

MAX-M10S

u-blox M10 standard precision GNSS module

Integration manual



Abstract

This document describes the features and application of the u-blox MAX-M10S module, an ultra-low-power standard precision GNSS receiver for high-performance asset-tracking applications.

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1 System description

This section gives an overview of the MAX-M10S receiver, and outlines the basics of operation with the receiver.

1.1 Overview

The MAX-M10S module features the u-blox M10 standard precision GNSS platform and provides exceptional sensitivity and acquisition times for all L1 GNSS signals.

The extremely low power consumption in continuous tracking mode allows great power autonomy for all battery-operated devices, such as asset trackers, without compromising on GNSS performance.

The MAX-M10S supports concurrent reception of up to four GNSS (GPS, GLONASS, Galileo, and BeiDou). The high number of visible satellites enables the receiver to select the best signals. This maximizes the position accuracy, in particular under challenging conditions such as in deep urban canyons. In the firmware described here, however, the number of concurrently received GNSS is limited to three. u-blox Super-S (Super-Signal) technology offers great RF sensitivity.

The MAX-M10S integrates a notch and an SAW filter in the RF path to increase the out-of-band immunity, and an LNA for maximum sensitivity in passive antenna designs.

The MAX-M10S offers backwards pin-to-pin compatibility with products from the previous u-blox generations, which saves the designer's effort and reduces costs when upgrading designs.

1.2 Architecture

The MAX-M10S receiver provides all the necessary RF and baseband processing to enable multi-constellation operation. The block diagram below shows the key functionality.

1.2.1 Block diagram

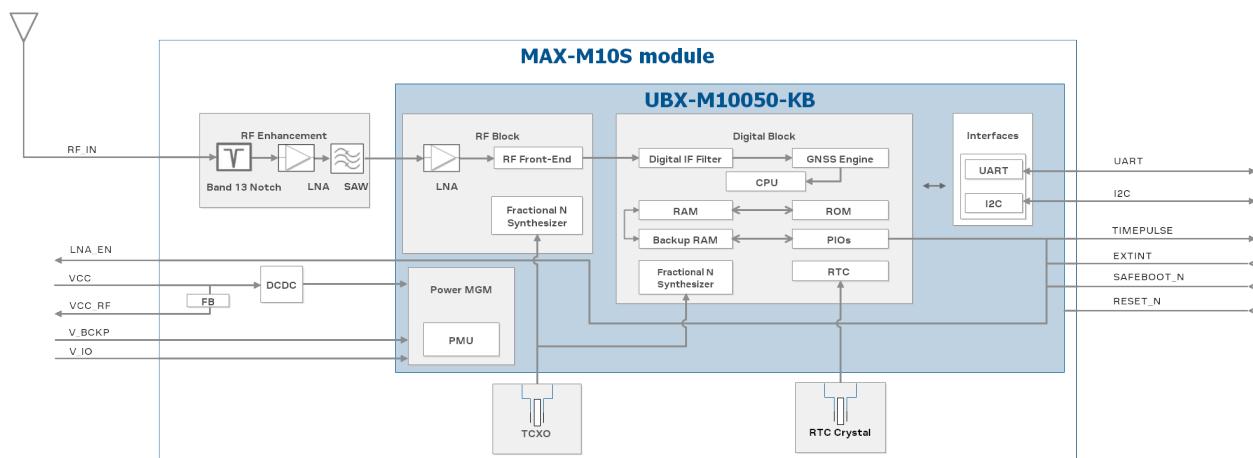


Figure 1: MAX-M10S block diagram

1.3 Pin assignment

The pin assignment of the MAX-M10S is shown below:

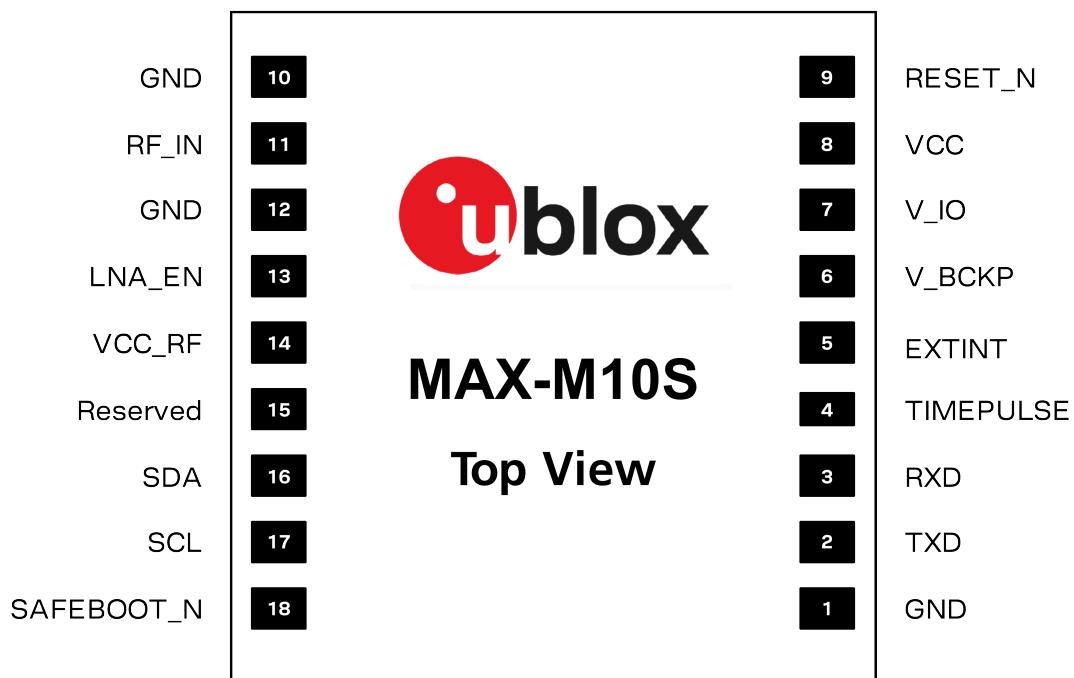


Figure 2: MAX-M10S pin assignment

Pin no.	Name	PIO no.	I/O	Description
1	GND	-	-	Connect to GND
2	TXD	1	O	UART TX. If not used, leave open. Alternative features ¹ .
3	RXD	0	I	UART RX. If not used, leave open. Alternative features ¹ .
4	TIMEPULSE	4	O	Time pulse signal. Alternative features ¹ .
5	EXTINT	5	I	External interrupt. Alternative features ¹ .
6	V_BCKP	-	I	Backup voltage supply. Leave open if no external backup supply.
7	V_IO	-	I	IO voltage supply. Connect to VCC.
8	VCC	-	I	Main voltage supply
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.
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.
12	GND	-	-	Connect to GND
13	LNA_EN	-	O	On/Off external LNA or active antenna
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.
15	Reserved	-	-	Reserved. Must be left open.
16	SDA	2	I/O	I2C data. If not used, leave open. Alternative features ¹ .

¹ Alternatively, this pin can be used for antenna supervisor OPENDET, SHORTDET, TX_READY, and data batching. Assign the function in the output pin carefully.

Pin no.	Name	PIO no.	I/O	Description
17	SCL	3	I	I2C clock. If not used, leave open. Alternative features ¹ .
18	SAFEBOOT_N	-	I	Safeboot mode. To enter safeboot mode, set this pin to low at receiver's startup. Otherwise, leave it open.

Table 1: MAX-M10S pin assignment

2 Receiver functionality

This section provides description of the receiver's functionality and features, and explains how to configure the receiver for various uses.

2.1 Receiver configuration

The MAX-M10S is fully configurable with UBX configuration interface keys. The configuration database in the receiver's RAM holds the current configuration, which is used by the receiver at run-time. It is constructed from several configuration sources when the receiver starts up. The configuration interface and the available keys are described in the interface description [2].

A configuration setting stored in the RAM remains effective until power-down or reset. If stored in BBR (battery-backed RAM), the setting will be used as long as the backup battery supply remains.

Configuration interface settings are held 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 and in this document. In u-center, a configuration group is identified as "Group name" and the configuration item is identified as the "item name".

The configuration messages will result in a UBX-ACK-ACK or UBX-ACK-NAK response. If several configuration messages are sent without waiting for this response then the receiver may pause processing of input messages until processing of a previous configuration message has been completed. When this happens a warning message "wait for cfg ACK" will be sent to the host.

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

2.1.1 Basic receiver configuration

This section summarizes the basic receiver configuration most commonly used.

2.1.1.1 Basic hardware configuration

The MAX-M10S receiver is configured with the default setting during the module production. The receiver starts up and is fully operational as soon as proper power supply, communication interfaces and antenna signal from the application are connected.

2.1.1.2 Internal LNA mode configuration

The MAX-M10S supports three modes for internal low-noise amplifier (LNA). The normal-gain mode is not recommended for MAX-M10S. Low-gain mode is the default. With an active antenna with high external gain, bypass mode can be used. This can be configured at run time with the configuration item CFG-HW-RF_LNA_MODE.

The internal LNA mode can also be permanently configured in the receiver's one-time programmable (OTP) memory. Changes to the bits in the OTP memory cannot be modified after they are programmed. The OTP configuration is only done once in production, and is subsequently automatically applied at every start-up. The internal LNA mode can be reconfigured at run time.

The default low-gain mode is pre-configured in the receiver and does not require configuration in production. The configuration string for setting the internal LNA in bypass mode in the OTP memory is given in [Table 2](#).

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 2: Internal LNA mode configuration in OTP memory

To configure the internal LNA in bypass mode in OTP memory:

1. Power up the system.
2. Test the communication interface by polling the UBX-MON-VER message.
3. Send the configuration string in [Table 2](#).
4. Power the receiver off and on or send UBX-CFG-RST message (the reset type must be set to a hardware reset). The new internal LNA setting is applied at start-up.
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.
6. The OTP memory configuration is completed.

2.1.1.3 Communication interface configuration

Several configuration groups allow configuring the operation mode of the various 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-*
I2C	CFG-I2C-*, CFG-I2CINPROT-*, CFG-I2COUTPROT-*, CFG-TXREADY-*

Table 3: Interface configuration

2.1.1.4 Message output configuration

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

For periodic output messages the rate relates to the event the message is related to. For example, the UBX-NAV-PVT (navigation, position, velocity and time solution) is related to the navigation epoch. If the rate of this message is set to one (1), it will be output for every navigation epoch. If the rate is set to two (2), it will be output every other navigation epoch. If the rate is zero, then the corresponding message will not be output. The rates of the output messages are individually configurable per communication interface. See the CFG-MSGOUT-* configuration group.

Some messages, such as UBX-MON-VER, are non-periodic and will only be 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 will not be output until the protocol is enabled for output on the interface. See [Communication interfaces and PIOs](#) [2] section for details.

2.1.1.5 GNSS signal configuration

The GNSS constellations are configurable with configuration keys. Each GNSS constellation can be enabled or disabled independently.

2.2 Communication interfaces and PIOs

The MAX-M10S supports communication over UART and I²C² interfaces for communication with a host CPU. Each protocol can be enabled on several interfaces at the same time with individual settings for, for example, baud rate, message rates, and so on. In MAX-M10S, several protocols can be enabled on a single interface the same time.

2.2.1 UART

The MAX-M10S supports a Universal Asynchronous Receiver/Transmitter (UART) port consisting of an RX and a TX line. UART can be used as a host interface which supports a configurable baud rate and protocol selection.

Neither handshaking signals nor hardware flow control signals are available in the UART interface. This serial interface operates in asynchronous mode. The baud rate can be configured for the serial interface. However, there is no support for setting a different baud rate for reception and transmission.

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

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

Table 4: Possible UART interface configurations

-  The default baud rate is 9600 baud. Using a low baud rate may cause buffering problems.

If the amount of data enabled is too much for a certain interface's bandwidth (for example baud rate of all UBX messages output is 9600 baud), the 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

² I²C is a registered trademark of Philips/NXP.

communication speed or the number of enabled messages should be carefully selected so that the expected number of bytes can be transmitted in less than one second.

2.2.2 I2C

The I2C protocol and electrical interface in MAX-M10S are fully compatible with the I2C industry standard fast mode. The interface allows communication with an external host CPU or u-blox cellular modules in slave mode, and with a maximum transfer rate of 400 kb/s.

-  The interface stretches the clock when the CPU is busy serving interrupts. The real bit rates may be slightly lower than the stated maximum transfer rate.

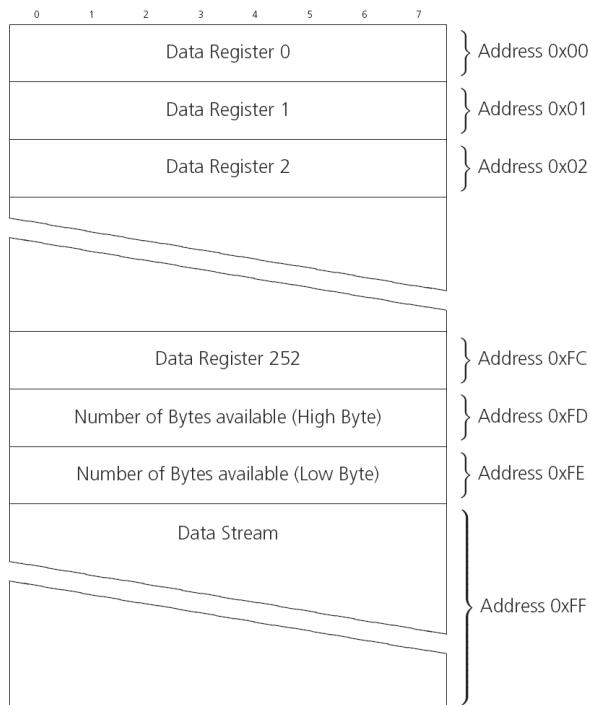
The SCL and SDA pins have internal pull-up resistors which should be sufficient for most applications. However, depending on the clock speed of the host and the capacitive load on the I2C lines, additional external pull-up resistors may be necessary. The higher the speed and the capacitance load, the lower the pull-up resistor needs to be.

Most of the u-blox receivers are configured by default with the same 7-bit address value (0x42). To poll or set the I2C slave address, use the CFG-I2C-ADDRESS configuration item (see u-blox M10 interface description [2]). The CFG-I2C-ADDRESS configuration item is an 8-bit value containing the I2C slave 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, the I2C slave address for each receiver must be configured to a different value.

2.2.2.1 I2C register layout

As shown in [Figure 3](#), 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.



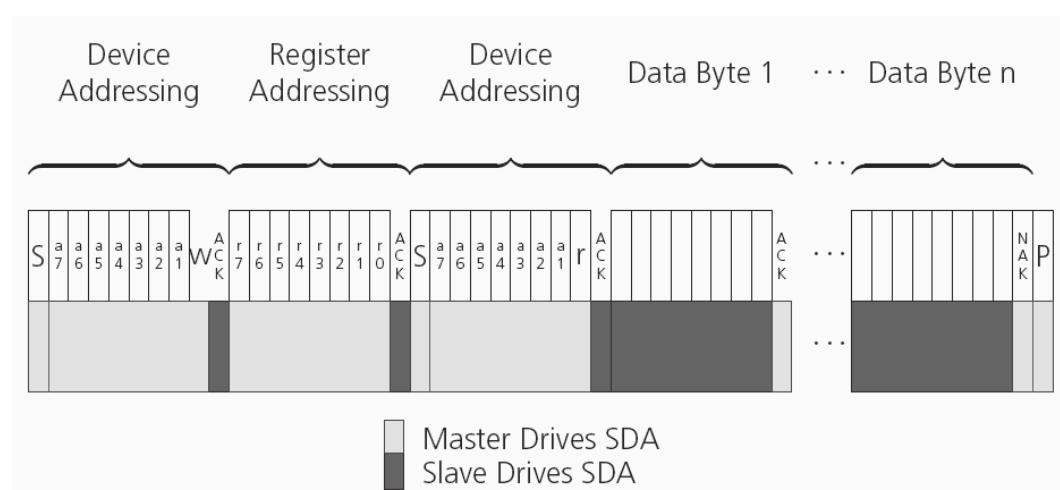


Figure 4: I2C random read access

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 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 reads will repeatedly read register 0xFF and receive the next byte of message data (or 0xFF value if no message data is waiting).

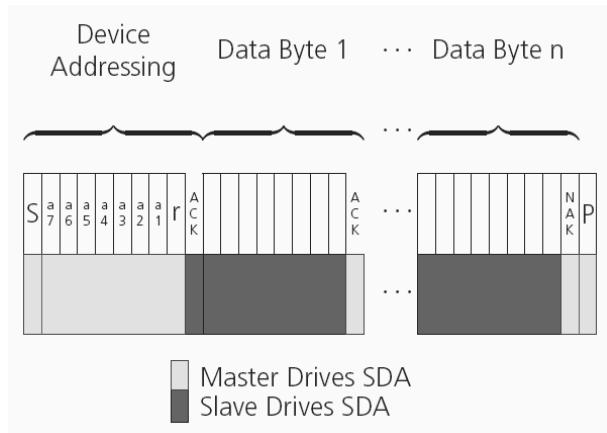


Figure 5: I2C current address read access

Only after addressing the slave, the receiver starts the data stream. If the master 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 (see MAX-M10S interface description [2]). 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.

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

The master 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.

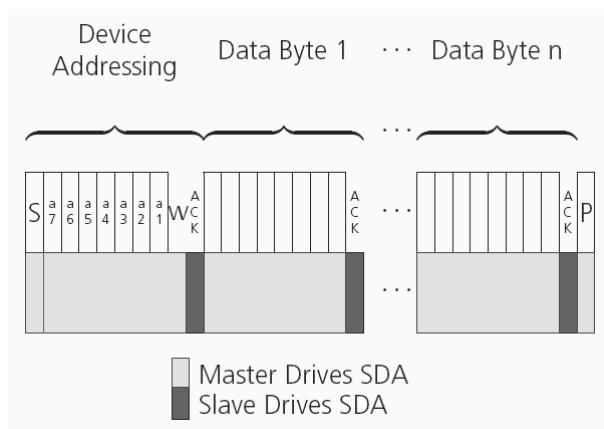


Figure 6: I2C write access

2.2.3 PIOs

This chapter describes the PIOs supported by the MAX-M10S. All the PIOs are supplied by V_IO. So all voltage levels of the PIOs are related to V_IO supply voltage. All the inputs have internal pull-up resistors in normal operation and can be left open if not used.

2.2.3.1 RESET_N

The MAX-M10S provides a RESET_N pin to reset the receiver. The RESET_N pin is an input-only pin with an internal pull-up resistor and should be left open for normal operation. Driving RESET_N low for at least 1 ms will trigger a reset of the receiver. The RESET_N complies with the 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, including Real-time clock (RTC) and GNSS orbit data in BBR, and triggers a cold start.
- ☞ No capacitor should be placed at RESET_N pin to GND, otherwise it could trigger a reset at every startup.

2.2.3.2 SAFEBOOT_N

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

- ☞ The SAFEBOOT_N pin has an internal 1 kΩ series resistor in front to prevent high current flow in case it is accidentally driven.

2.2.3.3 TIMEPULSE

The MAX-M10S features one time pulse signal in the TIMEPULSE pin. This can only be configured in PIO04.

- ☞ The TIMEPULSE pin is shared with SAFEBOOT_N pin. If this pin is low at the receiver start up, the receiver enters safeboot mode. In normal operation, this pin is used for time pulse. Make sure there is no load at this pin, which could cause the pin being low at startup.

2.2.3.4 LNA_EN

The system can turn an optional external LNA on and off using the LNA_EN signal to optimize the power consumption. The LNA_EN signal is also used to internally in MAX-M10S to control the integrated LNA. The LNA is turned on when LNA_EN is "high". The polarity cannot be changed.

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

2.2.3.5 EXTINT

The MAX-M10S supports one external interrupt pin named EXTINT. This is an external interrupt pin with fixed input voltage threshold with respect to V_IO. It can be used for functions such as accurate external frequency aiding, time mark aiding, wake up from power save mode, and ON/OFF control of the receiver.

The external frequency aiding can be used to calibrate the clock. This enables faster fix of satellite signals and can be used in normal operation as well as in production test. This EXTINT function is disabled by default and must be left open if unused. For more information on how to use this feature, see the MAX-M10S interface description [2].

-  If the EXTINT pin is configured for switching on/off the receiver, the internal pull-up becomes disabled. Make sure the EXTINT input is always driven within the defined voltage level by the host.

2.2.3.6 TX_READY

The MAX-M10S 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 associated signals to indicate that the buffer has bytes to be transmitted. The host application can wait on the signal instead of polling the interface. Each interface has its own indicator signal that can be assigned to any PIO/pin. Each signal is associated to one interface and cannot be shared.

The polarity of the signal (active-low or active-high) and the threshold for amount of bytes in the buffer can be configured with UBX-CFG-TXREADY configuration items. When the number of bytes in the buffer reaches the threshold, the corresponding 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.

If a PIO to be configured is invalid or already in use, the configuration for the TX_READY pin is ignored. The rest of the interface configuration is still applied if valid. The acknowledge message does not indicate if the TX_READY pin configuration was successfully set, it only indicates the successful configuration of the interface. To verify the configuration of the TX_READY pin, the interface configuration should be read back to check the setting of the TX_READY pin. The setting is set to disabled/all zero if the configuration failed.

The threshold when TX-ready signal is activated should not be set above 2 kB. Otherwise, it is possible that the internal message buffer gets full and some messages are discarded.

2.2.3.6.1 Extended TX timeout

If the host does not communicate over I2C for more than approximately 2 seconds, the device 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", in which case 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 polling data only when data is available, determined by the TX_READY pin becoming active.

2.3 Power management

2.3.1 Operating modes

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

2.3.1.1 Continuous mode

The MAX-M10S 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.

A lower current consumption will be achieved when a valid position is obtained quickly after 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 will take more time and consumes more power.

2.3.2 Backup modes

The MAX-M10S supports two backup modes: hardware backup mode and software standby mode.

In these backup modes, the receiver maintains the real-time clock (RTC) oscillator and the battery-backed RAM (BBR). The estimate of GNSS time maintained by the RTC oscillator and the navigation data maintained in the BBR speed up the receiver restart after backup or standby mode.

2.3.2.1 Hardware backup mode

The HW backup mode always requires an independent backup battery. The receiver automatically enters the HW backup mode if the VCC and V_IO are removed.

In this mode the V_BCKP is supplied within its supply range to provide power for BBR and RTC to allow better TTFF, accuracy, availability and power consumption at next startup. As no V_IO is supplied, the PIOs cannot be driven by external MCU. If driving of the PIOs cannot be avoided, buffers are required for isolating the PIOs.

2.3.2.2 Software standby mode

In SW standby mode, the VCC and V_IO are both supplied. Send a UBX-RXM-PMREQ configuration message to enter this mode. The message turns off the VCC supply inside the chip. The V_IO supply maintains the BBR, RTC and PIOs.

As V_IO is still supplied, the PIOs can be driven by an external host processor. No buffers are required for isolating the PIOs, which reduces costs. For more information on how to use this feature, see the interface description [2].



V_BCKP should be left open if not used.

2.4 Clocks and time

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

2.4.1 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 will initially indicate 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 will jump to an estimate of GNSS time.

2.4.2 GNSS time bases

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

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

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

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



The receiver allows users to independently choose GNSS signals used in the receiver (using CFG-SIGNAL-*) and the input/output time base (usingCFG-TP-*). For example it is possible

to instruct the receiver to use GPS and GLONASS satellite signals to generate BeiDou time. This practice will compromise time pulse accuracy if the receiver cannot measure the timing difference between the constellations directly and is therefore not recommended.

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

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

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

Table 5: GNSS time messages

2.4.3 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 will not be as stable as the atomic clocks to which GNSS systems are referenced and consequently clock bias will tend to accumulate. However, when selecting the next navigation epoch, the receiver will always try 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 will occasionally vary. This means that when producing one fix per second, there will normally be 1000 clock ticks between fixes, but sometimes, to correct drift away from GNSS system time, there will be 999 or 1001.

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

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

When insufficient information is available for the receiver to perform any of these time-base conversions precisely, pre-defined 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).

-  u-blox receivers employ multiple GNSS system times and/or receiver local times (in order to support multiple GNSS systems concurrently), so users should not use UBX messages reporting GNSS system time or receiver local time. It is recommended to use messages that report UTC time and other messages are retained only for backwards compatibility reasons.

2.4.4 iTow timestamps

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

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

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

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

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

-  `validDate` means that the receiver has knowledge of the current date. However, it must be noted that this date might be wrong for various reasons. Only when the `confirmedDate` flag is set, the probability of the incorrect date information drops significantly.
-  `validTime` means that the receiver has knowledge of the current time. However, it must be noted that this time might be wrong for various reasons. Only when the `confirmedTime` flag is set, the probability of incorrect time information drops significantly.
-  `fullyResolved` means that the UTC time is known without full seconds ambiguity. When deriving UTC time from GNSS time the number of leap seconds must be known, with the exception of GLONASS. It might take several minutes to obtain such information from the

GNSS payload. When the one second ambiguity has not been resolved, the time accuracy is usually in the range of ~20s.

2.4.6 UTC representation

UTC time is used in many NMEA and UBX messages. In NMEA messages it is always reported rounded to the nearest hundredth of a second. Consequently, 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) will have been rounded up. Therefore, some or all of them must be adjusted in order 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.

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

Which master clock the UTC time is referenced to is output in the message UBX-NAV-TIMEUTC.

The preferred variant of UTC time can be specified using CFG-NAVSPG-UTCSTANDARD configuration item.

2.4.7 Leap seconds

Due to the slightly uneven spin rate of the Earth, UTC time gradually moves out of alignment with the mean solar time (that is, the sun no longer appears directly overhead at 0 longitude at midday). Occasionally, a "leap second" is announced to bring UTC back into close alignment with the mean solar time. Usually this means adding an extra second to the last minute of the year, but this can also happen on 30th June. When this happens, UTC clocks are expected to go from 23:59:59 to 23:59:60, and only then on to 00:00:00.

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

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

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

2.4.8 Date ambiguity

All GNSS frequently transmit information about the current time within their data message. In most cases, this is a time of week (often abbreviated to TOW), which indicates the elapsed number of seconds since the start of the week (midnight Saturday/Sunday). In order to map this to a full date, it is necessary to know the week and so the GNSS also transmit a week number, typically every 30 seconds. Unfortunately the GPS L1C/A data message was designed in a way that only allows the bottom 10 bits of the week number to be transmitted. This is 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, GPS L1 receivers cannot tell the difference between, for example, 1980, 1999 or 2019 etc.

Fortunately, although BeiDou and Galileo have similar representations of time, they transmit sufficient bits for the week number to be unambiguous for the foreseeable future (the first ambiguity will be in 2078 for Galileo and not until 2163 for BeiDou). GLONASS has a different structure, based on a time of day, but again transmits sufficient information to avoid any ambiguity during the expected lifetime of the system (the first ambiguous date will be in 2124). Therefore, the receiver regards the date information transmitted by GLONASS, BeiDou and Galileo to be unambiguous and, where necessary, use this to resolve any ambiguity in the GPS date.

-  Customers attaching the receiver to simulators should be aware that GPS time is referenced to 6th January 1980, GLONASS to 1st January 1996, Galileo to 22nd August 1999 and BeiDou to 1st January 2006; the receiver cannot be expected to work reliably with signals simulated before these dates.

2.4.8.1 GPS-only date resolution

In circumstances where 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 a reference rollover week number. This reference rollover week number is hard-coded at compile time and is normally set a few weeks before the software is completed, but it can be overridden by CFG-NAVSPG-WKNROLLOVER configuration item to any value.

The following example illustrates how this works: Assume that the reference rollover week number set in the firmware at compile time is 1524 (which corresponds to a week in calendar year 2009, but would be transmitted by the satellites as 500). In this case, if the receiver sees transmissions containing week numbers in the range of 500 ... 1023, these will be interpreted as week numbers 1524 ... 2047 (calendar year 2009 ... 2019), whereas transmissions with week numbers from 0 to 499 are interpreted as week numbers 2048 ... 2547 (calendar year 2019 ... 2028).

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

2.5 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 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 7](#) below).

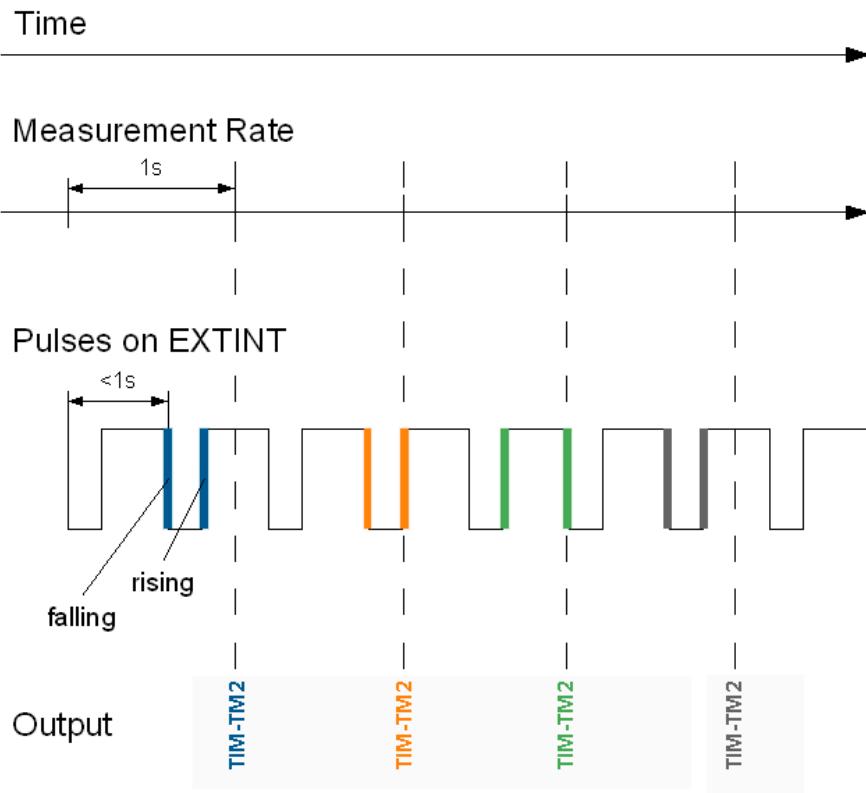


Figure 7: Time mark

2.6 Time pulse

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

Pulse Mode: Rising

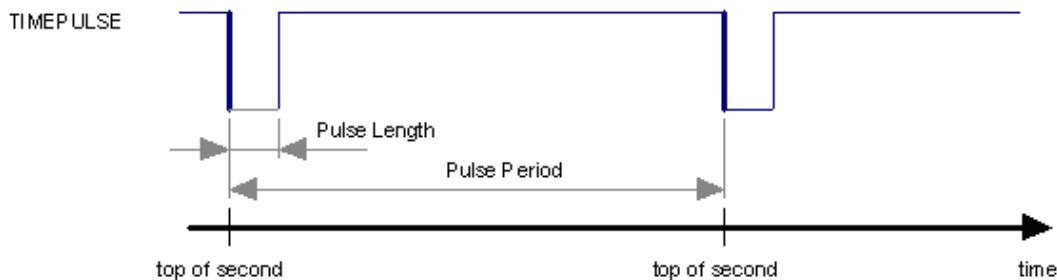
Pulse Mode: Falling


Figure 8: Time pulse

2.6.1 Recommendations

- The time pulse can be aligned to a wide variety of GNSS times or to variants of UTC derived from them (see the chapter time bases). However, it is strongly recommended that the choice of time base is aligned with the available GNSS signals (so 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). This will involve 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.

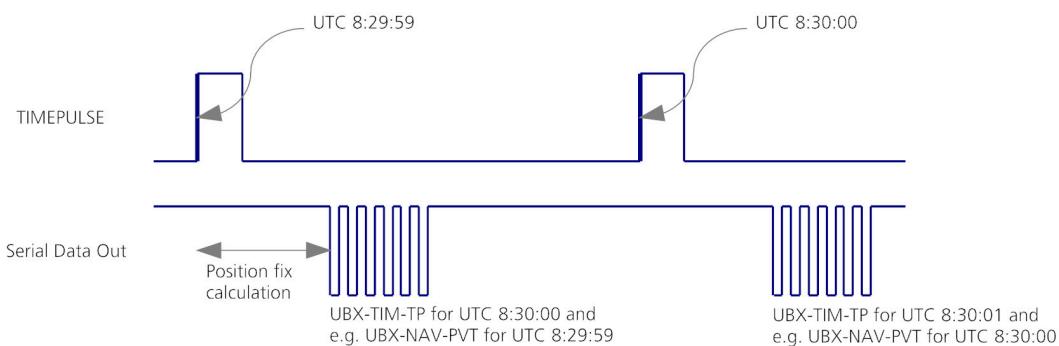


Figure 9: Time pulse and TIM-TP

2.6.2 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 will be 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) and (4) Galileo time grid. Also affects the time output by UBX-TIM-TP message.



The maximum pulse length cannot exceed the pulse period.

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

2.6.2.1 Example

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

- **CFG-TP-TP1_ENA = 1**
- **CFG-TP-PERIOD_TP1 = 1 000 000 µs**
- **CFG-TP-LEN_TP1 = 100 000 µs**
- **CFG-TP-TIMEGRID_TP1 = 1 (GPS)**
- **CFG-TP-PULSE_LENGTH_DEF = 0 (Period)**
- **CFG-TP-ALIGN_TO_TOW_TP1 = 1**
- **CFG-TP-USE_LOCKED_TP1 = 1**
- **CFG-TP-POL_TP1 = 1**
- **CFG-TP-PERIOD_LOCK_TP1 = 100 000 µs**
- **CFG-TP-LEN_LOCK_TP1 = 100 000 µs**

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.

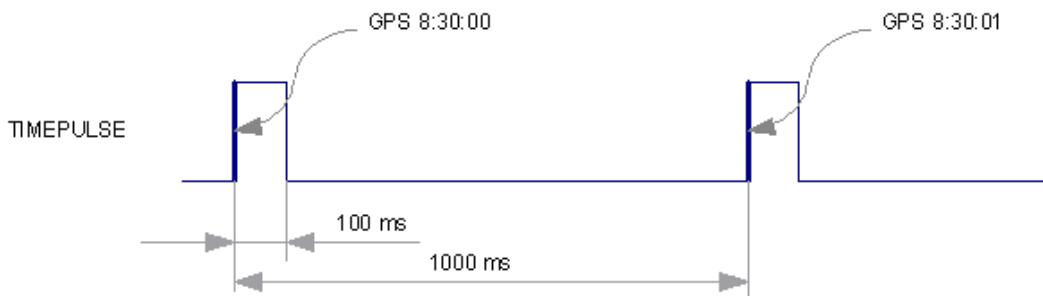


Figure 10: Time pulse signal with the example parameters

2.7 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 start-up performance.

2.7.1 Real-time clock

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

2.7.2 Time assistance

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

The current GNSS time can be supplied to the receiver as a coarse value via the standard communication interfaces. This method suffers from communication latency and unpredictable

delays so the accuracy of the supplied time is poor. Accuracy of the supplied time can be improved greatly if the host system has a very good sense of the current time and can deliver an exactly timed pulse to the EXTINT pin. This pulse informs the receiver when the supplied time assistance data is to be applied.

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

2.7.3 Frequency assistance

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

Frequency assistance can improve the cold start speed in crystal-based designs. For TCXO-based designs the frequency assistance has only minimal impact as the receiver is quick to acquire accurate frequency from satellite transmissions. A stable external reference frequency can be used to speed up receiver testing in production test setup. The host system may also be able to provide the reference frequency to improve the cold start speed.

2.7.4 Clock drift assistance

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

3 Hardware integration

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

3.1 Power supply

The MAX-M10S has up to three 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 must be connected together (see [Figure 11](#)).

Power supply at V_BCKP pin is optional. If present, it enables the hardware backup mode when the main supply is not present (see [Figure 12](#)).

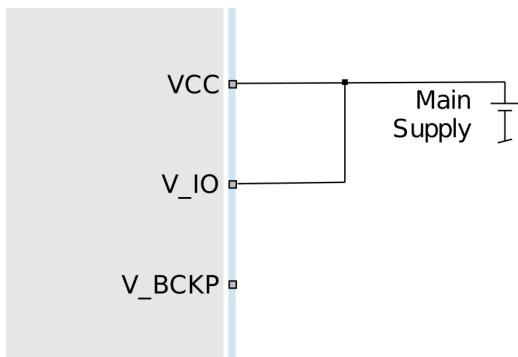


Figure 11: VCC and V_IO connected to the main supply. No external power supply at V_BCKP.

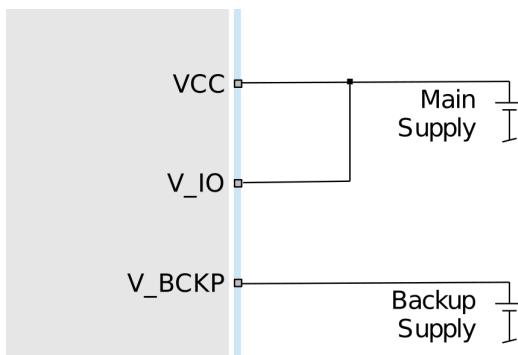


Figure 12: VCC and V_IO connected to the main supply, and external power supply at V_BCKP

3.1.1 VCC

VCC provides power to the core and RF domains. Consequently, it always needs to be supplied to start up the receiver or for operation in continuous mode. The VCC pin branches the power to an internal DCDC converter for reduced power consumption and to the RF domain through a ferrite bead.

During operation, the current drawn by the module may vary. For this reason, it is important that the supply circuitry is able to support the peak power for a short time. Refer to the MAX-M10S data sheet [\[1\]](#) for power requirements.

- ☞ VCC and V_IO must be connected together.
- ☞ Do not add series resistance greater than 0.2Ω on the supply line to avoid voltage ripple due to the dynamic current conditions.

- ☞ The output voltage at VCC_RF pin is derived from the VCC supply, and consequently, interrupted if VCC supply is removed.

3.1.2 V_IO

V_IO supplies all the digital IOs, clock, and the backup domain. The current drawn at V_IO also depends on the activity and loading of the PIOs plus the crystal or TCXO consumption.

A power interruption on this pin will erase the backup RAM memory unless there is an external supply connected to V_BCKP.

- ☞ V_IO and VCC must be connected together.
- ☞ Do not add series resistance greater than $0.2\ \Omega$ on the supply line to avoid voltage ripple due to the dynamic current conditions.

Refer to the MAX-M10S data sheet [1] for power requirements.

3.1.3 V_BCKP

A backup power supply can be connected to the V_BCKP pin to keep the backup RAM memory and the RTC alive in case of voltage interruption at V_IO pin.

The main benefits are the data preservation in the backup RAM and the quick position fix after restart, as it maintains the time in RTC and the GNSS orbit data in backup RAM. This ensures that any subsequent re-starts will provide a faster TTFF.

Maintaining the orbit data and RTC time by V_BCKP is called HW backup mode. Thus, if this mode is wanted, ensure the V_BCKP supply is an external backup supply, which is not affected in case of power interruption of the main supply.

The GNSS satellite ephemeris data is typically valid for up to 4 hours. To enable hot starts ensure that the battery or capacitor at V_BCKP is able to supply the backup current for at least 4 hours. For warm starts or when using the AssistNow Autonomous, where the time information has to be known at startup, the V_BCKP source must be able to supply current for up to a few days.

- ☞ 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 HW backup mode is not used, leave the V_BCKP pin open (see Figure 11).

3.2 RF front-end

GNSS receivers operate with very low signal levels, ranging from -130 dBm to approximately -167 dBm. This alone is a challenge for the GNSS application design. The out-of-band interferers 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-M10S RF front-end is designed for the highest sensitivity. The integrated RF circuit is matched to $50\ \Omega$ and includes a built-in DC block, an LTE Band 13 notch filter, an LNA, and an SAW filter. Refer to [Block diagram](#) for an overview of the RF front-end. The MAX-M10S offers the best GNSS performance for designs with low or moderate RF interference levels.

For designs with other radio systems, an external SAW filter may be required to improve the immunity against RF interference. The external SAW filter converts the MAX-M10S RF front-end into an SAW - Band 13 notch - LNA - SAW circuit for the highest immunity, complete with built-in

LTE Band 13 protection. The external SAW filter can be selected for an optimal trade-off between sensitivity and immunity.

3.2.1 Internal LNA modes

In addition to the LNA integrated in the RF front-end circuit in MAX-M10S, there is an internal LNA in the UBX-M10050-KB chip.

The internal LNA in the UBX-M10050-KB has three operating modes: normal gain, low gain and bypass mode.

- By default, the internal LNA is configured for the low-gain mode for optimized sensitivity and immunity against RF interference.
- For RF front-end designs with 10 - 15 dB or higher total external gain, the bypass mode is recommended to improve the immunity. The power consumption is also slightly reduced in the bypass mode.
- The normal-gain mode is not recommended for MAX-M10S.

The internal LNA mode can be configured at run time or set permanently in the one-time-programmable (OTP) memory in production. The configuration in OTP memory is automatically applied at every start-up. Refer to [Internal LNA mode configuration](#) for more information.

 Refer to MAX-M10S data sheet [1] for RF parameters and power consumption for the internal LNA modes.

3.2.2 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.

[Figure 13](#) shows a typical out-of-band immunity level for an unprotected MAX-M10S RF input. The internal LNA is in low-gain mode (default). The measurement is done at room temperature using a test signal with 64QAM modulation and 10 MHz bandwidth similar to an LTE signal.

In general, the immunity is lower close to the receiver's in-band. The narrow frequency bands with a lower immunity are related to the internal operation of the receiver. At 500 MHz and 800 MHz ranges, the reduced immunity is due to harmonic multiples generated at the integrated LNA input falling at the receiver's in-band. Adding an external SAW filter in front of the RF input protects the LNA suppressing the harmonic generation. The SAW filter also further improves the overall immunity of the design.

 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.

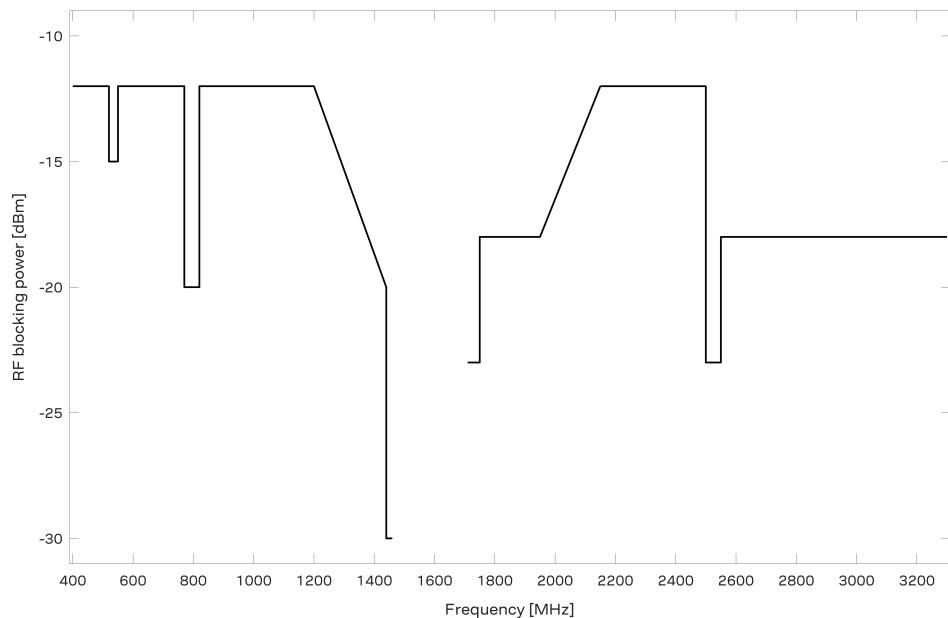


Figure 13: MAX-M10S out-of-band immunity level at 400 - 1460 MHz and 1710 - 3300 MHz for the low-gain mode (default). Preliminary data subject to change.

Table 6 shows tabulated values for out-of-band immunity at selected cellular and Wi-Fi frequencies.

Parameter	699	785	915	1710	1880	1980	2350	2440	2690
Frequency (MHz)	699	785	915	1710	1880	1980	2350	2440	2690
Immunity level (dBm)	-12	-20	-12	-23	-18	-18	-12	-12	-18

Table 6: MAX-M10S out-of-band immunity for the low-gain mode at selected frequencies. Preliminary data subject to change.

3.3 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 as short as possible, especially with passive antennas.

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.

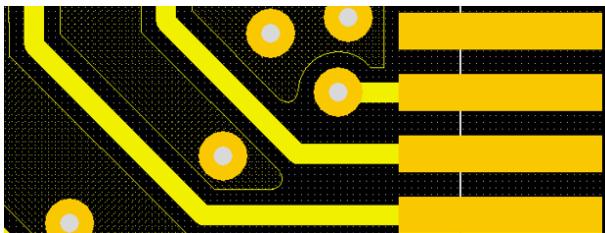


Figure 14: GND stub ended with a via

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 50Ω . Select accordingly the stack-up, copper, and dielectric properties of the PCB 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.

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

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

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

3.3.1 Package footprint, copper and solder mask

Figure 15 shows the dimensions of the MAX-M10S form factor.

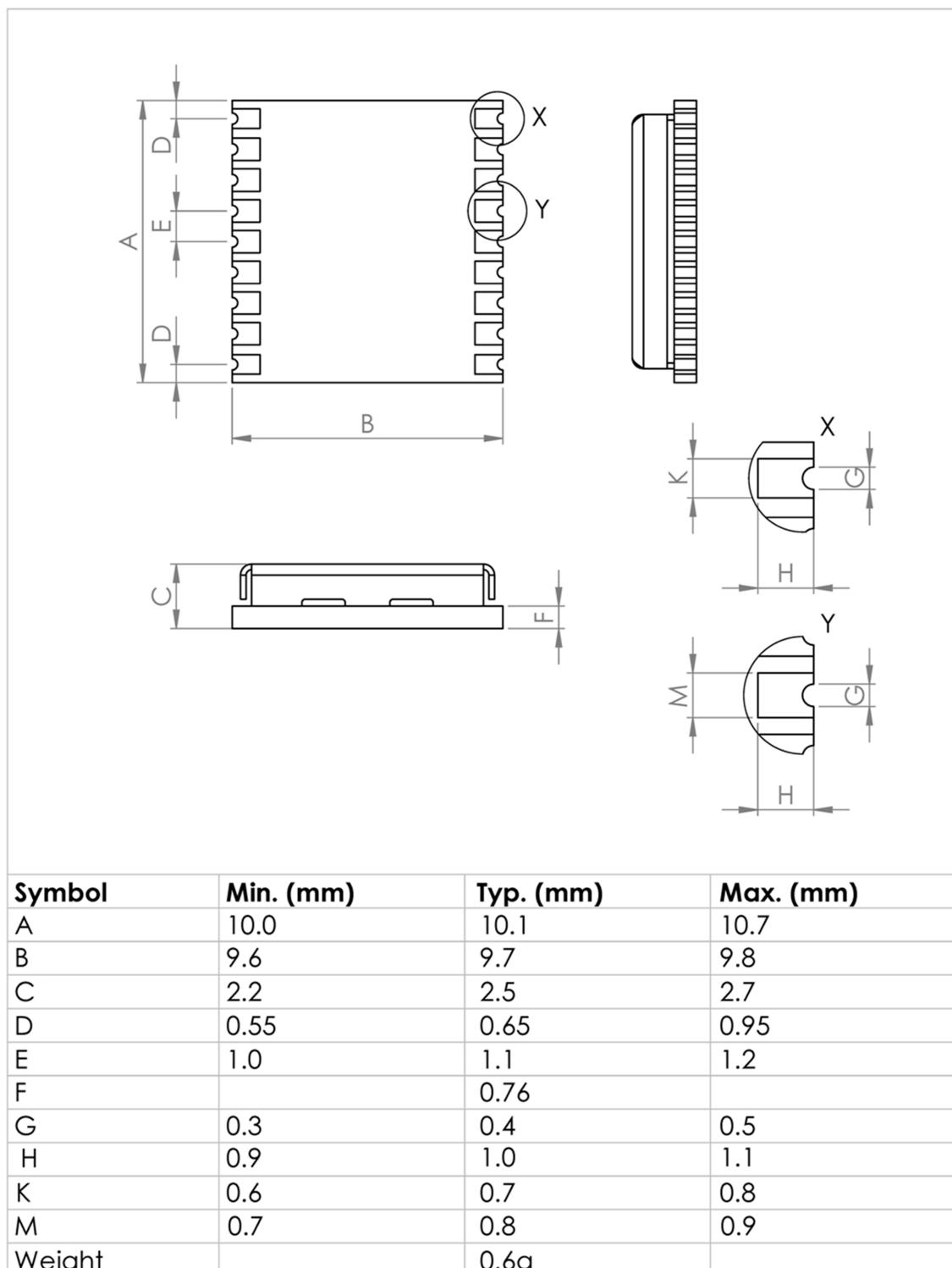


Figure 15: MAX-M10S mechanical dimensions

[Figure 16](#) and [Figure 17](#) describe the footprint and provide the recommendations for the paste mask. Note that the copper and solder masks have the same size and position.

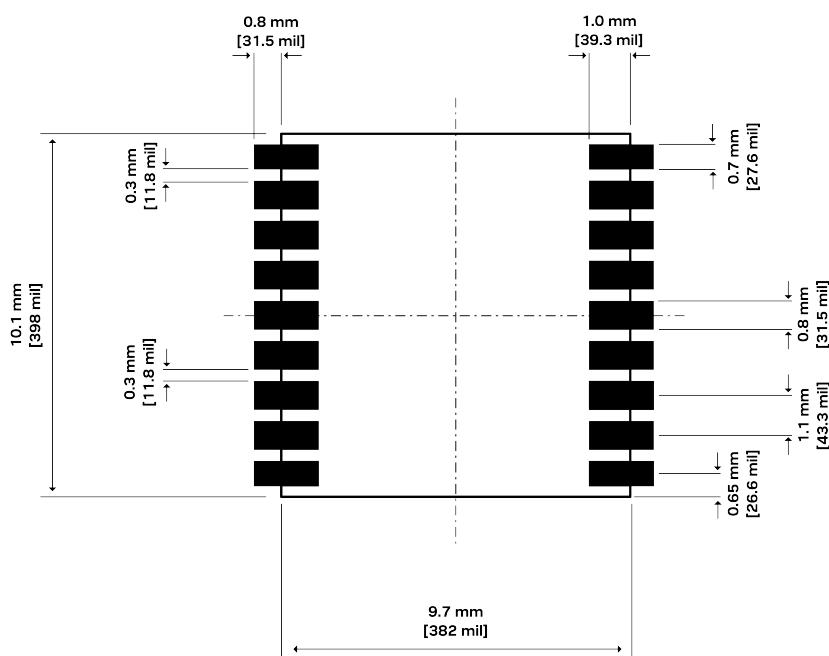


Figure 16: Recommended copper land and solder mask opening for MAX-M10S

MAX form factor (10.1 x 9.7 x 2.5) mm. All pins have 1.1 mm pitch and are 0.8 mm wide, except the 4 pads at each corner (pin 1, 9, 10 and 18) that are only 0.7 mm.

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.

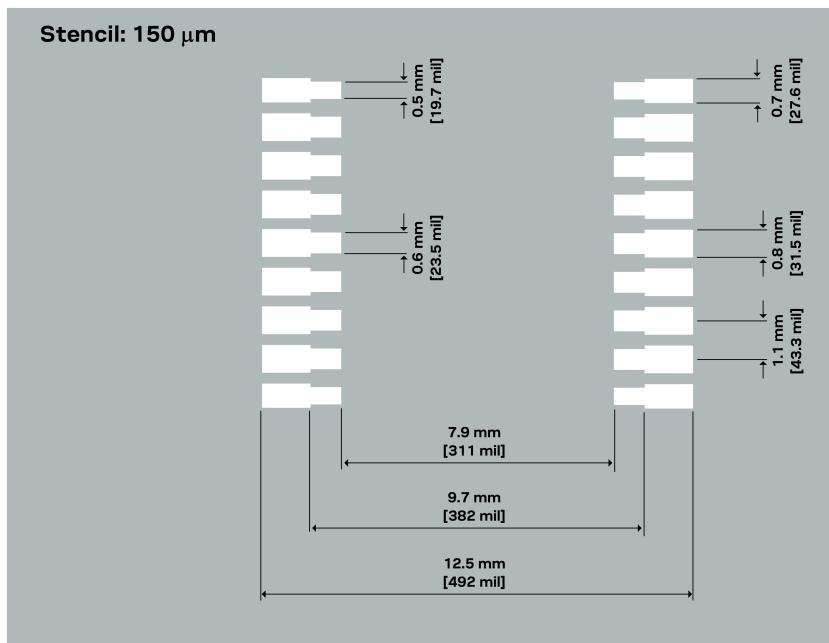


Figure 17: Recommended paste mask pattern for MAX-M10S

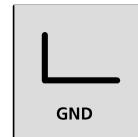
4 Product handling

4.1 Safety

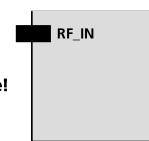
4.1.1 ESD precautions

 u-blox chips and modules contain highly sensitive electronic circuitry and are electrostatic sensitive devices (ESD). Observe precautions for handling! Failure to observe these precautions can result in severe damage to the GNSS receiver!

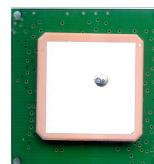
- Unless there is a galvanic coupling between the local GND (that is, the work desk) and the PCB GND, then the first point of contact when handling the PCB must always be between the local GND and PCB GND.
- Before mounting an antenna patch, connect ground of the device.



- When handling the RF pin, do not come into contact with any charged capacitors and be careful when contacting materials that can develop charges (for example, patch antenna ~10 pF, coax cable ~50-80 pF/m or soldering iron).



- To prevent electrostatic discharge through the RF input, do not touch any exposed antenna area. If there is any risk that such exposed antenna area is touched 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, make sure to use an ESD-safe soldering iron (tip).



4.1.2 Safety precautions

The MAX-M10S 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.

4.2 Packaging

The MAX-M10S receivers are delivered as hermetically sealed, reeled tapes in order to enable efficient production, production lot set-up and tear-down. For more information, see the u-blox package information reference [3].

4.2.1 Reels

MAX-M10S receivers are deliverable in quantities of 500 pieces on a reel. The modules are shipped on reel type B, as specified in the u-blox Packaging information reference [3].

4.2.2 Tapes

Figure 18 shows the feed direction and illustrates the orientation of the components on the tape.

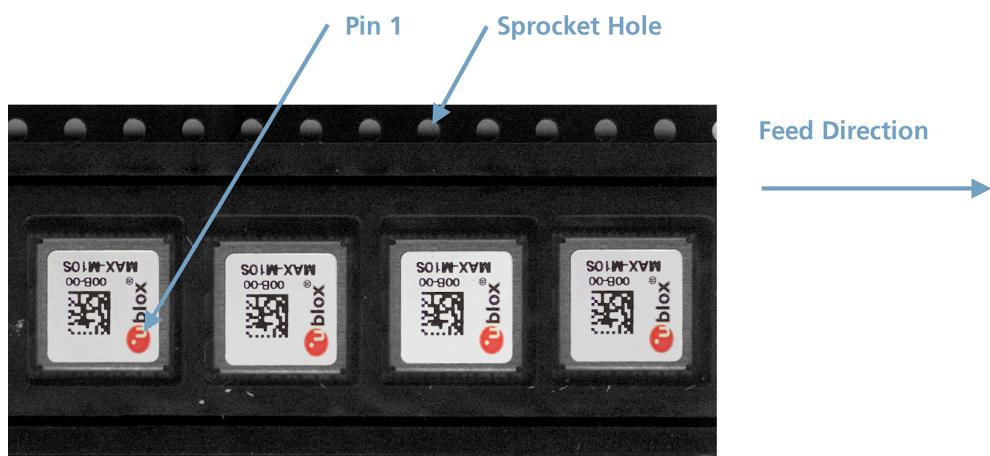
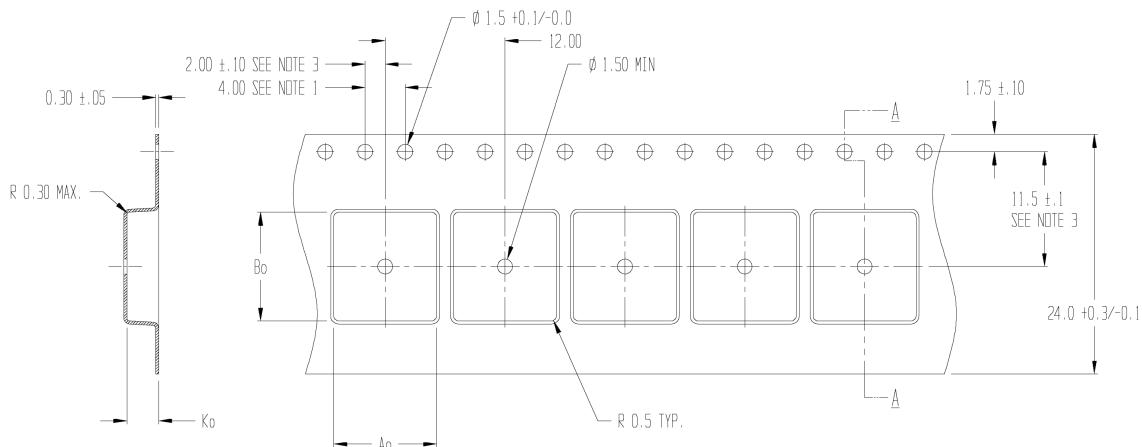


Figure 18: Orientation of the components on the tape

The pin 1 is indicated by the the u-blox logo on the module sticker. The feed direction into the pick and place pick-up is from the reel (located on the left of the figure) towards right, and the tape is feeded to the right.

The dimensions of the tape are specified in Figure 19 (measurements in mm).


SECTION A - A

$A_0 = 10.30$
 $B_0 = 10.90$
 $K_0 = 3.20$

Measurements in mm.

Tolerances unless noted: 1PI ± .2 2PI ± .10

Notes:

1. 10 sprocket hole pitch cumulative tolerance ± 0.2
2. Pocket position relative to sprocket hole measured as true position of pocket, not pocket hole.
3. A_0 and B_0 are calculated on a plane at a distance "R" above the bottom of the pocket.

Figure 19: Tape dimensions (mm)

4.2.3 Moisture sensitivity level

The moisture sensitivity level (MSL) for MAX-M10S modules is specified in the table below.

Package	MSL level
LLC (professional grade)	4

Table 7: MSL level

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

4.3 Soldering

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

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

Soldering paste

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

- Soldering paste: OM338 SAC405 / Nr.143714 (Cookson Electronics)
- Alloy specification: Sn 95.5/ Ag 4/ Cu 0.5 (95.5% tin/ 4% silver/ 0.5% copper)
- Melting temperature: 217 °C

- **Stencil:** The exact geometry, distances, stencil thicknesses and solder paste volumes must be adapted to the customer's specific production processes. See section [Package footprint, copper and solder mask](#) for details.

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.

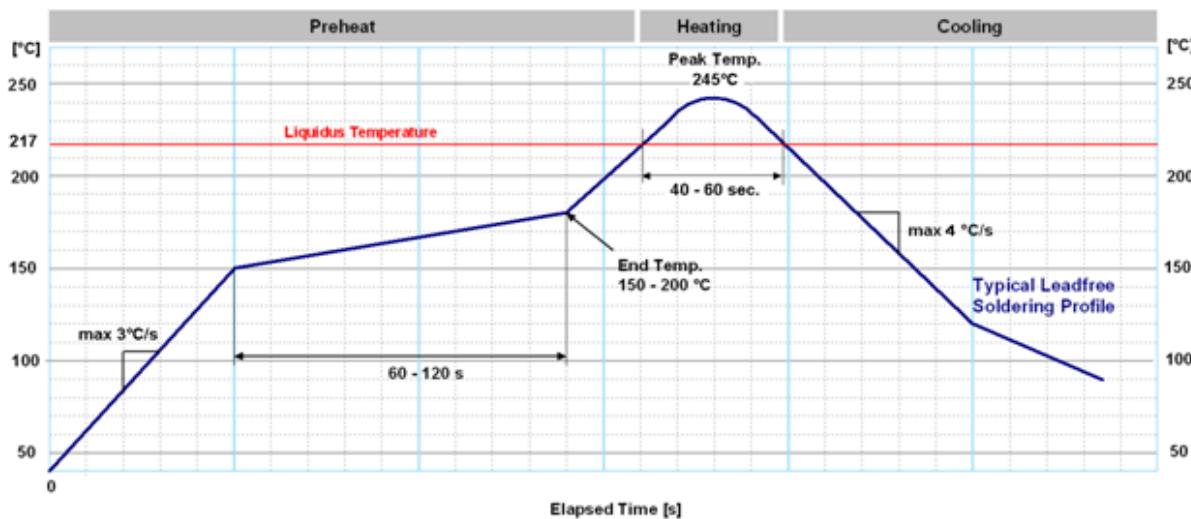


Figure 20: Soldering profile

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 re-work 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 re-applying 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 GNSS receiver.

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

Appendix

A Reference designs

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

A.1 Typical design

Here are some key features for a typical design with minimal external components:

- VCC and V_IO must be connected together to a single supply as shown in [Figure 21](#). Both hardware backup and software standby modes are supported.
- V_BCKP is optional and can be excluded from the design, but the hardware backup mode will no longer be available and BBR is not maintained. The EXTINT pin can be used for time aiding and the GNSS orbit data can be aided using AssistNow services or downloaded to the host and fed back to the receiver at startup.
- An external SAW filter can be added in front of RF_IN as shown in [Figure 22](#), which allows an SAW-LNA-SAW RF front-end circuit for improving out-of-band immunity against RF interference from other sources. This is especially useful when MAX-M10S is used in cellular applications.
- Passive or active antenna can be used. The active antenna can be supplied either with the VCC_RF output from MAX-M10S or from an external supply as shown in [Figure 23](#).
- 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.

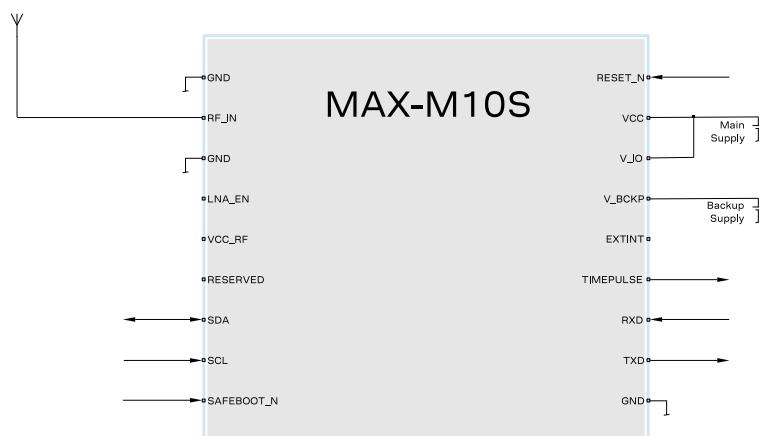


Figure 21: Typical MAX-M10S design

A.2 Antenna supervisor designs

Here are some key features for a 2-pin or 3-pin antenna supervisor design:

- VCC and V_IO must be connected together to a single supply and V_BCKP supply is applied separately, which allows the use of hardware backup and software standby modes.

- An external SAW filter can be placed on the RF path as shown in [Figure 22](#), which allows an SAW-LNA-SAW RF front-end circuit for improving out-of-band immunity against RF interference from other sources. This is especially useful when MAX-M10S is used in cellular applications.
- An active antenna can be supplied with the VCC_RF output from MAX-M10S or from an external supply. In addition, the active antenna supply can be turned on/off by the LNA_EN signal that controls the internal LNA of MAX-M10S.
- External open-drain buffers and operational amplifiers are also needed depending on if 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 the case of 3-pin antenna supervisor design as shown in [Figure 23](#).

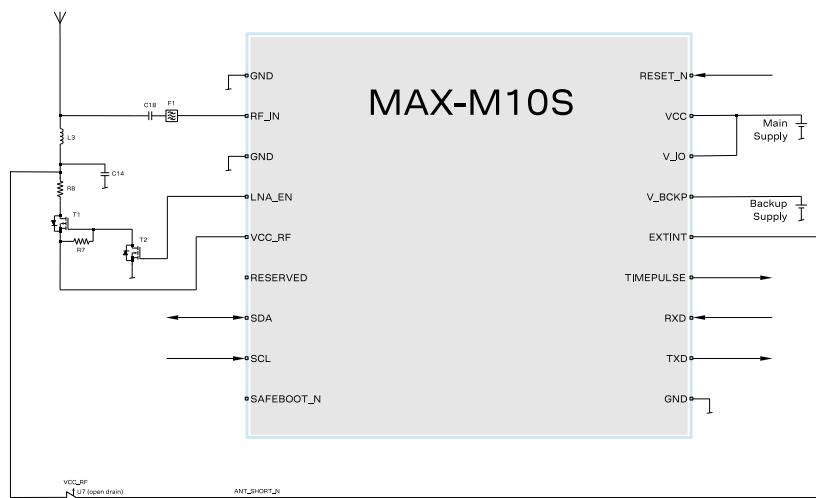


Figure 22: 2-pin antenna supervisor design

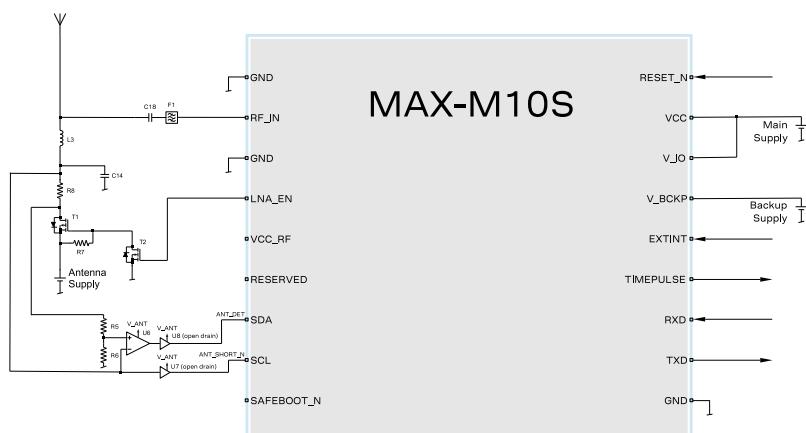


Figure 23: 3-pin antenna supervisor design

B External components

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

B.1 Standard capacitors

[Table 8](#) presents the recommended capacitor values for MAX-M10S.

Name	Use	Type / Value
C14	RF Bias-T capacitor	10 nF, 10%, 16 V, X7R
C18	DC block	47 pF, 5%, 25 V, COG

Table 8: Standard capacitors

B.2 Standard resistors

[Table 9](#) presents the recommended resistor values for MAX-M10S.

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

Table 9: Standard resistors

B.3 Inductors

[Table 10](#) presents the recommended inductor values for MAX-M10S.

Name	Use	Type / Value	Recommended component
L3	RF Bias-T inductor	27 nH, 5%	Murata LQG15H, LQW15A series Johanson Technology L-07W series Any other inductor with impedance >500 Ω at GNSS frequency and current rating above 300 mA.

Table 10: Recommended inductors

B.4 Operational amplifier

Name	Manufacturer	Order no.
U6	Linear Technology	LT6000, LT6003

Table 11: Recommended parts list for the operational amplifier

B.5 Open-drain buffers

Name	Manufacturer	Order no.
U7, U8	Fairchild	NC7WZ07P6X

Table 12: Recommended parts list for the open-drain buffers

B.6 Antenna supervisor switch transistors

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

Table 13: Recommended parts list for the antenna supervisor switch transistors

Related documents

- [1] MAX-M10S Data sheet, [UBX-20035208](#)
 - [2] u-blox M10 SPG 5.00 Interface description, [UBX-20053845](#)
 - [3] u-blox Packaging information reference, [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	Name	Status / comments
R01	29-Apr-2021	imar, jesk, mdur, msul, oola, rmak	Advance information

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