

Product name	Description	Version
ST-1612i-BT	Multi-constellation GNSS timing module (GPS, BEIDOU, GALILEO, QZSS), UART interface.	1.4
ST-1612i-GT	Multi-constellation GNSS timing module (GPS, GLONASS, GALILEO, QZSS), UART interface	
ST-1612i-BTs	Multi-constellation GNSS timing module (GPS, BEIDOU, GALILEO, QZSS), USB interface.	
ST-1612i-GTs	Multi-constellation GNSS timing module (GPS, GLONASS, GALILEO, QZSS), USB interface.	



1 Introduction

LOCOSYS ST-1612i-BT/ST-1612i-GT modules can simultaneously acquire and track multiple satellite constellations that include GPS, BEIDOU/GLONASS, GALILEO and QZSS. ST-1612i-BT/ST-1612i-GT feature accurate PPS for timing applications. It has T-RAIM algorithm and position hold auto survey mode. Besides, 1PPS output is available with only one visible satellite. Its precision GNSS timing is suitable for applications such as radio base stations, femtocell and smart grid.

2 Features

- Support GPS, BEIDOU/GLONASS, GALILEO, QZSS
- Capable of SBAS (WAAS, EGNOS, MSAS, GAGAN)
- 48 tracking channels and 2 fast acquisition channels
- T-RAIM provides high PPS integrity
- 15 ns 1 σ PPS accuracy with 3.9 ns CDF 50%
- Position hold auto survey mode
- IATF 16949 quality control
- Small form factor 16 x 12.2 x 2.4 mm
- SMD type, RoHS compliant

3 Application

- 5G Femtocell · Microcell · Smallcell
- Financial network
- High Speed Router
- Traffic Control System
- Energy Control System
- Data Network Center
- Video Surveillance System
- Smart Grid System
- Industrial Computer

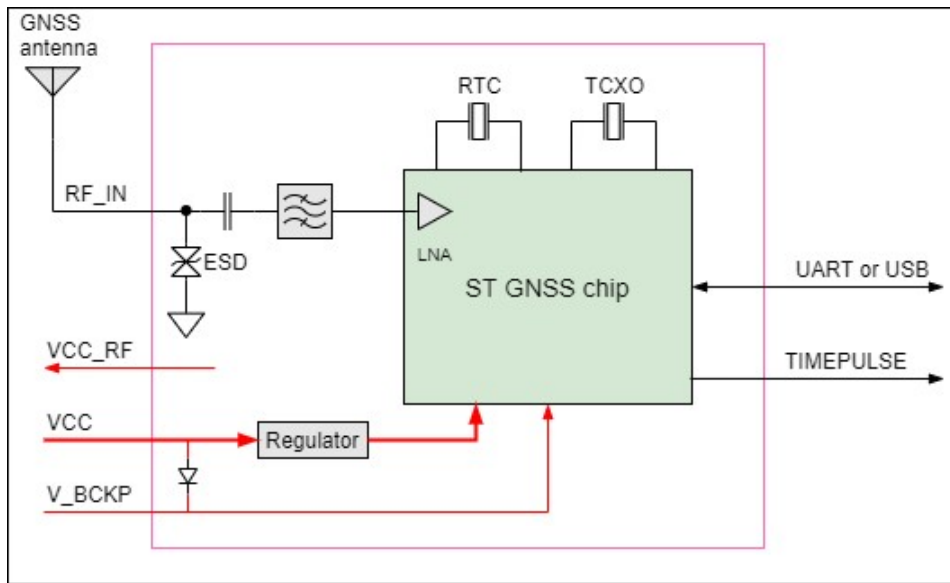


Fig 3-1 System block diagram.

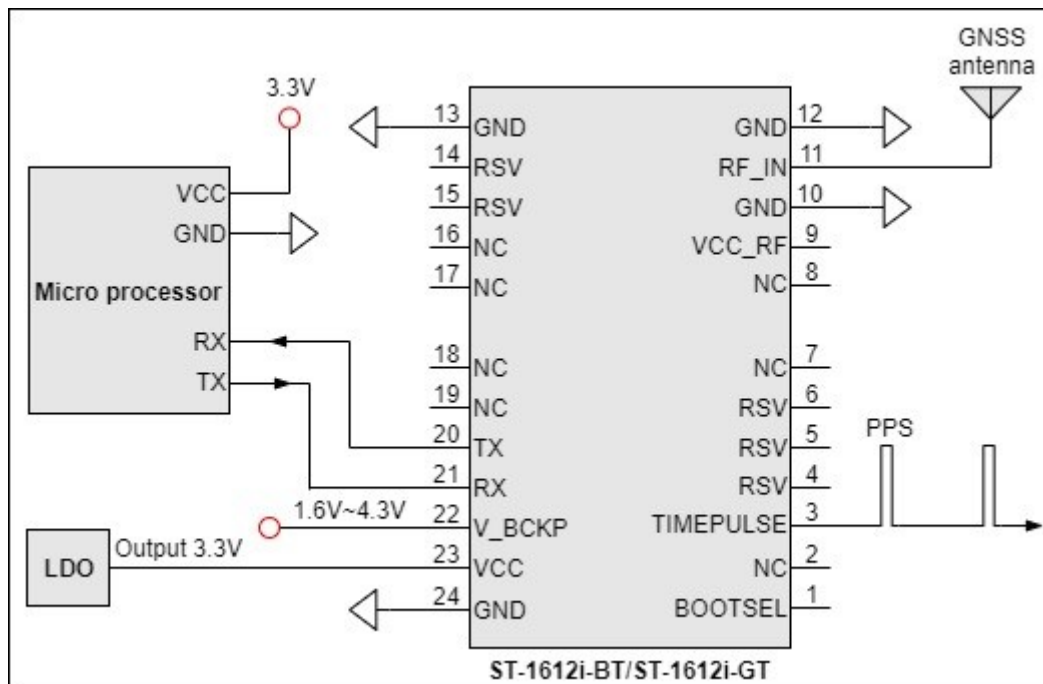


Fig 3-2 Typical application circuit that uses a passive antenna.

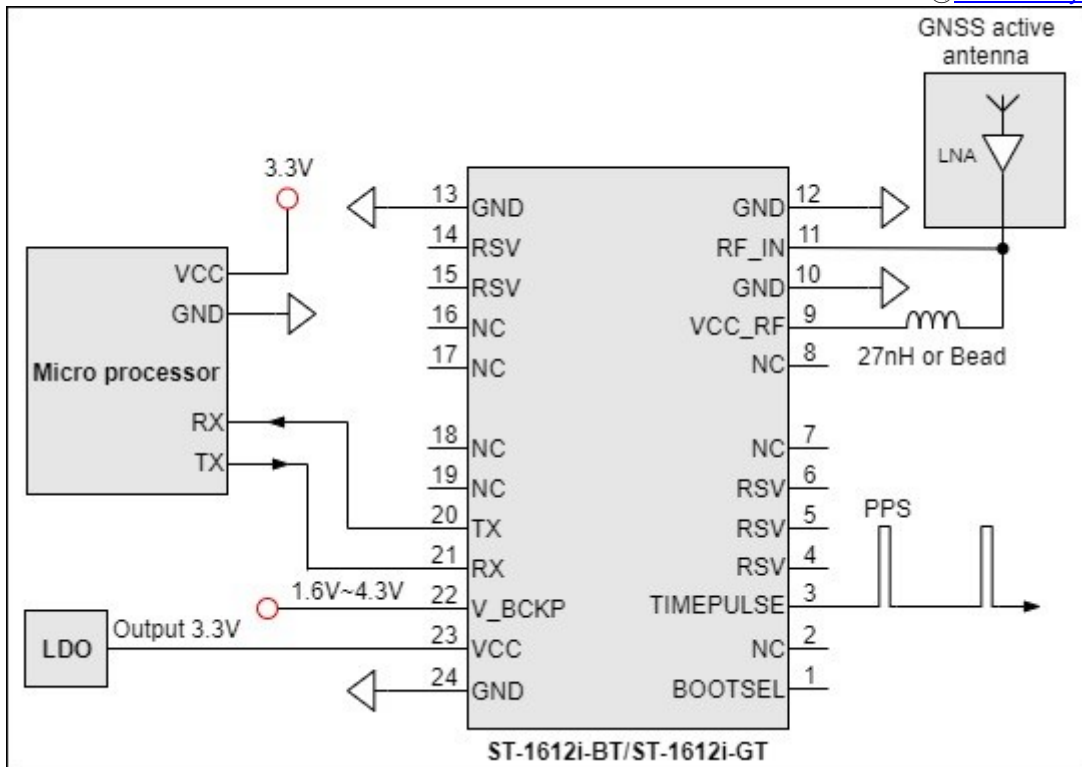


Fig 3-3 Typical application circuit that uses an active antenna.

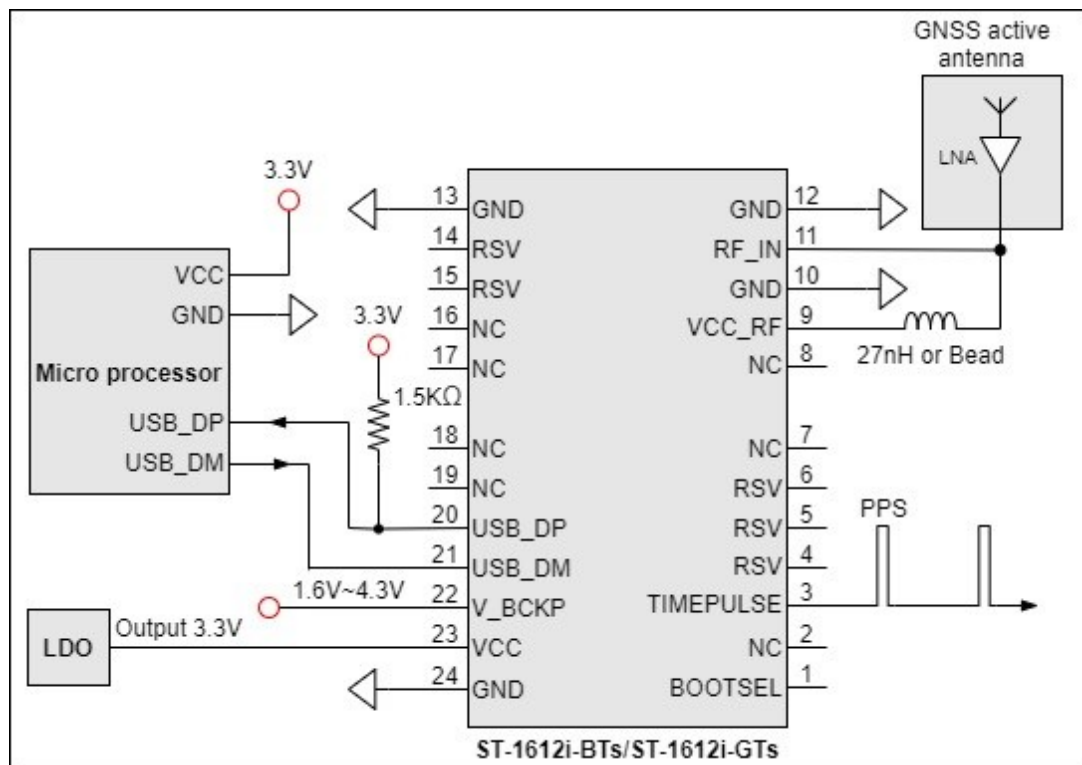


Fig 3-4 Typical application circuit that uses USB interface.

4 GNSS receiver

4.1 GNSS receiver

Chip	Teseo III series	
Frequency	GPS: L1C/A (1575.42MHz) BEIDOU: B1 (1561.098MHz) GLONASS L1OF (1598.0625MHz ~ 1605.375MHz) GALILEO: E1B/C (1575.42MHz) QZSS: L1C/A (1575.42MHz)	
Channels	Support 48 channels	
Update rate	1Hz default, up to 5Hz.	
Sensitivity	Tracking	up to -161dBm (with external LNA)
	Cold start	up to -146.5dBm (with external LNA)
Acquisition Time	Cold Start (Open Sky)	32s (typical)
	Hot Start (Open Sky)	< 2s (typical)
Position Accuracy	Autonomous	1.8m CEP
	SBAS	1.5m CEP (depends on accuracy of correction data).
Max. Altitude	< 18,000 m	
Max. Velocity	< 515 m/s	
Protocol Support	NMEA 0183 ver. 3.01	38400 bps ^(1, 2) , 8 data bits, no parity, 1 stop bits (default) 1Hz: GGA, GSA, GSV, RMC 1Hz: \$PSTMPPSDATA, \$PSTMPOSHOLD

Note 1: Both baud rate and output message rate are configurable to be factory default.

Note 2: For USB interface, it is a virtual COM. USB driver of MS Windows and Linux is supported.

4.2 Timing performance

PPS accuracy	Cumulative Distribution Function ⁽¹⁾	Temperature	50% CEP	RMS	99%
		Room temperature	3.9 ns	4.7 ns	10 ns
		-40°C	3.9 ns	4.7 ns	10 ns
		85°C	4.2 ns	5.5 ns	13 ns

Note 1: Tested at 25°C, -40°C and 85°C.

Note 2: PPS accuracy Synchronized to UTC or GPS 15 ns 1σ.

5 Software interface

5.1 NMEA output message

Table 5.1-1 NMEA output message

NMEA record	Description
GGA	Global positioning system fixed data
GSA	GNSS DOP and active satellites
GSV	GNSS satellites in view
RMC	Recommended minimum specific GNSS data

● GGA--- Global Positioning System Fixed Data

Table 5.1-2 contains the values for the following example:

\$GPGGA,051951.000,2503.71325,N,12138.74397,E,2,30,0.6,113.69,M,15.3,M,*,*69

Table 5.1-2 GGA Data Format

Name	Example	Units	Description
Message ID	\$GPGGA		GGA protocol header
UTC Time	051951.000		hhmmss.sss
Latitude	2503.71325		ddmm.mmmmm
N/S indicator	N		N=north or S=south
Longitude	12138.74397		dddmm.mmmmm
E/W Indicator	E		E=east or W=west
Position Fix Indicator	2		See Table 5.1-3
Satellites Used	30		Satellites in use
HDOP	0.6		Horizontal Dilution of Precision
MSL Altitude	113.69	meters	Height above mean sea level, max: 100000.0 m
Units	M	meters	Unit for MSL Altitude
Geoid Separation	15.3	meters	Geoidal separation measure in "M" = meters
Units	M	meters	
Age of Diff. Corr.		second	Null. Not supported.
Diff. Ref. Station ID			Null. Not supported.
Checksum	*69		
<CR> <LF>			End of message termination

Table 5.1-3 Position Fix Indicators

Value	Description
0	Fix not available or invalid
1	GPS SPS Mode, fix valid
2	Differential GPS, SPS Mode, fix valid
3-5	Not supported

6	Dead Reckoning Mode, fix valid
---	--------------------------------

● GSA---GNSS DOP and Active Satellites

Table 5.1-4 contains the values for the following example:

```
$GNGSA,A,3,09,19,02,05,06,17,12,,,,,1.2,0.6,1.0*2D
$GNGSA,A,3,195,199,193,,,,,,1.2,0.6,1.0*1F
$GNGSA,A,3,307,308,313,315,326,,,,,,1.2,0.6,1.0*16
$GNGSA,A,3,173,141,142,143,144,146,148,150,151,153,154,156,1.2,0.6,1.0*23
$GNGSA,A,3,161,174,152,,,,,,1.2,0.6,1.0*1A
```

Table 5.1-4 GSA Data Format

Name	Example	Units	Description
Message ID	\$GNGSA		GSA protocol header
Mode 1	A		See Table 5.1-5
Mode 2	3		See Table 5.1-6
ID of satellite used	09		Sv on Channel 1
ID of satellite used	19		Sv on Channel 2
....		
ID of satellite used			Sv on Channel 12
PDOP	1.2		Position Dilution of Precision
HDOP	0.6		Horizontal Dilution of Precision
VDOP	1.0		Vertical Dilution of Precision
Checksum	*23		
<CR> <LF>			End of message termination

Table 5.1-5 Mode 1

Value	Description
M	Manual- forced to operate in 2D or 3D mode
A	Automatic-allowed to automatically switch 2D/3D

Table 5.1-6 Mode 2

Value	Description
1	Fix not available
2	2D
3	3D

● GSV---GNSS Satellites in View

Table 5.1-7 contains the values for the following example:

```
$GPGSV,3,1,10,19,53,141,47,06,48,048,46,05,47,266,46,02,45,335,47*74
$GPGSV,3,2,10,17,37,145,47,09,29,052,41,12,26,272,41,13,15,190,*73
```

```
$GPGSV,3,3,10,42,54,141,41,50,51,134,42,,,,,,*7F
$QZGSV,1,1,03,193,75,062,47,195,65,146,47,199,60,167,42,,,,*67
$GAGSV,2,1,05,313,62,027,48,307,61,190,45,308,57,054,46,315,32,100,42*63
$GAGSV,2,2,05,326,28,322,41,,,,,,*66
$BDGSV,4,1,15,154,80,293,48,174,75,096,51,151,69,352,50,143,59,206,45*6A
$BDGSV,4,2,15,148,54,012,46,141,54,141,46,153,46,335,47,146,47,178,44*69
$BDGSV,4,3,15,156,43,183,45,161,40,035,47,142,40,243,42,144,39,117,42*68
$BDGSV,4,4,15,173,27,231,43,150,23,220,40,152,23,129,40,,,,*63
```

Table 5.1-7 GSV Data Format

Name	Example	Units	Description
Message ID	\$GPGSV		GSV protocol header
Total number of messages ¹	3		Range 1 to 8
Message number ¹	1		Range 1 to 8
Satellites in view	10		
Satellite ID	19		Channel 1 (Range 01 to 196)
Elevation	53	degrees	Channel 1 (Range 00 to 90)
Azimuth	141	degrees	Channel 1 (Range 000 to 359)
SNR (C/No)	47	dB-Hz	Channel 1 (Range 00 to 99, null when not tracking)
....			
Satellite ID	02		Channel 4 (Range 01 to 32)
Elevation	45	degrees	Channel 4 (Range 00 to 90)
Azimuth	335	degrees	Channel 4 (Range 000 to 359)
SNR (C/No)	47	dB-Hz	Channel 4 (Range 00 to 99, null when not tracking)
Checksum	*74		
<CR> <LF>			End of message termination

Note 1: Depending on the number of satellites tracked multiple messages of GSV data may be required.

● RMC---Recommended Minimum Specific GNSS Data

Table 5.1-8 contains the values for the following example:

```
$GPRMC,051951.000,A,2503.71325,N,12138.74397,E,0.0,0.0,260819,,,D*67
```

Table 5.1-8 RMC Data Format

Name	Example	Units	Description
Message ID	\$GPRMC		RMC protocol header
UTC Time	051951.000		hhmmss.sss
Status	A		A=data valid or V=data not valid
Latitude	2503.71325		ddmm.mmmmm
N/S Indicator	N		N=north or S=south

Longitude	12138.74397		dddmm.mmmmm
E/W Indicator	E		E=east or W=west
Speed over ground	0.0	knots	True
Course over ground	0.0	degrees	
Date	260819		ddmmyy
Magnetic variation		degrees	
Variation sense			E=east or W=west (Not shown)
Mode	D		A=autonomous, D=DGPS, E=DR, N=Data not valid, R=Coarse Position, S=Simulator
Checksum	*67		
<CR> <LF>			End of message termination

5.2 Proprietary NMEA output message

Table 5.2-1 Proprietary NMEA output message

NMEA record	Description
PSTMPPSDATA	Reports the Pulse Per Second data
PSTMPOSHOLD	Reports the Position Hold status and position

● PSTMPPSDATA--- Reports the Pulse Per Second data

Table 5.2-2 contains the values for the following example:

\$PSTMPPSDATA,1,1,1,0,0,0,0.100000,0.633,420,420.633,0,1,1,10,0,38,3,6,18,2,0,0,7.040e-09,65473905.37,25999978.97,4*16

Table 5.2- 2 PSTMPPSDATA Data Format

Name	Example	Units	Description
Message ID	\$PSTMPPSDATA		PSTMPPSDATA protocol header
On_off	1		PPS signal ON/OFF status 0: OFF 1: ON
PPS_valid	1		Global PPS validity flag 0: PPS not valid 1: PPS valid
Synch_valid	1		PPS synchronization validity 0: Not valid 1: valid
Out_mode	0		0 = PPS_OUT_MODE_ALWAYS 1 = PPS_OUT_MODE_ON_EVEN_SECONDS 2 = PPS_OUT_MODE_ON_ODD_SECONDS
Ref_time	0		0 = UTC

			<p>1 = GPS.UTC (GPS Time)</p> <p>2 = GLONASS.UTC (GLONASS Time)</p> <p>3 = UTC_SU</p> <p>4 = GPS.UTC_FROM_GLONASS</p> <p>NOTES:</p> <p>UTC(SU) is the Soviet Union UTC, it is derived from GLONASS time applying the UTC delta time downloaded from GLONASS satellites.</p> <p>GPS.UTC_FROM_GLONASS is the GPS time derived from GLONASS time applying the GPS delta time downloaded from GLONASS satellites.</p> <p>If the software is configured to work in GLONASS only mode, UTC(SU) is identical to UTC and GPS.UTC_FROM_GLONASS is identical to GPS.UTC.</p>
Ref_constellation	0		<p>0 = GPS</p> <p>1 = GLONASS</p> <p>7 = BEIDOU</p> <p>NOTE: the reference constellation reports which reference time has been used for the PPS generation.</p>
Pulse_duration	0.100000	second	Pulse duration (s)
Pulse_delay	0	ns	Pulse delay (ns)
GPS_delay	633	ns	GPS path RF delay (ns)
GLO_delay	420	ns	GLONASS path RF delay (ns)
BEI_delay	420	ns	<p>BEIDOU path RF delay (ns)</p> <p>Note: this parameter is always zero if Beidou constellation is not supported by the hardware platform.</p>
GAL_delay	633	ns	GALILEO path RF delay (ns)
Inverted_polarity	0		<p>Pulse polarity inversion:</p> <p>0 = not inverted</p> <p>1 = inverted</p>
Fix_cond	1		<p>Selected GNSS fix condition for PPS signal generation:</p> <p>1 = NO_FIX</p> <p>2 = 2D_FIX</p> <p>3 = 3D_FIX</p>
Sat_th	1		Selected minimum number of satellites for PPS signal generation.
Elev_mask	10		Selected minimum satellite elevation for time correction.
Const_mask	0		Selected constellations for time correction.

Ref_sec	38		Second at which the reported PPS data is applied. According to the reference time configuration it could be a UTC or a GPS or a GLONASS or a BEIDOU time second.
Fix_status	3		GNSS position fix status when the time has been corrected. 1 = NO_FIX 2 = 2D_FIX 3 = 3D_FIX
Used_sats	6		Used satellites for time correction.
GPS_utc_delta_s	18	second	UTC leap seconds (s)
GPS_utc_delta_ns	2	ns	UTC – GPS delta time (ns)
GLONASS_utc_delta_ns	0	ns	UTC – GLONASS delta time (ns)
GALILEO_utc_delta_ns	0	ns	UTC-GALILEO delta time (ns)
Quantization_error	7.040e-09	second	Quantization error (s)
PPS_clock_freq	65473905.37	Hz	PPS clock frequency (Hz)
TCXO_clock_freq	25999978.97	Hz	TCXO clock frequency (Hz)
Checksum	*16		
<CR> <LF>			End of message termination

● **PSTMPOSHOLD--- Reports the Position Hold status and position**

Table 5.2-3 contains the values for the following example:

\$PSTMPOSHOLD,1,2503.71236,N,12138.74569,E,120.19*43

Table 5.2- 3 PSTMPOSHOLD Data Format

Name	Example	Units	Description
Message ID	\$PSTMPOSHOLD		PSTMPPSDATA protocol header
On_off	1		Position Hold enabling/disabling status 0: disabled 1: enabled
Latitude	2503.71236		ddmm.mmmmm
N/S Indicator	N		N=north or S=south
Longitude	12138.74569		dddmm.mmmmm
E/W Indicator	E		E=east or W=west
Alt	120.19	meter	Height above mean sea level. (maximum 100,000)
Checksum	*43		
<CR> <LF>			End of message termination

5.3 Proprietary NMEA commands

Proprietary NMEA commands work until next system startup. All settings described in the section can be configured as factory default. Please contact us for your settings.

5.3.1 \$PSTMENABLEPOSITIONHOLD

Enable/disable and set position for the Position Hold feature.

Synopsis:

```
$PSTMENABLEPOSITIONHOLD,<on_off>,<Lat>,<LatRef>,<Lon>,<LonRef>,<Alt><cr><lf>
```

Arguments:

Parameter	Format	Description
on_off	Decimal, 1 digit	Set the position hold enable/disable status: 0: disabled. 1: enabled.
Lat	DDMM.MMMMM	Latitude (Degree-Minute.Minute decimals)
LatRef	'N' or 'S'	Latitude direction (North or South)
Lon	DDDMM.MMMMM	Longitude (Degree-Minute.Minute decimals)
LonRef	'E' or 'W'	Longitude Direction (East or West)
Alt	Dddddd.dddd	Mean sea level altitude in meters (-1500 to 100000).

Results:

- If success, the following message is sent:

If on_off = 1

```
$PSTMPOSITIONHOLDENABLED*<checksum><cr><lf>
```

If on_off = 0

```
$PSTMPOSITIONHOLDDISABLED*<checksum><cr><lf>
```

- In case of error, the following message will be sent:

```
$PSTMENABLEPOSITIONHOLDERROR*<checksum><cr><lf>
```

Examples:

```
$PSTMENABLEPOSITIONHOLD,1,4811.365,N,01164.123,E,0530.0
```

5.3.2 \$PSTMSETCONSTMASK

Set the GNSS constellation mask. It allows switching the GNSS constellation at run-time. In case of reset, constellation mask is restored to default value.

Synopsis:

```
$PSTMSETCONSTMASK,<constellation_mask><cr><lf>
```

Arguments:

Parameter	Format	Description
-----------	--------	-------------

constellation_mask	Decimal, 1-9999	It is a bit mask where each bit enable/disable a specific constellation independently by the others: bit 0: GPS constellation enabling/disabling bit 1: GLONASS constellation enabling/disabling bit 2: QZSS constellation enabling/disabling bit 3: GALILEO constellation enabling/disabling bit 7: BEIDOU constellation enabling/disabling
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Results:

- If success, the following message is sent:

```
$PSTMSETCONSTMASKOK,<constellation_mask>*<checksum><cr><lf>
```

- In case of error, the following message will be sent:

```
$PSTMSETCONSTMASKERROR*<checksum><cr><lf>
```

Examples:

- Enabling GPS only:

```
$PSTMSETCONSTMASK,1*14
```

- Enabling GLONASS only:

```
$PSTMSETCONSTMASK,2*17
```

- Enabling GPS and GLONASS:

```
$PSTMSETCONSTMASK,3*16
```

5.3.3 \$PSTMPPS

Allow interfacing all parameters for Pulse Per Second management. This is a parametric command.

Synopsis:

```
$PSTMPPS,<cmd_mode>,<cmd_type>,<par_1>,...,<par_N><cr><lf>
```

Arguments:

Parameter	Format	Description
cmd_mode	Decimal, 1 digit	Select the command operation mode: 1 = GET operation (to get data from PPS manager) 2 = SET operation (to set data into PPS manager)
cmd_type	Decimal	1 = PPS_IF_ON_OFF_CMD 2 = PPS_IF_OUT_MODE_CMD 3 = PPS_IF_REFERENCE_CONSTELLATION_CMD 4 = PPS_IF_PULSE_DELAY_CMD 5 = PPS_IF_PULSE_DURATION_CMD 6 = PPS_IF_PULSE_POLARITY_CMD 7 = PPS_IF_PULSE_DATA_CMD 8 = PPS_IF_FIX_CONDITION_CMD

		9 = PPS_IF_SAT_TRHESHOLD_CMD 10 = PPS_IF_ELEVATION_MASK_CMD 11 = PPS_IF_COSTELLATION_MASK_CMD 12 = PPS_IF_TIMING_DATA_CMD 13 = PPS_IF_POSITION_HOLD_DATA_CMD 14 = PPS_IF_AUTO_HOLD_SAMPLES_CMD 15 = PPS_IF_TRAIM_CMD 16 = PPS_IF_TRAIM_USED_CMD 17 = PPS_IF_TRAIM_RES_CMD 18 = PPS_IF_TRAIM_REMOVED_CMD 19 = PPS_IF_REFERENCE_TIME_CMD 20 = PPS_IF_CONSTELLATION_RF_DELAY_CMD
par_1 ... par_N		Parameters list according to the command type specification (see below).

5.3.3.1 Getting PPS Data (cmd_mode = 1)

5.3.3.1.1 PPS_IF_PULSE_DATA_CMD

\$PSTMPPS,1,7<cr><lf>

Response:

\$PSTMPPS,1,7,<out_mode>,<reference_time>,<pulse_delay>,<pulse_duration>,<pulse_polarity>
 <cr><lf>

Parameter	Format	Description
out_mode	Decimal, 1 digit	0 = PPS always generated. 1 = PPS generated on even seconds. 2 = PPS generated on odd seconds.
reference_time	Decimal, 1 digit	0 = UTC 1 = GPS.UTC 2 = GLONASS.UTC 3 = UTC_SU 4 = GPS.UTC_FROM_GLONASS 5 = COMPASS.UTC 6 = UTC_NTSC 7 = GST 8 = UTC_GST 9 = GPS_FROM_GST NOTES: UTC(SU) is the Soviet Union UTC, it is derived from GLONASS

		time applying the UTC delta time downloaded from GLONASS satellites. GPS.UTC_FROM_GLONASS is the GPS time derived from GLONASS time applying the GPS delta time downloaded from GLONASS satellites.If the software is configured to work in GLONASS only mode, UTC(SU) is identical to UTC and GPS.UTC_FROM_GLONASS is identical to GPS.UTC.
pulse_delay	Decimal	Pulse delay (ns)
pulse_duration	Double	Pulse duration (s)
pulse_polarity	Decimal, 1 digit	0 = not inverted 1 = inverted

5.3.3.1.2 PPS_IF_TIMING_DATA_CMD

\$PSTMPPS,1,12<cr><lf>

Response:

\$PSTMPPS,1,12,<fix_condition>,<sat_th>,<elevation_mask>,<constellation_mask>,<gps_rf_delay>,<glonass_rf_delay><cr><lf>

Parameter	Format	Description
fix_condition	Decimal, 1 digit	1 = NOFIX 2 = 2DFIX 3 = 3DFIX
sat_th	Decimal	Minimum number of satellites for the PPS generation.
elevation_mask	Decimal	Minimum satellite elevation for satellite usage in timing filtering.
constellation_mask	Decimal (bit mask)	Satellite constellation selection for usage in timing filtering. bit0 = GPS bit1 = GLONASS bit 7 = BEIDOU
GPS_rf_delay	Decimal	GPS path RF delay (ns)
GLONASS_rf_delay	Decimal	GLONASS path RF delay (ns)

5.3.3.1.3 PPS_IF_POSITION_HOLD_DATA_CMD

\$PSTMPPS,1,13<cr><lf>

Response:

\$PSTMPPS,1,13,<on_off>,<lat>,<lat_dir>,<lon>,<lon_dir>,<h_msl><cr><lf>

Parameter	Format	Description
on_off	Decimal, 1 digit	0 = Position Hold disabled.

		1 = Position Hold enabled.
lat	DDmm.mmmmm	Position Hold position latitude.
lat_dir	N or S	North or South direction.
lon	DDDmm.mmmmm	Position Hold position longitude.
lon_dir	E or W	East or West direction.
h_msl	Double	Position Hold mean sea level altitude.

5.3.3.1.4 PPS_IF_TRAIM_CMD

```
$PSTMPPS,1,15<cr><lf>
```

Response:

```
$PSTMPPS,1,15,<traim_enabled>,<traim_solution>,<ave_error>,<used_sats>,<removed_sats>  
<cr><lf>
```

Parameter	Format	Description
traim_enabled	Decimal, 1 digit	TRAIM ON/OFF status 0 = OFF 1 = ON
traim_solution	Decimal, 1 digit	TRAIM Algorithm status: 0 = UNDER Alarm 1 = OVER Alarm 2 = UNKNOWN
ave_error	Decimal	Average time error (ns)
used_sats	Decimal	Number of satellite used for timing correction.
removed_sats	Decimal	Number of satellites removed by the timing correction.

5.3.3.1.5 PPS_IF_TRAIM_USED_CMD

```
$PSTMPPS,1,16<cr><lf>
```

Response:

```
$PSTMPPS,1,16,<traim_enabled>,<used_sats>,<sat1>,...,<satN><cr><lf>
```

Parameter	Format	Description
traim_enabled	Decimal, 1 digit	TRAIM ON/OFF status 0 = OFF 1 = ON
used_sats	Decimal	Number of satellite used for timing correction.
sat1 .. satN	Decimal	List of satellites IDs

5.3.3.1.6 PPS_IF_TRAIM_RES_CMD

```
$PSTMPPS,1,17<cr><lf>
```

Response:

```
$PSTMPPS,1,17,<traim_enabled>,<used_sats>,<res1>,...,<resN><cr><lf>
```

Parameter	Format	Description
traim_enabled	Decimal, 1 digit	TRAIM ON/OFF status 0 = OFF 1 = ON
used_sats	Decimal	Number of satellite used for timing correction.
Res1 .. resN	Decimal	List of satellites residuals [ns]. Each residual corresponds to the satellite in the used sat list at the same message position.

5.3.3.1.7 PPS_IF_TRAIM_REMOVED_CMD

```
$PSTMPPS,1,18<cr><lf>
```

Response:

```
$PSTMPPS,1,18,<traim_enabled>,<rem_sats>,<sat1>,...,<satN><cr><lf>
```

Parameter	Format	Description
traim_enabled	Decimal, 1 digit	TRAIM ON/OFF status 0 = OFF 1 = ON
rem_sats	Decimal	Number of satellite removed by timing correction.
sat1 .. satN	Decimal	List of satellites IDs.

5.3.3.2 setting PPS Data (cmd_mode = 2)

5.3.3.2.1 PPS_IF_ON_OFF_CMD

```
$PSTMPPS,2,1,<on_off><cr><lf>
```

Parameter	Format	Description
on_off	Decimal, 1 digit	0 = PPS disabled. 1 = PPS enabled.

5.3.3.2.2 PPS_IF_OUT_MODE_CMD

```
$PSTMPPS,2,2,<out_mode><cr><lf>
```

Parameter	Format	Description
out_mode	Decimal, 1 digit	0 = PPS always generated. 1 = PPS generated on even seconds. 2 = PPS generated on odd seconds.

5.3.3.2.3 PPS_IF_REFERENCE_TIME_CMD

```
$PSTMPPS,2,19,<reference_time><cr><lf>
```

Parameter	Format	Description
reference_time	Decimal, 1 digit	0 = UTC 1 = GPS.UTC. 2 = GLONASS.UTC. 3 = UTC_SU 4 = GPS.UTC_FROM_GLONASS NOTES: UTC(SU) is the Soviet Union UTC, it is derived from GLONASS time applying the UTC delta time downloaded from GLONASS satellites. GPS.UTC_FROM_GLONASS is the GPS time derived from GLONASS time applying the GPS delta time downloaded from GLONASS satellites. If the software is configured to work in GLONASS only mode, UTC(SU) is identical to UTC and GPS.UTC_FROM_GLONASS is identical to GPS.UTC.

5.3.3.2.4 PPS_IF_PULSE_DELAY_CMD

```
$PSTMPPS,2,4,<pulse_delay><cr><lf>
```

Parameter	Format	Description
pulse_delay	Decimal	Pulse delay (ns)

Note: User can use this parameter to compensate the delay both from the antenna cable and PPS output cable. For example, the delay of the antenna cable and PPS output cable are 15ns and 6ns, respectively. That is total 21ns. Then the command is \$PSTMPPS,2,4,-21

5.3.3.2.5 PPS_IF_CONSTELLATION_RF_DELAY_CMD

```
$PSTMPPS,2,20,<sat_type><time_delay><cr><lf>
```

Parameter	Format	Description
sat_type	Decimal	Satellite constellation type: 0 = GPS 1 = GLONASS 3 = GALILEO 7 = BEIDOU

time_delay	Decimal	Time delay (ns)
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Note: User should not change these parameters that are for internal compensation of GNSS module.

5.3.3.2.6 PPS_IF_PULSE_DURATION_CMD

```
$PSTMPPS,2,5,<pulse_duration><cr><lf>
```

Parameter	Format	Description
pulse_duration	Double	Pulse duration (s)

5.3.3.2.7 PPS_IF_PULSE_POLARITY_CMD

```
$PSTMPPS,2,6,<pulse_polarity><cr><lf>
```

Parameter	Format	Description
pulse_polarity	Decimal, 1 digit	0 = not inverted. 1 = inverted.

5.3.3.2.8 PPS_IF_PULSE_DATA_CMD

```
$PSTMPPS,2,7,<out_mode>,<reference_time>,<pulse_delay>,<pulse_duration>,<pulse_polarity>  
<cr><lf>
```

Parameter	Format	Description
out_mode	Decimal, 1 digit	0 = PPS always generated. 1 = PPS generated on even seconds. 2 = PPS generated on odd seconds.
reference_time	Decimal, 1 digit	0 = UTC 1 = GPS.UTC 2 = GLONASS.UTC 3 = UTC_SU 4 = GPS.UTC_FROM_GLONASS 5 = COMPASS.UTC 6 = UTC_NTSC 7 = GST 8 = UTC_GST 9 = GPS_FROM_GST
pulse_delay	Decimal	Pulse delay (ns)
pulse_duration	Double	Pulse duration (s)
pulse_polarity	Decimal, 1 digit	0 = not inverted. 1 = inverted.

5.3.3.2.9 *PPS_IF_FIX_CONDITION_CMD*

\$PSTMPPS,2,8,<fix_condition><cr><lf>

Parameter	Format	Description
fix_condition	Decimal, 1 digit	1 = NOFIX. 2 = 2DFIX. 3 = 3DFIX.

5.3.3.2.10 *PPS_IF_SAT_TRHESHOLD_CMD*

\$PSTMPPS,2,9,<sat_th><cr><lf>

Parameter	Format	Description
sat_th	Decimal	Minimum number of satellites for the PPS generation.

5.3.3.2.11 *PPS_IF_ELEVATION_MASK_CMD*

\$PSTMPPS,2,10,<elevation_mask><cr><lf>

Parameter	Format	Description
elevation_mask	Decimal	Minimum satellite elevation for satellite usage in timing filtering.

5.3.3.2.12 *PPS_IF_COSTELLATION_MASK_CMD*

\$PSTMPPS,2,11,<constellation_mask><cr><lf>

Parameter	Format	Description
constellation_mask	Decimal (bit mask)	Satellite constellation selection for usage in timing filtering. bit0 = GPS bit1 = GLONASS bit7 = BEIDOU NOTES: This parameter enables the usage of mixed constellations satellites in the timing filtering. If bit0 is enabled GPS satellites are used to correct the GLONASS reference time together with GLONASS satellites. If bit1 is enabled, GLONASS satellites are used to correct the GPS reference time together with the GPS satellites. When constellation mask is zero (default) only GPS sats are used to correct the GPS reference time and only GLONASS sats are used to

		correct the GLONASS reference time. Same description is valid also for GPS and BEIDOU constellations enabling/disabling bit0 and bit7.
--	--	-------------------------------------------------------------------------------------------------------------------------------------------

5.3.3.2.13 PPS_IF_TIMING_DATA_CMD

\$PSTMPPS,2,12,<fix_condition>,<sat_th>,<elevation_mask>,<constellation_mask><cr><lf>

Parameter	Format	Description
fix_condition	Decimal, 1 digit	1 = NOFIX. 2 = 2DFIX. 3 = 3DFIX.
sat_th	Decimal	Minimum number of satellites for the PPS generation.
elevation_mask	Decimal	Minimum satellite elevation for satellite usage in timing filtering.
constellation_mask	Decimal (bit mask)	Satellite constellation selection for usage in timing filtering. bit0 = GPS bit1 = GLONASS bit7 = BEIDOU

5.3.3.2.14 PPS_IF_POSITION_HOLD_DATA_CMD

\$PSTMPPS,2,13,<on_off>,<lat>,<lat_dir>,<lon>,<lon_dir>,<h_msl><cr><lf>

Parameter	Format	Description
on_off	Decimal, 1 digit	0 = Position Hold disabled. 1 = Position Hold enabled.
lat	DDmm.mmmmm	Position Hold position latitude.
lat_dir	N or S	North or South direction.
lon	DDDmm.mmmmm	Position Hold position longitude.
lon_dir	E or W	East or West direction
h_msl	Double	Position Hold mean sea level altitude.

5.3.3.2.15 PPS_IF_AUTO_HOLD_SAMPLES_CMD

\$PSTMPPS,2,14,<auto_ph_samples><cr><lf>

Parameter	Format	Description
auto_ph_samples	Decimal	Number of position samples for the auto position algorithm. If the number of samples is set to "0", the auto position hold feature is disabled.

		The position average evaluation is restarted every time the command is executed.
--	--	----------------------------------------------------------------------------------

The position hold auto survey mode is default enabled. Default position samples are 2000 points.

5.3.3.2.16 PPS_IF_TRAIM_CMD

```
$PSTMPPS,2,15,<on_off>,<alarm><cr><lf>
```

Parameter	Format	Description
on_off	Decimal, 1 digit	0 = TRAIM disabled. 1 = TRAIM enabled.
alarm	Double	TRAIM alarm [s] – scientific notation is allowed.

6 Pin assignment and descriptions



Table 6-1 Pin descriptions

Pin #	Name	Type	Description	Note
1	BOOTSEL		Boot mode selection. High: firmware update. Leave unconnected for normal operation.	
2	NC		Not connected	
3	TIMEPULSE	O	Time pulse (1PPS, default 100 ms pulse/sec)	
4	RSV		Reserved pin. Leave unconnected.	
5	RSV		Reserved pin. Leave unconnected.	
6	RSV		Reserved pin. Leave unconnected.	
7	NC		Not connected	
8	NC		Not connected	
9	VCC_RF	O	Output voltage for active antenna	1
10	GND	P	Ground	
11	RF_IN	I	GNSS RF signal input	
12	GND	P	Ground	
13	GND	P	Ground	
14	RSV		Reserved pin. Leave unconnected.	

15	RSV		Reserved pin. Leave unconnected.	
16	NC		Not connected	
17	NC		Not connected	
18	NC		Not connected	
19	NC		Not connected	
20	TX/USB_DP	O	Serial output (Default NMEA) or USB D+	2
21	RX/USB_DM	I	Serial input (Default NMEA) or USB D-	
22	V_BCKP	I	Backup battery input	3
23	VCC	I	DC supply input	
24	GND	P	Ground	

Note:

1. VCC_RF does not have short circuit protection.
2. When the module is USB enabled, please connect a 1.5K ohm resistor between USB_DP and VCC pins.
3. V_BCKP needs to be powered 1ms earlier than VCC. If V_BCKP and VCC are tied and powered together, the voltage rise time must be between 2ms and 50ms.

7 DC & Temperature characteristics

7.1 Absolute maximum ratings

Parameter	Symbol	Ratings	Units
DC Supply Input Voltage	VCCabs.	3.6	V
Backup Battery Input Voltage	V_BCKPabs.	4.3	V
Operating Temperature Range	Topr_abs.	-40 ~ 85	°C
Storage Temperature Range	Tstg_abs.	-40 ~ 85	°C

7.2 DC Electrical characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
DC Supply Input Voltage	VCC		3.0	3.3	3.6	V
Backup Battery Input Voltage	V_BCKP		1.6		4.3	V
VCC_RF Output Voltage	VCC_RF			VCC		V
Supply Current	I _{ss}	VCC = 3.3V, w/o active antenna, Peak Acquisition Tracking		68 69 ⁽¹⁾	180	mA mA mA
Backup Battery Current	I _{bat}	VCC = 0V		8		uA
VCC_RF Output Current	I _{out}	VIN = 3.3V			25	mA
High Level Input Voltage	V _{IH}		2.0		3.6	V
Low Level Input Voltage	V _{IL}		-0.3		0.8	V
High Level Output Voltage	V _{OH}		2.6			V
Low Level Output Voltage	V _{OL}				0.4	V

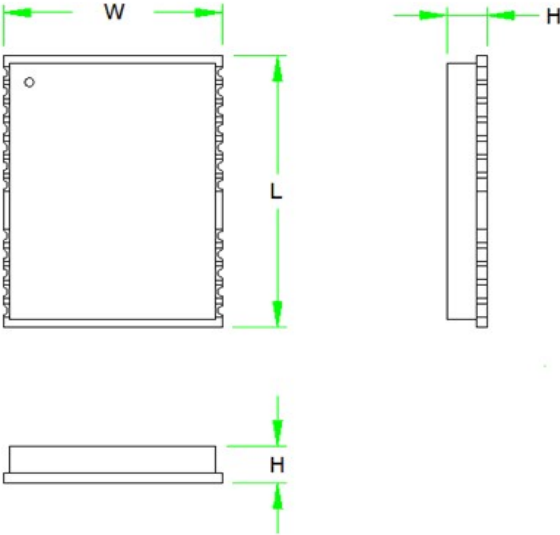
Note 1. Measured for 12 hours when position fix (1Hz) is available and input voltage is 3.3V with UART interface.

7.3 Temperature characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units
Operating Temperature	Topr	-40	-	85	°C
Storage Temperature	Tstg	-40	25	85	°C

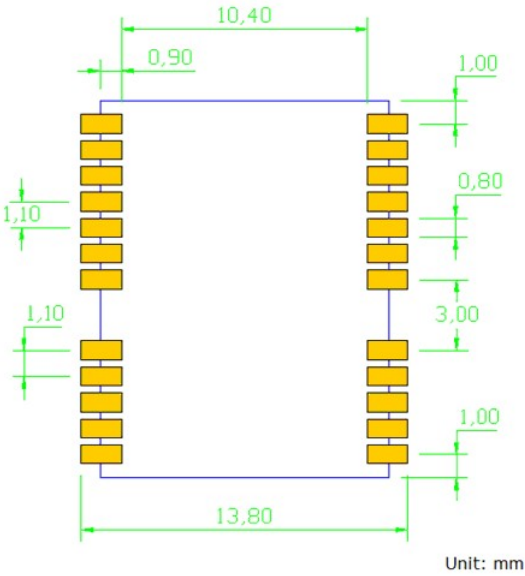
8 Mechanical specification

8.1 Outline dimensions



Symbol	Min. (mm)	Typ. (mm)	Max. (mm)
W	12.1	12.2	12.3
L	15.7	16.0	16.4
H	2.2	2.4	2.6

8.2 Recommended land pattern dimensions



Note: The recommended land pattern dimensions are shown for reference only, as actual pad layouts may vary depending on application.

9 Product handling

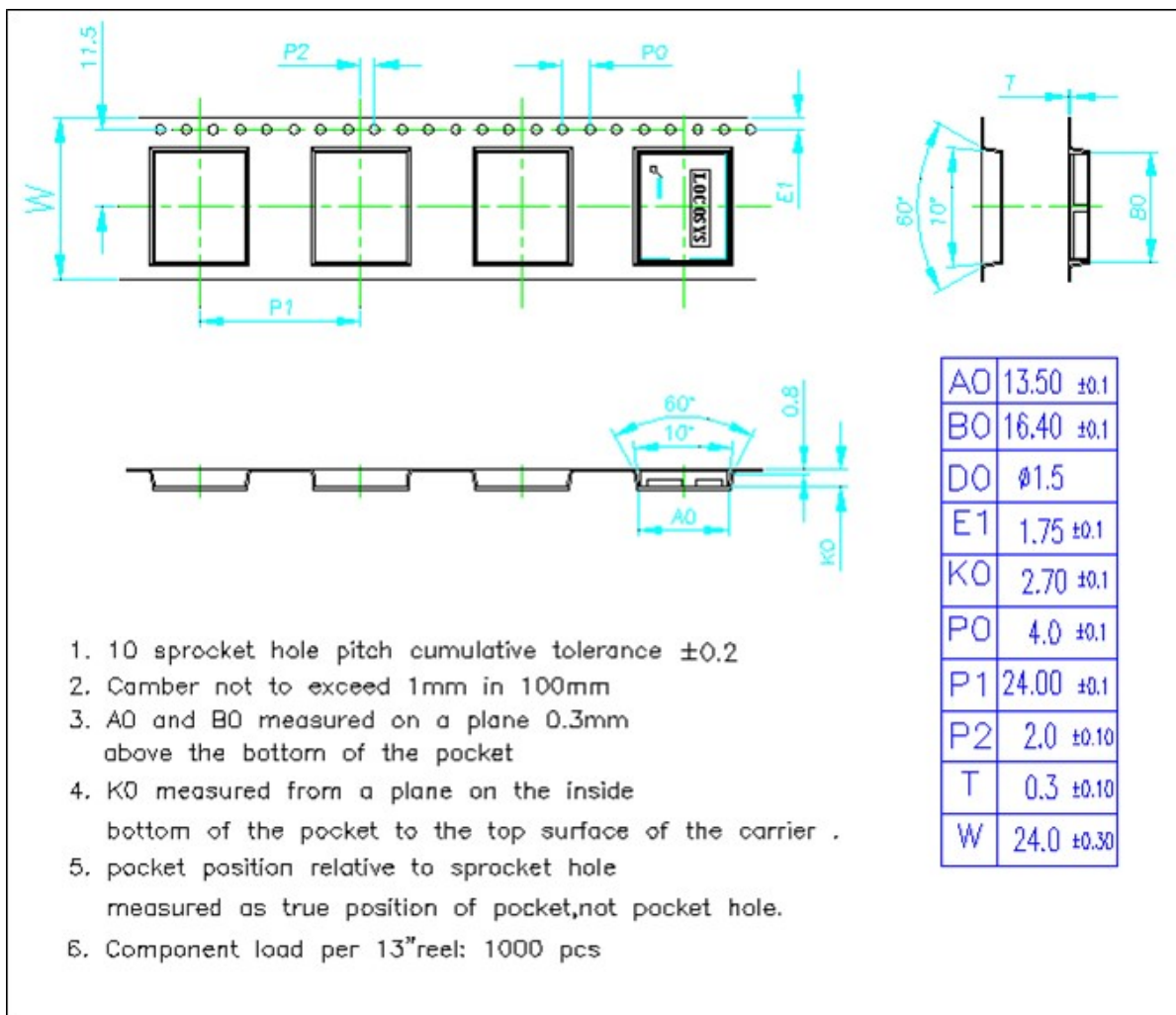
9.1 ESD precaution

GNSS modules are electrostatic sensitive devices. Handling the modules without proper ESD protection may result in severe damage to them. ESD protection must be implemented throughout the processing, handling and even when the modules are being returned for repair.

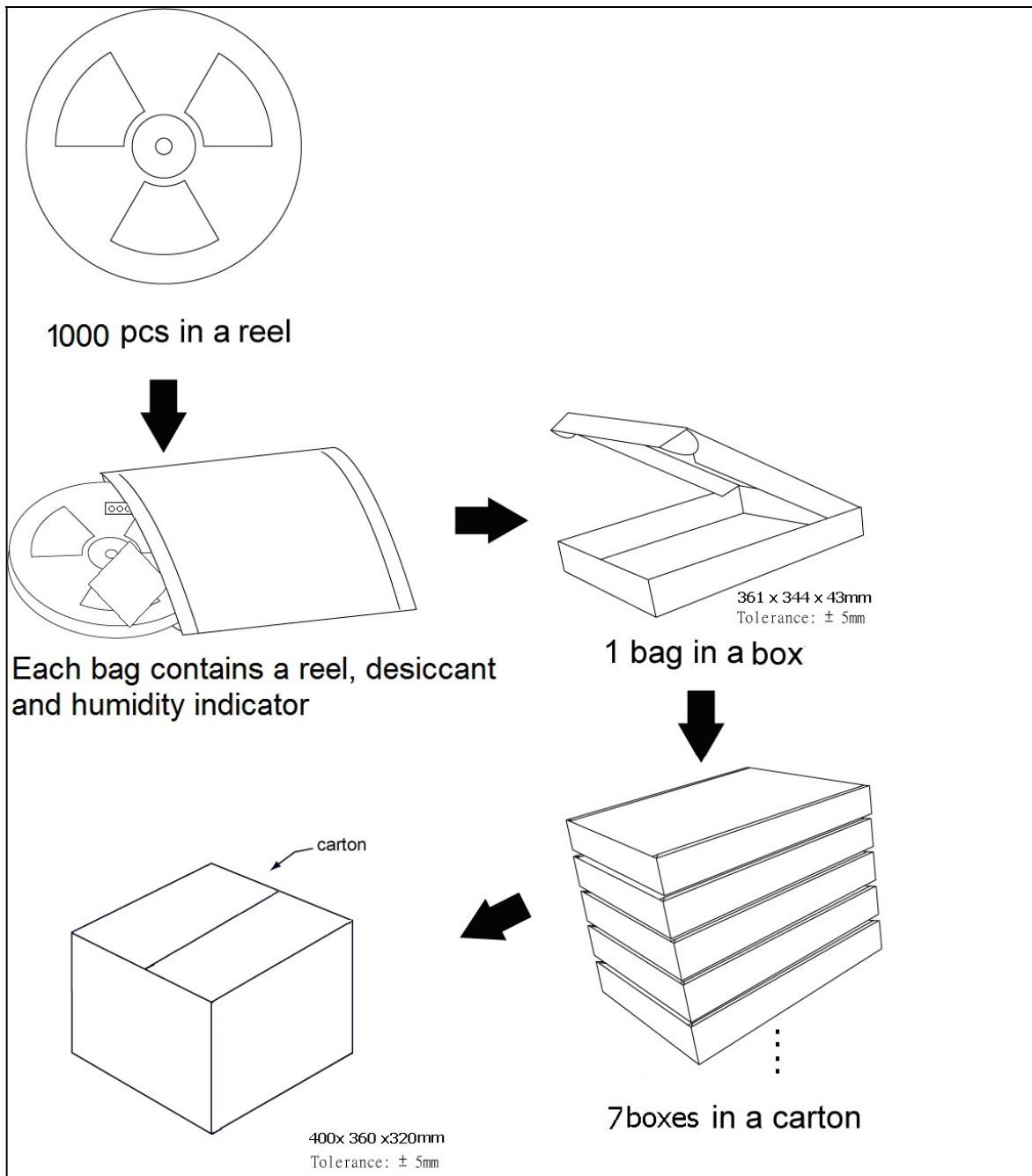
9.2 Packaging

The modules are sealed in a moisture barrier ESD bag with the appropriate units of desiccant and a humidity indicator card. It should not be opened until the modules are ready to be soldered onto the application.

9.2.1 Tape and reel packaging



9.2.2 Box packaging



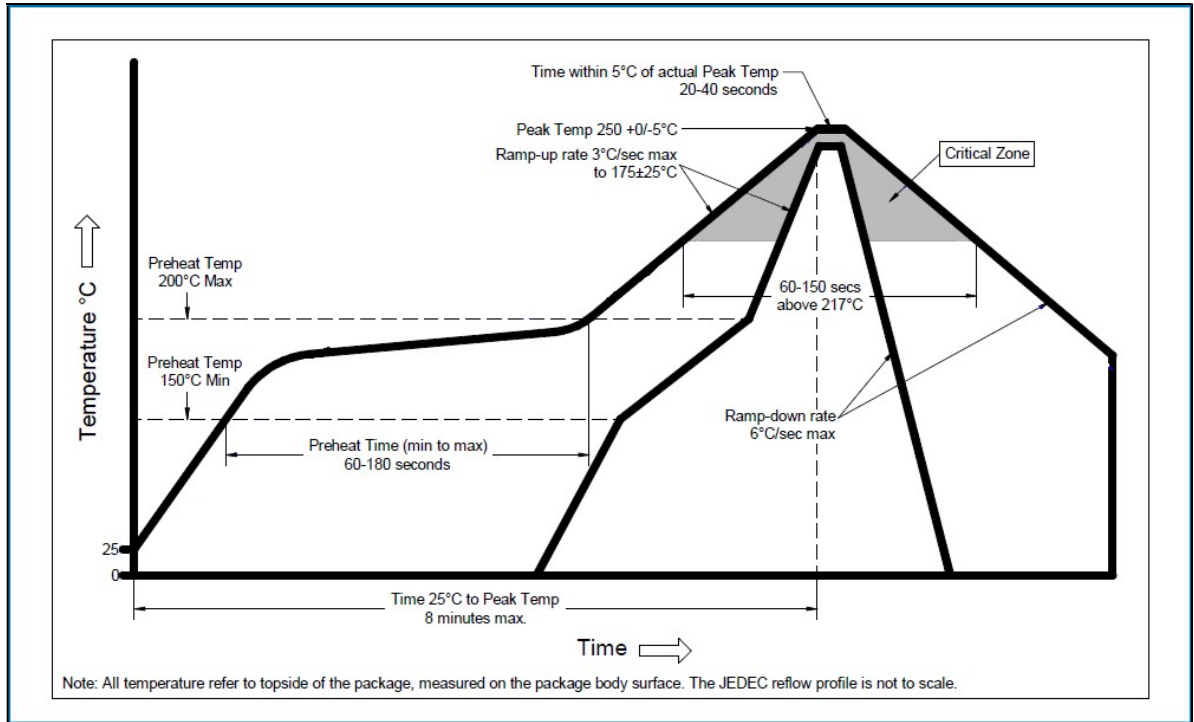
9.3 Moisture sensitivity level

The moisture sensitivity level of the module is 3. After the sealed bag is opened, modules should be mounted within 168 hours at factory conditions of $\leq 30^{\circ}\text{C}$ and 60% RH or stored at $\leq 20\%$ RH.

The modules require baking before mounting if above conditions are not met. If baking is required, the modules without the tape and reel may be baked for:

- a. 192 hours at $40^{\circ}\text{C} + 5^{\circ}\text{C} / -0^{\circ}\text{C}$ and $< 5\%$ RH
- b. 24 hours at $125^{\circ}\text{C} + 5^{\circ}\text{C} / -0^{\circ}\text{C}$

9.4 Reflow soldering



Note the module mounted to the top side (first reflow side) may fall off during reflow soldering of the bottom side.

10 Product marking and ordering information

10.1 Product marking

The marking of the module is engraved on the metal shielding that has product information, such as LOCOSYS logo, product name and manufacturing date.

10.2 Ordering information

Product name	Description	Remark
ST-1612i-BT	Multi-constellation GNSS timing module, UART interface.	GPS, BEIDOU, GALILEO, QZSS
ST-1612i-GT	Multi-constellation GNSS timing module, UART interface.	GPS, GLONASS, GALILEO, QZSS
ST-1612i-BTs	Multi-constellation GNSS timing module, USB interface.	GPS, BEIDOU, GALILEO, QZSS
ST-1612i-GTs	Multi-constellation GNSS timing module, USB interface.	GPS, GLONASS, GALILEO, QZSS

Note: ST-1612i-GT is the most popular. We recommend customers to use for their new design.

Document change list

Revision 0.1

- Draft release on August 27, 2019

Revision 0.2 (October 15, 2019)

- Modify application circuit on page 2.
- Modify pin assignment and descriptions on page 21& 22.

Revision 0.3 (February 14, 2020)

- Added the modules with USB interface.
- Modified Fig 3-1 to add USB interface.
- Added Fig 3-4.
- Added USB pins description in section 6.

Revision 0.9 (June 30, 2020)

- Changed maximum update rate from 10Hz to 5Hz in section 4.1
- Changed the tracking sensitivity from -163dBm to -161dBm in section 4.1
- Changed the code start sensitivity from -147dBm to -146.5dBm in section 4.1
- Changed the cold start time from 36s to 32s in section 4.1
- Changed the hot start time from 1s to < 2s (typical) in section 4.1
- Changed the value of “Cumulative Distribution Function” in section 4.2
- Changed the peak current from 208 mA to 180 mA in section 7.1
- Changed the tracking current from 67 mA to 69 mA in section 7.1
- Revised the module’s thickness in section 8.1

Revision 1.0 (July 7, 2020)

- First official release.

Revision 1.1 (July 10, 2020)

- Revised the form factor from “16 x 12.2 x 2.3” to ”16 x 12.2 x 2.4” in section 2

Revision 1.2 (October 20, 2020)

- Added application description in section 3.

Revision 1.3 (November 4, 2020)

- Added the note of V_BCKP pin in section 6.

Revision 1.4 (June 4, 2021)

- Changed CDF of PPS accuracy from 3.9ns, 5ns and 11ns to 4.2ns, 5.5ns and 13ns at 85°C in section 4.2