies the GNSS signal enhancing the sensitivity of the receiver. The RF input is matched to $50\ \Omega$ and includes a built-in DC block.

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

4.3.1 Internal LNA modes

In addition to the wide-band LNA integrated in the RF front-end circuit in MAX-F10S, there are internal LNAs in the u-blox F10 receiver.

The internal L1 and L5 band LNAs in the receiver have three operating modes: normal gain, low gain, and bypass mode.

- By default, the internal L1 and L5 band LNAs are configured for the low-gain mode for optimized immunity and sensitivity. For designs with external gain above 30 dB, the bypass mode must be used to maintain the dynamic range.
- The bypass mode can be used up to 40 dB external gain. There are also minor improvements in immunity and power consumption in the bypass mode.
- Normal-gain mode is not recommended for MAX-F10S.

The internal LNA mode can be configured at run time in BBR and RAM layers using the configuration item CFG-HW-RF_LNA_MODE and applying a reset or set permanently in the one-time-programmable (OTP) memory in production. The configuration in the OTP memory is automatically applied at every startup. Refer to [Internal LNA mode configuration](#) for more information.

4.3.2 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.

MAX-F10S out-of-band immunity data are currently not available.



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.

4.3.3 Interference coupling

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).

It is more difficult to estimate RF interference from other parts of the design. 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.

The maximum power coupled into the receiver RF input is compared against the immunity limit of the receiver defined in [Out-of-band blocking immunity](#).

4.3.4 Antenna power supply

[Figure 23](#) 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 VCC_RF pin can be used to supply an active antenna. VCC_RF is a RF filtered supply voltage derived from the VCC supply. Refer to the Data sheet[1] for the VCC_RF specification.

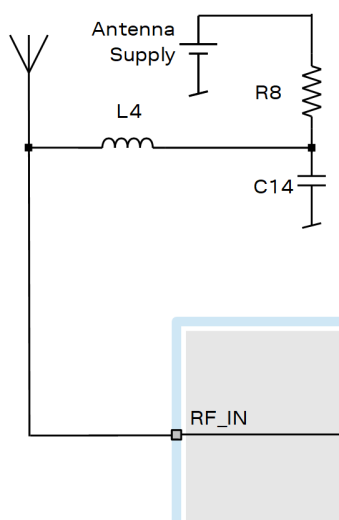


Figure 23: Antenna supply network

4.4 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.

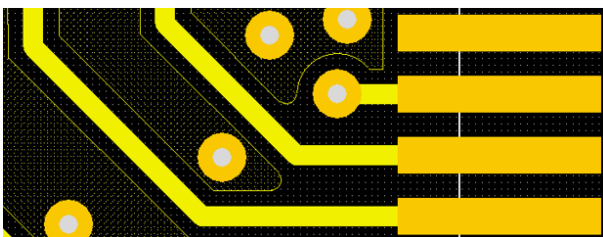


Figure 24: GND stub ended with a via

It is recommended to ground the area below the module, on the top and second layer. Avoid signal lines crossing below the module at these two layers.

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.

4.4.1 Package footprint, copper and solder mask

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

Figure 25 and Figure 26 describe the footprint and provide recommendations for the paste mask. Note that the copper and solder masks have the same size and position.

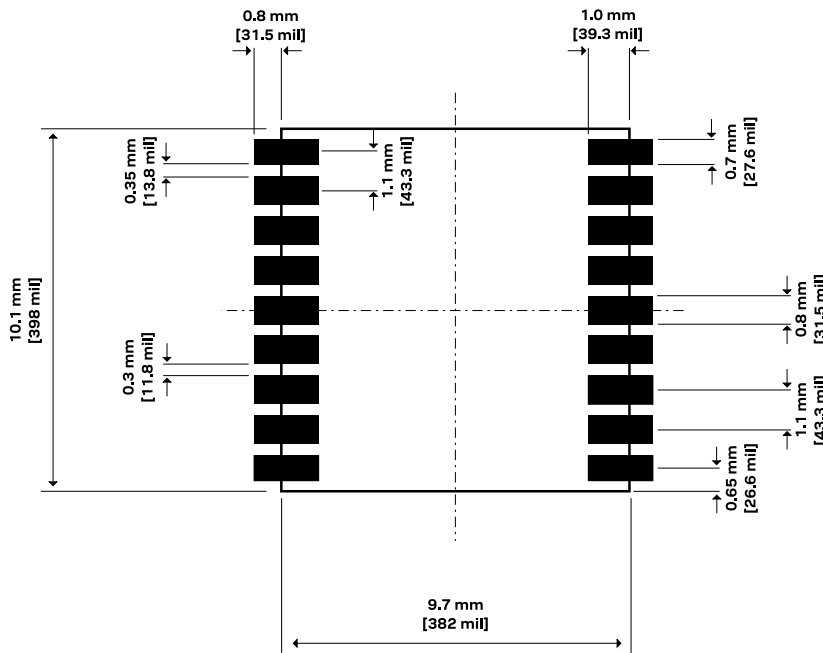


Figure 25: Recommended copper land and solder mask opening for MAX-F10S

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 .

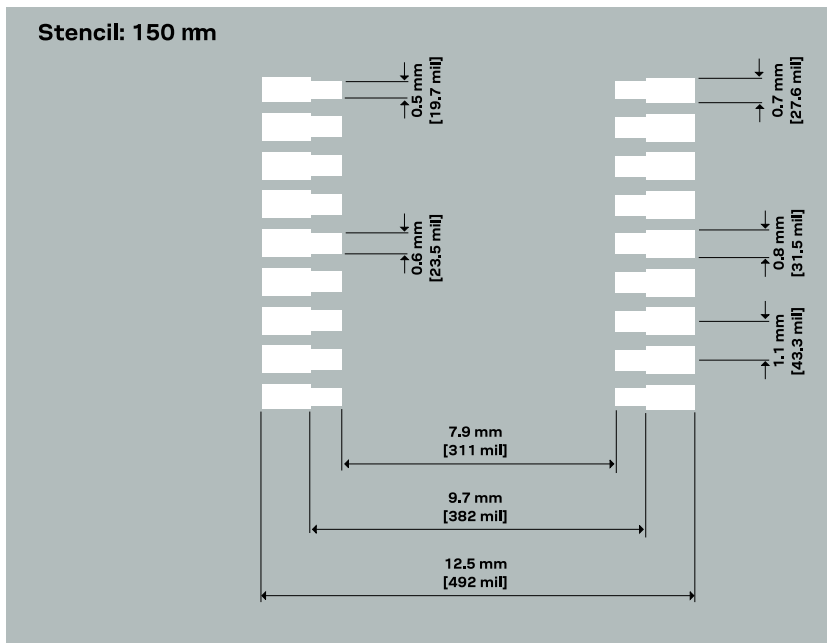


Figure 26: Recommended paste mask pattern for MAX-F10S



These are only recommendations and not specifications. The exact geometry, distances, stencil thicknesses and solder paste volumes must be adapted to the customer's specific production processes (for example, soldering).

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 27](#).
- 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)

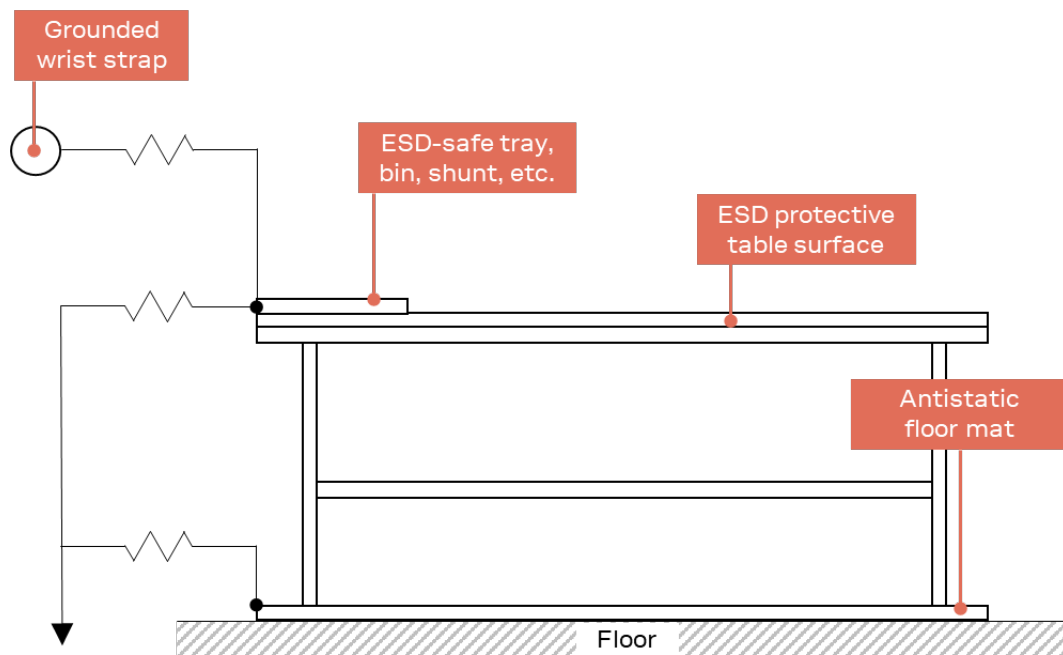


Figure 27: Standard workstation setup for safe handling of ESD-sensitive devices

5.1.2 Safety precautions

The MAX-F10S 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 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.

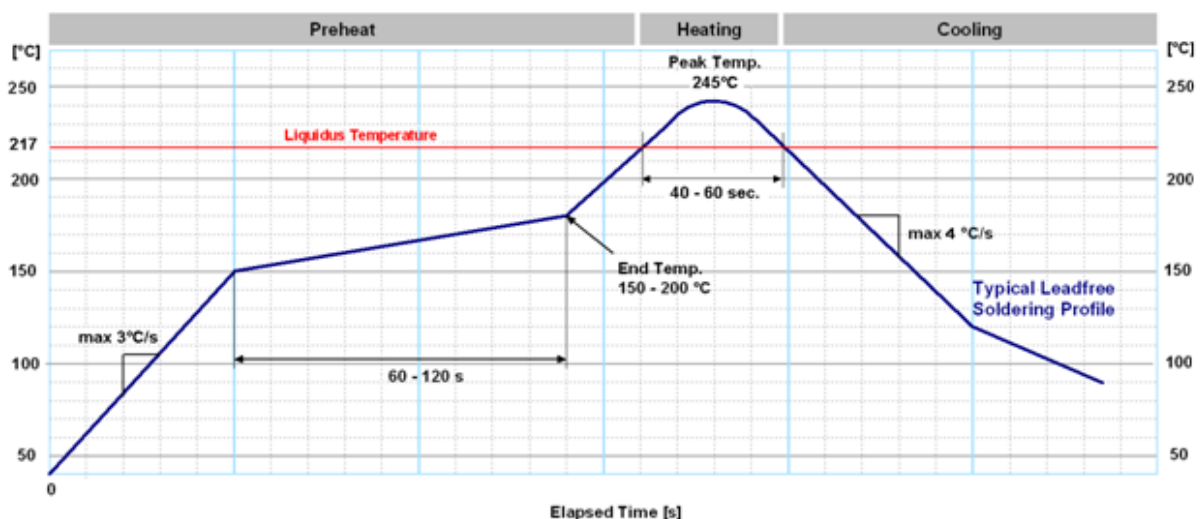


Figure 28: Soldering profile



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.

Appendix

A Migration

u-blox is committed to ensuring that products in the same form factor are backwards compatible over several technology generations. This section describes important differences to consider when migrating from u-blox 7/8/M8/M10 to u-blox F10.

A.1 Hardware changes

Table 36 lists the key **hardware-related changes** between MAX-F10S and MAX-7/8/M8/M10 modules.

Feature	Change	Action needed / Remarks
Absolute maximum ratings	The absolute maximum voltage for PIOs changed to $V_{IO} + 0.3 \text{ V}$ in MAX-F10S and MAX-M10S/M.	A HW change is required if main supply voltage source is not within the specified range.
VCC, V_{IO}	The V_{IO} voltage range is selected with the VIO_SEL pin. V_{IO} supply voltage cannot be higher than $VCC + 0.3 \text{ V}$ in MAX-F10S and MAX-M10S.	For designs with 1.8 V supply at V_{IO} , switch off V_{IO} supply 100 ms before VCC when transitioning to hardware backup mode. Alternatively, put the receiver in software standby mode by sending the UBX-RXM-PMREQ message before switching off V_{IO} and VCC. Refer to the minimum and maximum V_{IO} ramp requirements in the MAX-F10S data sheet [1].
VCC and V_{IO} supply range	MAX-F10S, MAX-M10S VCC: 1.76 V - 3.6 V MAX-F10S, MAX-M10S V_{IO} : 1.76 V - 1.98 V, 2.7 V - 3.6 V MAX-M10M VCC: 1.76 V - 5.5 V MAX-M10M V_{IO} : 1.68 V - 1.98 V, 2.7 V - 3.6 V MAX-7C/8C/M8C: 1.65 V - 3.6 V	A HW change is required when migrating from a MAX-7C/8C/M8C design that uses less than 2.7 V VCC and V_{IO} supply because VIO_SEL (pin 15) needs to be connected to GND in MAX-F10S and the voltage range for 1.8 V designs is different.
V_{BCKP} supply range	MAX-F10S, MAX-M10S/M: 1.65 V - 3.6 V MAX-7/8/M8: 1.4 V - 3.6 V	A HW change is required when migrating from a MAX-7/8/M8 design that uses less than 1.65 V V_{BCKP} supply.
Backup current	The hardware backup current into V_{BCKP} in MAX-F10S, MAX-M10S/M is higher than in MAX-7Q/7W/8Q/M8Q/W modules. The hardware backup current in MAX-F10S, MAX-M10S/M is significantly lower than in MAX-7C/8C/M8C modules.	Check the backup battery capacity if it is still suitable for the target design requirements.
Software standby current	The software standby current into V_{IO} in MAX-F10S, MAX-M10S/M is higher than in MAX-7Q/8Q/M8Q/W modules. MAX-7W has higher software backup current than MAX-F10S. The software standby current in MAX-F10S, MAX-M10S/M is significantly lower than in MAX-7C/8C/M8C.	Check if the changes in current affects target design/application requirements.
Pin-out	1:1 pin-out mapping with MAX-7Q/7C/8Q/8C/MAX-M10S/M modules, but not with MAX-7W/M8W.	A HW change is required for MAX-7W/M8W designs that use V_{ANT} (pin 15) to supply an active antenna, which is VIO_SEL in MAX-F10S.

Feature	Change	Action needed / Remarks
RF front-end	SAW-LNA-SAW MAX-F10S includes an L1, L5 dual-band SAW filter, a wide-band LNA and a L1, L5 diplexer SAW on the RF path which allows the use of dual-band passive antenna and efficiently rejects out-of-band blocking signals. MAX-F10S L1 3.5 dB, L5 3 dB MAX-M10S noise figure: 1.5 dB MAX-7/8/M8 noise figure: 3.5 dB	External BOM savings are possible if the same components have been added externally on the RF path of the MAX-7/8/M8 design. Use the internal LNA of the receiver in bypass mode when an active antenna is used. The internal LNA mode of the receiver can be configured to low gain and bypass modes because the MAX-F10S module has an LNA on the RF path. This allows flexible optimization of the receiver performance and power consumption with respect to the selected RF front-end/antenna. The default internal LNA mode on MAX-F10S is set to low gain. Check that the external RF path (antenna and filtering) is suitable for all of the GNSS signals in use.
Absolute max RF input power	MAX-F10S and MAX-M10S: 0 dBm MAX-M10M: +15 dBm MAX-M8 modules: +15 dBm MAX-7 modules: +13 dBm	-
SAFEBOOT_N, TIMEPULSE	The SAFEBOOT_N pin is internally connected to TIMEPULSE pin through a 1 kΩ series resistor in M10 and F10.	Do not drive the TIMEPULSE pin low at startup because it will put the receiver in safeboot mode.
RESET_N	MAX-F10S and MAX-M10S/M: clears the RTC time and BBR contents (GNSS orbit data). MAX-7/8Q/M8: clears only the RTC time.	After resetting MAX-F10S and MAX-M10S/M with the RESET_N pin, the TTFF is similar to performing a cold start. After resetting the MAX-7/8Q/M8 modules, the TTFF is typically around 6 s in open-sky conditions.
Digital IO	External IO isolation is required. The output current of the digital IOs is 2 mA in M10 and F10 compared to 4 mA in MAX-7 and MAX-8Q/M8 modules, except for the TIMEPULSE pin, which still provides 4 mA drive strength.	Caution! Risk of receiver damage. If the IO pins are not isolated, the GNSS receiver may get permanently damaged when high current is drawn from the IO pins. Use external IO isolation to avoid receiver damage. Do not drive IOs when VCC and V_IO are not supplied. Removing the VCC or V_IO supply does not isolate the module IO pins from the the host device IO pins. Additional external pull-up resistors may be required to increase the drive strength of the digital IO output pin or adjust the load accordingly.

Table 36: MAX-F10S hardware features compared to MAX-7/8/M8/M10 modules

Migrating from MAX-7W/M8W to MAX-F10S requires special care and may require some re-design because there are changes in the assignment of pins 13 and 15, as shown in [Figure 29](#). Consequently, pin 15 should be left open (i.e. not connected) when migrating from MAX-7W/M8W because there is no built-in antenna supervisor support in MAX-F10S. Therefore, in MAX-F10S, the active antenna supply and antenna supervisor circuitry (if used) need to be connected externally as shown in [Antenna supervisor designs](#).

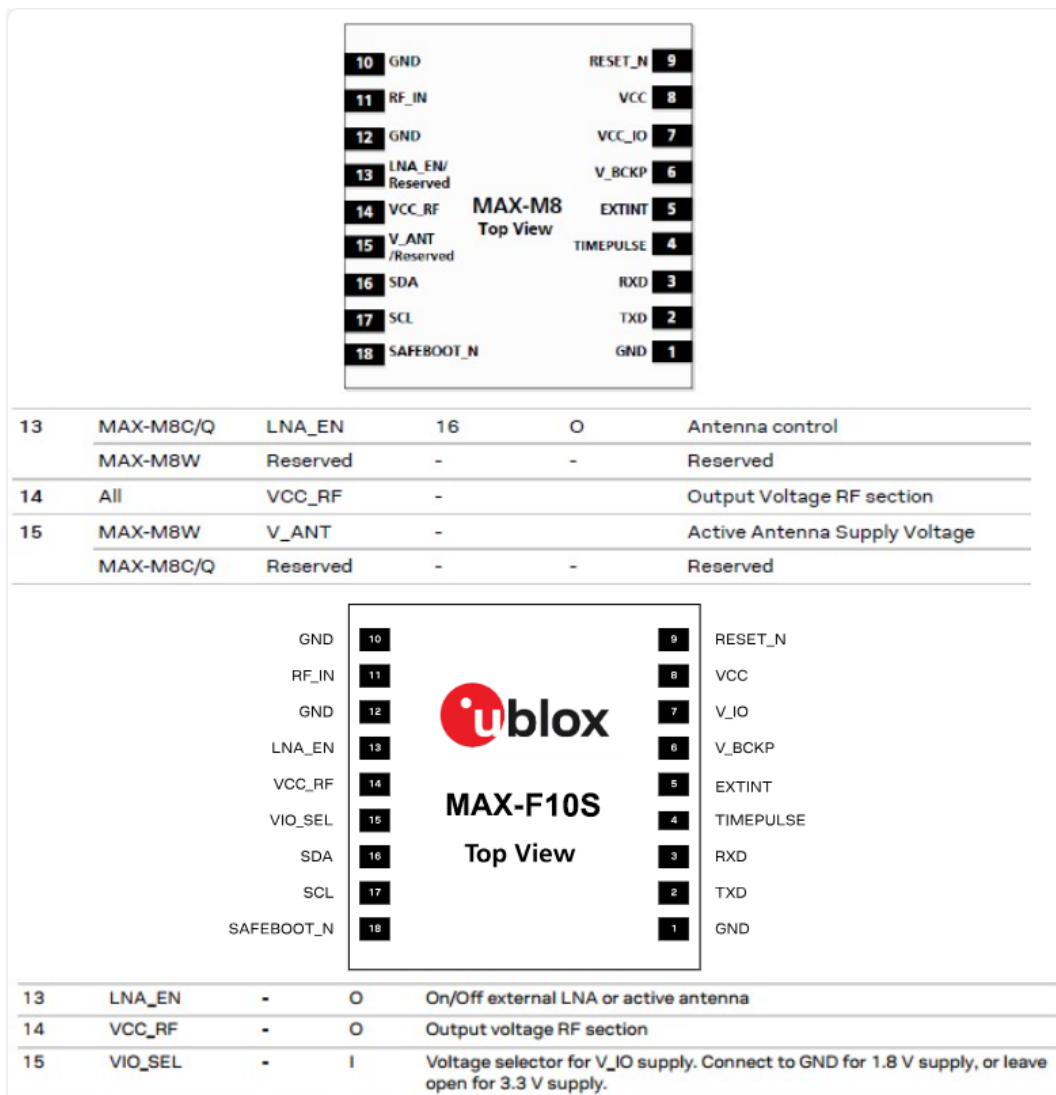


Figure 29: MAX-M8 vs. MAX-F10S comparison (pin 13 - 15)

Refer to the product Data sheets for details.

A.2 Firmware changes

Table 37 presents a summary of the key firmware-related changes between u-blox F10 and u-blox 7/8/M8/M10.

Feature	Change	Action needed / Remarks
Signals		
Default GNSS configuration	MAX-F10S: Dual band L1/L5 signals for GPS, Galileo, BeiDou B1C/B2a and SBAS. MAX-M10S: GPS, Galileo, BeiDou B1I, QZSS and SBAS. MAX-M10M: GPS, Galileo, QZSS and SBAS. MAX-M8Q/C/W: GPS, GLONASS, QZSS and SBAS. MAX-7Q/7C/7W/8Q/8C: GPS, QZSS and SBAS.	Code change (optional) HW change (optional): requires antenna selection or antenna frequency tuning and any additional filtering in the previous MAX-7/8/M8/M10 designs to support L5 frequency band.

Feature	Change	Action needed / Remarks
GPS L5	New signal.	Code change (optional)
BeiDou B1C	New signal in M10 and F10. BeiDou satellite IDs up to 63 supported.	Code change (optional)
BeiDou B1I	Not supported.	Code change (optional)
BeiDou B2a	New signal. BeiDou satellite IDs up to 63 supported.	Code change (optional)
Galileo E5a	New signal.	Code change (optional)
GLONASS	Not supported.	Code change
SBAS	New SBAS PRN selection in M10 and F10: 123, 126-129, 131, 133, 136-138.	Code change (optional)
QZSS L1S	SLAS corrections are now applied for navigation in M10 and F10.	Code change (optional)
QZSS IMES	Not supported in M10 and F10.	Code change (optional)
NavIC SPS L5	New signal.	Code change (optional)
Protocols		
NMEA	Supports NMEA V4.11, V4.10, V4.0, V2.3, and V2.1. NMEA V4.11 is enabled by default. In M10 and F10, the NMEA GSV messages for zero signal C/No level are grouped separately as compared to u-blox 7/8/M8. If the signal's C/No level is 0, the FW treats it as an unknown signal for not being able to track it and sets the "signal ID" to zero. The firmware creates two separate GSV message groups. The first group contains GSV messages for the tracked signals with non-zero C/No and the second group contains GSV messages for the untracked signals with zero C/No. In the untracked signals message group, the C/No field is blank (i.e. ,). There is no configuration to revert this to the u-blox 7/8/M8 format.	Code change (optional)
RTCM	Not supported in M10 and F10.	Code change
General		
Configuration concept	New configuration concept in M10 and F10 using UBX-CFG-VALSET and UBX-CFG-VALGET messages.	Code change
Navigation update rate	Navigation update rate up to 20 Hz for single GNSS in F10 and 10 Hz for multi-GNSS constellations.	Code change (optional)
Power save mode (PSM)	PSM is not supported. Hardware backup and software standby modes are supported.	Code change (optional)
Altitude limit	The maximum altitude limit increased to 80 000 m in M10 and F10.	-
AssistNow	Simultaneous operation of AssistNow Online, Offline and Autonomous supported in M10 and F10. New AssistNow Offline data download options are available. The time period can be limited to a resolution of days to reduce the data package size.	Code change (optional)
Geofencing	Not supported in M10 and F10.	Code change
Data logging	Not supported in M10 and F10.	Code change
Galileo return link message	Galileo search and rescue (SAR) return link message UBX-RXM-RLM in M10 and F10.	Code change (optional)
RF spectrum view	New message in M10 and F10. UBX-MON-SPAN shows in-band RF spectrum around the GNSS band. This can be used to identify potential in-band RF interference sources in the design.	Code change (optional)
Protection level	New feature in M10 and F10. Real-time position accuracy estimate with 95% confidence level with the message UBX-NAV-PL.	Code change (optional)

Feature	Change	Action needed / Remarks
Satellite masking	New feature. Includes CFG-NAVMASK-SV_MASK_* configuration keys for excluding certain satellites from navigation that are known to introduce signal distortions and performance degradation due to multi-path effects. Recommended to be used for receivers that are stationary.	Code change (optional)
Security		
Message integrity	New feature in M10 and F10. Authentication of data output based on private/public key pair.	Code change (optional)
Unique chip identifier	A unique chip identifier output in boot screen and in the UBX-SEC-UNIQID message in M10 and F10.	Code change (optional)
Configuration lock	New security feature in M10 and F10 that is enabled with CFG-SEC-CFG_LOCK message for locking the receiver configuration.	Code change (optional)
Additional changes for u-blox-7 migration	Support for multiple GNSS and new signals: Galileo E1, BeiDou B1I, and GLONASS L1OF. Multiple GNSS assistance (MGA) with AssistNow services. Spoofing detection added. Wrist dynamic model added. Odometer to measure traveled distance with support for different user profiles. Time pulse and time mark reference changed from GPS to UTC.	Code change (optional)

Table 37: MAX-F10S firmware features

For more information on the supported features and messages in the u-blox F10 receiver, refer to the SPG 6.00 Release note and Interface description [2], [3].

B Reference designs

The [External components](#) section provides the specification and recommendations for the external components that are shown in each reference design.

This section provides some reference designs for typical and antenna supervisor design cases.



Designs with 1.8 V main supply or with independent supply for VCC and V_IO must fulfill certain requirements when transitioning to hardware backup mode. Refer to [Supply design examples](#) for more details.

B.1 Typical design

Here are some key features for a MAX-F10S typical design:

- VCC and V_IO are connected together to a single supply. In designs with 3.3 V supply, the VIO_SEL pin must be left open, as shown in [Figure 30](#). In designs with 1.8 V supply, the VIO_SEL pin must be connected to GND, as shown in [Figure 31](#).
- V_BCKP supply is optional. If present, the hardware backup mode is supported. This mode maintains the time and GNSS orbit data in the battery-backed RAM memory if the main supply is switched off.
If there is no backup supply, time aiding with the UBX-MGA-INITIME-UTC message (optionally with a timing signal at the EXTINT pin) and the GNSS orbit data from the AssistNow services or stored on the host controller can be used to reduce the TTFF.
- A passive or active antenna can be used. An active antenna can be supplied either with the VCC_RF output from MAX-F10S, as shown in [Figure 32](#), or from an external supply, as shown in [Figure 33](#). Nevertheless, the internal LNA provides enough gain for passive antennas.
- MAX-F10S has an integrated RF circuit which includes an L1, L5 dual-band SAW filter followed by a wide-band low-noise amplifier (LNA) and a L1, L5 diplexer SAW filter stage, hence no additional

RF front-end components are needed. The RF front-end is designed for high immunity against RF interference and is suitable for designs with a cellular transmitter.

- UART and I2C communication interfaces are available.
- For an absolute minimum design using UART, other PIOs (RESET_N, EXTINT, TIMEPULSE, SDA, SCL, SAFEBOOT_N) can be left open.

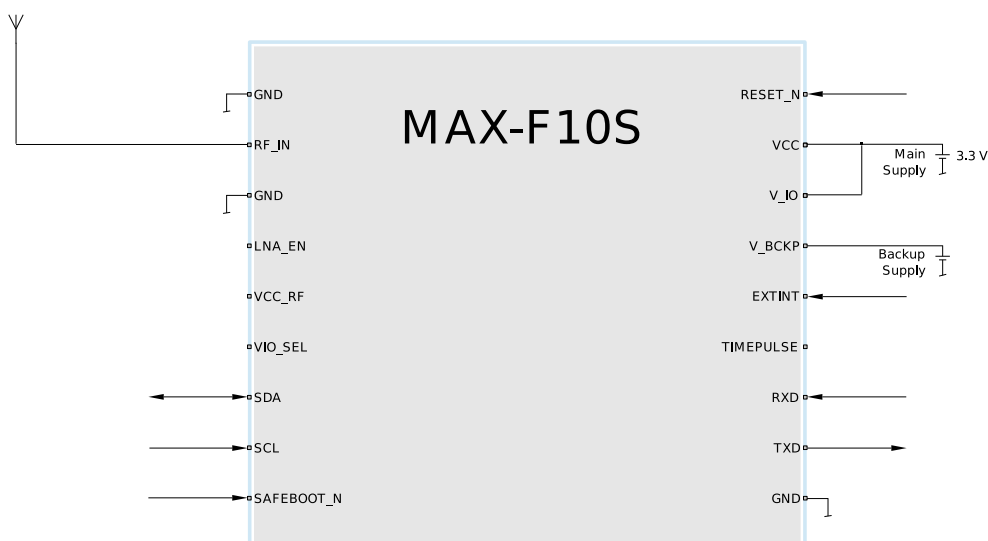


Figure 30: Typical 3.3 V design

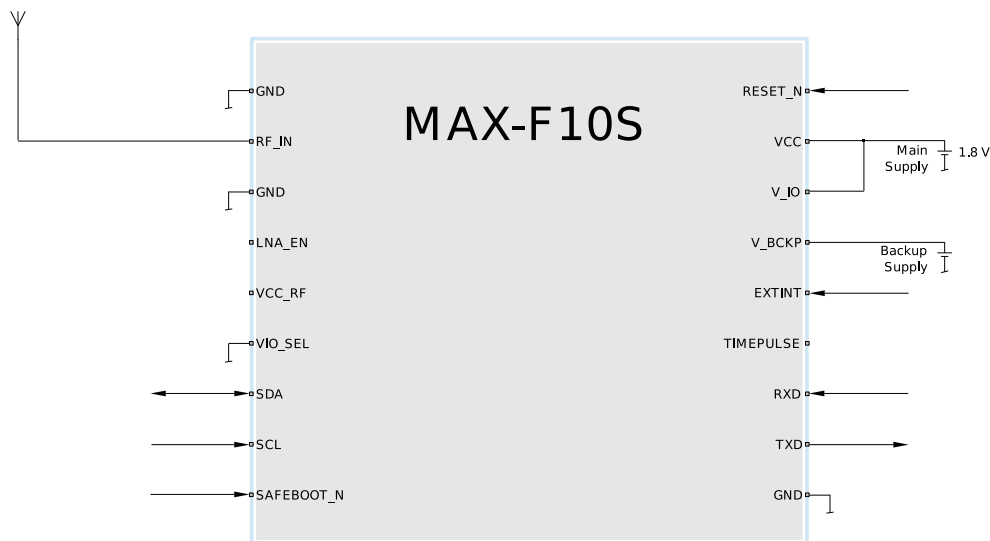


Figure 31: Typical 1.8 V design

B.2 Antenna supervisor designs

Figure 32 and Figure 33 show a reference design for a 2-pin and 3-pin antenna supervisor design respectively. Here are some key features:

- VCC and V_IO are connected together to a single supply.
- Supply at V_BCKP is optional. If present, the hardware backup mode is supported. This mode maintains the time and GNSS orbit data in the battery-backed RAM memory if the main supply is switched off.
If there is no backup supply, time aiding with the UBX-MGA-INI-TIME_UTC message (optionally with a timing signal at the EXTINT pin) and the GNSS orbit data from the AssistNow services or stored on the host controller can be used to reduce the TTFF.
- An active antenna can be supplied with the VCC_RF output from MAX-F10S or from an external supply. VCC_RF is a filtered output voltage supply, which outputs VCC - 0.1 V. In addition, the active antenna supply can be turned on/off by the LNA_EN signal, which also controls the internal LNA of MAX-F10S.
- External open drain buffers and operational amplifiers are also needed depending on whether a 2-pin or 3-pin antenna supervisor design is used.
- UART and I2C communication interfaces are available. I2C PIOs (SDA and SCL) can be used in a 3-pin antenna supervisor design as shown in Figure 33. In this case, the I2C interface needs to be disabled before assigning the new function to the PIOs.



Disable the I2C interface with the CFG-I2C-ENABLED configuration key when I2C pins are used for antenna supervisor functions. Likewise, disable the UART interface (CFG-UART1-ENABLED) or TIMEPULSE (CFG-TP-TP1_ENA) when the pins are used for antenna supervisor functions.

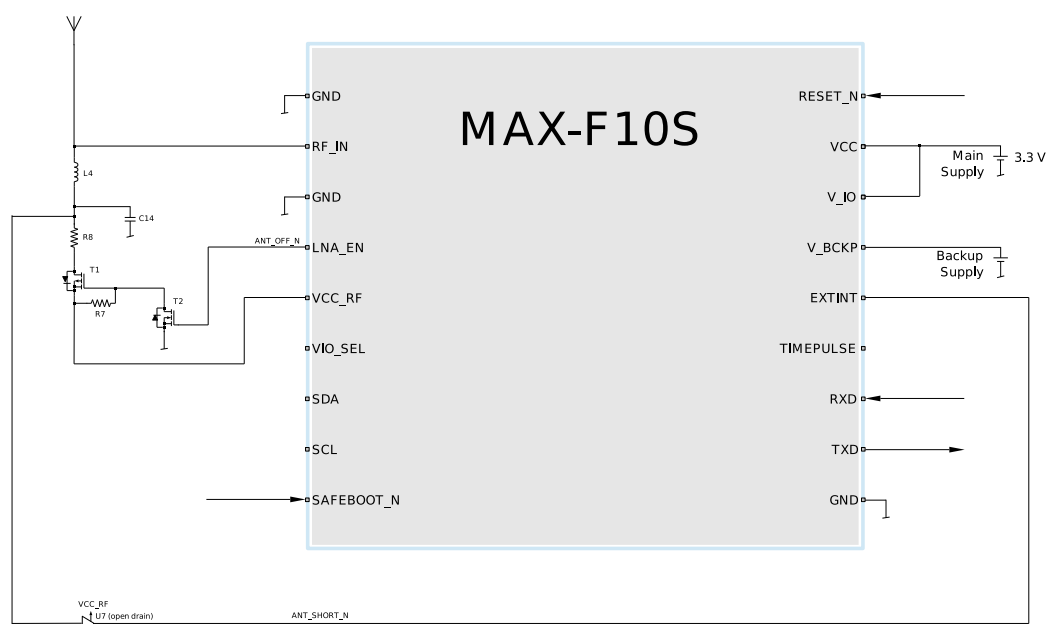


Figure 32: 2-pin antenna supervisor design

The 2-pin antenna supervisor configuration required for the [Figure 32](#) reference design is listed in [Table 38](#).

Configuration key	Value
CFG-HW-ANT_CFG_VOLTCTRL	1 (true), default (no configuration required)
CFG-HW-ANT_SUP_SWITCH_PIN	7, default (no configuration required)
CFG-HW-ANT_CFG_SHORTDET	1 (true)
CFG-HW-ANT_CFG_SHORTDET_POL	0 (false)
CFG-HW-ANT_SUP_SHORT_PIN	5
CFG-HW-ANT_CFG_PWRDOWN	1 (true)
CFG-HW-ANT_CFG_PWRDOWN_POL	0 (false), default (no configuration required)
CFG-HW-ANT_CFG_RECOVER	1 (true)

Table 38: Configuration for the 2-pin antenna supervisor design

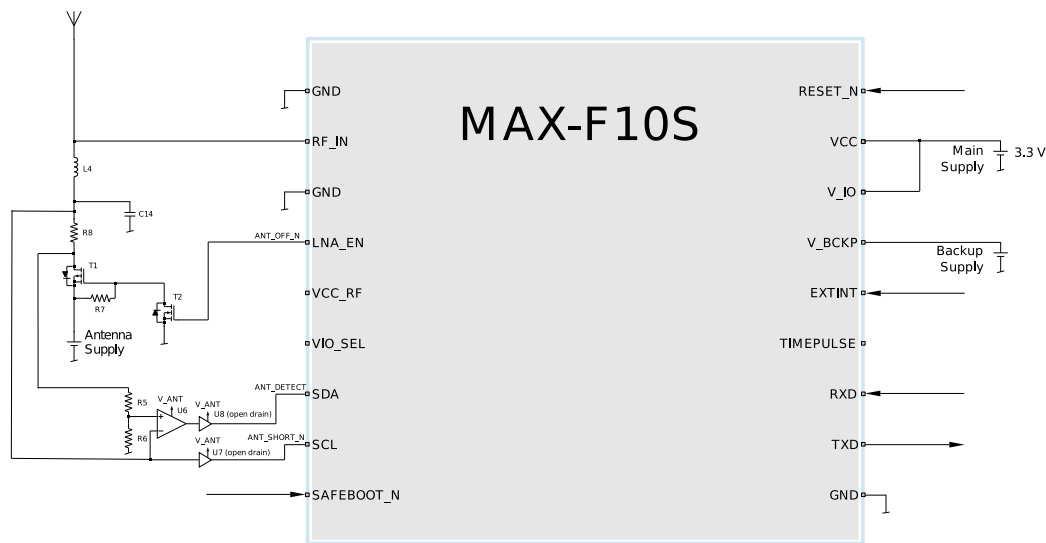


Figure 33: 3-pin antenna supervisor design

The 3-pin antenna supervisor configuration required for the [Figure 33](#) reference design is listed in [Table 39](#).

Configuration key	Value
CFG-I2C-ENABLED	0 (false)
CFG-HW-ANT_CFG_VOLTCTRL	1 (true), default (no configuration required)
CFG-HW-ANT_SUP_SWITCH_PIN	7, default (no configuration required)
CFG-HW-ANT_CFG_SHORTDET	1 (true)
CFG-HW-ANT_CFG_SHORTDET_POL	0 (false)
CFG-HW-ANT_SUP_SHORT_PIN	3
CFG-HW-ANT_CFG_OPENDET	1 (true)
CFG-HW-ANT_CFG_OPENDET_POL	1 (true), default (no configuration required)
CFG-HW-ANT_SUP_OPEN_PIN	2
CFG-HW-ANT_CFG_PWRDOWN	1 (true)
CFG-HW-ANT_CFG_PWRDOWN_POL	0 (false), default (no configuration required)
CFG-HW-ANT_CFG_RECOVER	1 (true)

Table 39: Configuration for the 3-pin antenna supervisor design

C External components

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

C.1 Standard capacitors

Table 40 presents the recommended capacitor values for MAX-F10S.

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

Table 40: Standard capacitors

C.2 Standard resistors

Table 41 presents the recommended resistor values for MAX-F10S.

Name	Use	Type / Value
R5	Antenna supervisor voltage divider	560 Ω , 5%, 0.1 W
R6	Antenna supervisor voltage divider	100 k Ω , 5%, 0.1 W
R7	Pull-up resistor at antenna supervisor transistor	100 k Ω , 5%, 0.1 W
R8	Antenna supply current limiter/shunt resistor	10 Ω , 5%, 0.25 W

Table 41: Standard resistors

C.3 Inductors

Table 42 presents the recommended inductor values for MAX-F10S.

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 42: Recommended inductors

C.4 Operational amplifier

Name	Manufacturer	Order no.
U6	Linear Technology	LT6000, LT6003

Table 43: Recommended parts list for the operational amplifier

C.5 Open drain buffers

Name	Manufacturer	Order no.
U7, U8	Fairchild	NC7WZ07P6X

Table 44: Recommended parts list for the open drain buffers

C.6 Switch transistors

Table 45 presents the recommended switch transistors for MAX-F10S.

Name	Manufacturer	Order no.	Comments
T1, T2	Vishay	Si1016X-T1-GE3	p-channel, n-channel MOSFET

Table 45: Recommended parts list for the antenna switch transistors

Related documents

- [1] MAX-F10S Data sheet, [UBXDOC-963802114-12732](#)
- [2] u-blox F10 SPG 6.00 Release note, [UBXDOC-963802114-12318](#)
- [3] u-blox F10 SPG 6.00 Interface description, [UBX-23002975](#)
- [4] 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	14-Aug-2024	Initial release

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