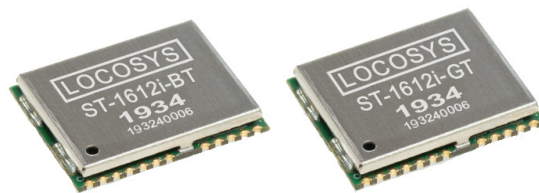


| Product name | Description | Version |
|--------------|---|---------|
| ST-1612i-BT | Multi-constellation GNSS timing module (GPS, BEIDOU, GALILEO, QZSS), UART interface. | 1.3 |
| ST-1612i-GT | Multi-constellation GNSS timing module (GPS, GLONASS, GALILEO, QZSS), UART interface | |
| ST-1612i-BTs | 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

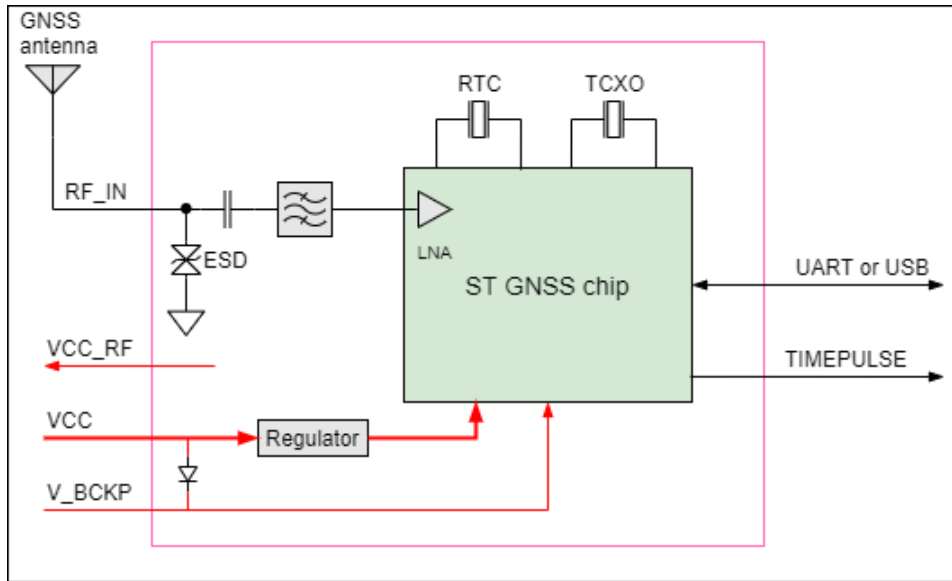


Fig 3-1 System block diagram.

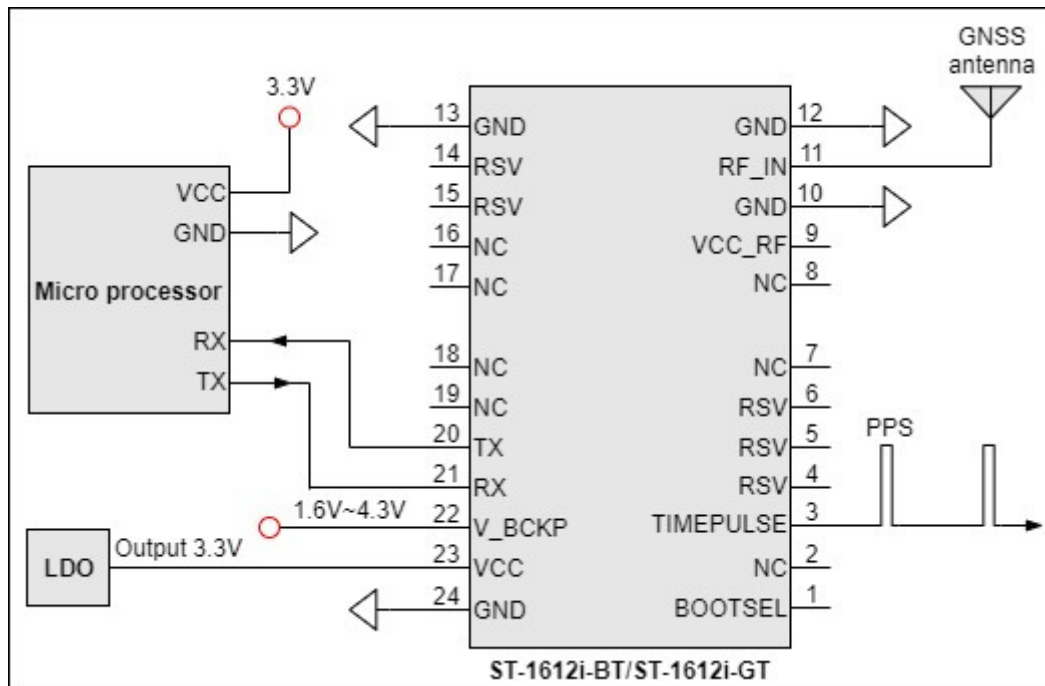


Fig 3-2 Typical application circuit that uses a passive antenna.

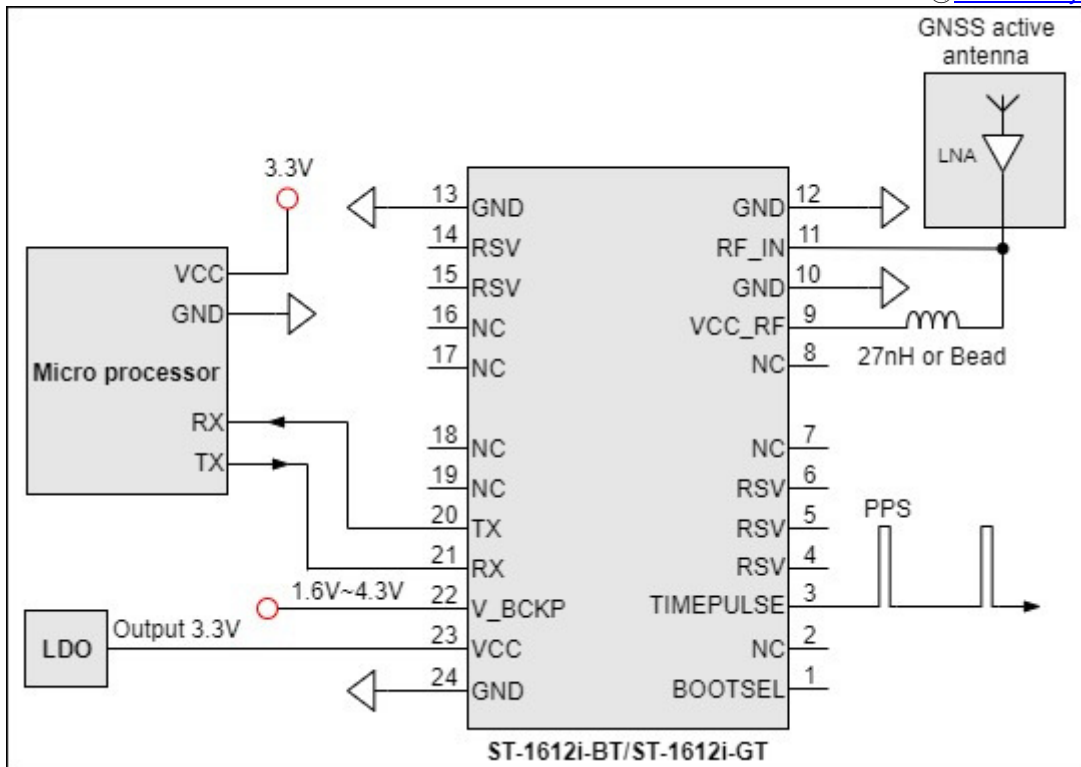


Fig 3-3 Typical application circuit that uses an active antenna.

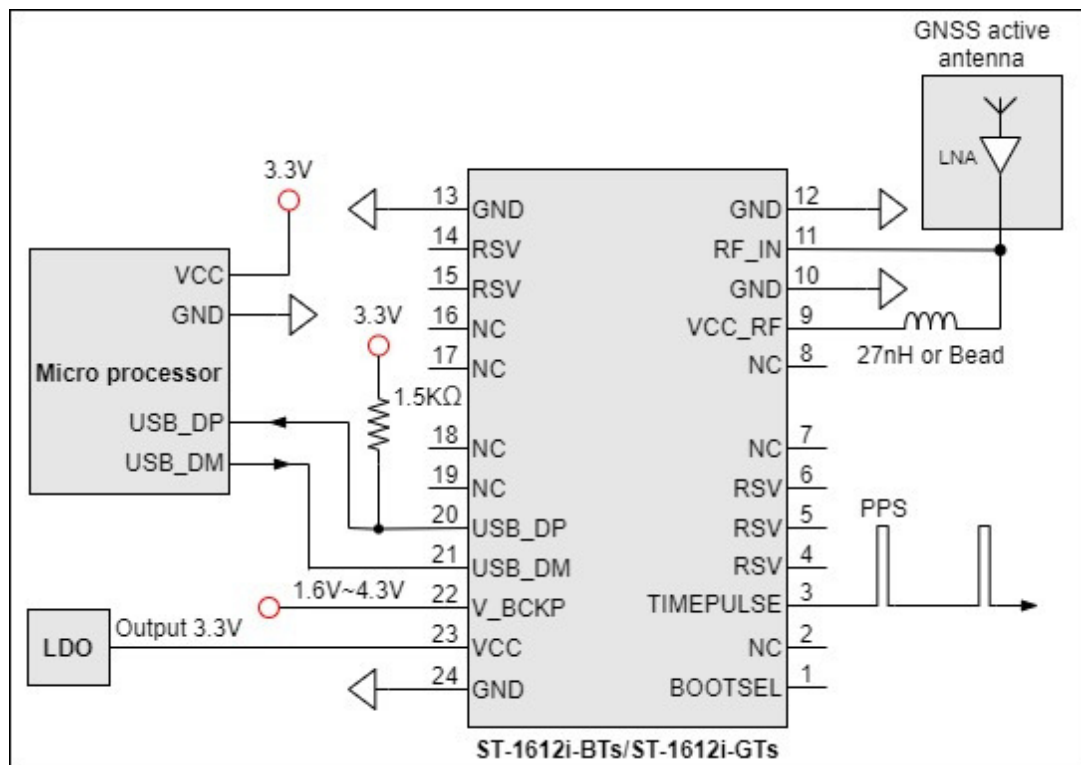


Fig 3-4 Typical application circuit that uses USB interface.

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 | 3.9 ns | 5 ns | 11 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 |
|--------------------|--------------------|---|

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) |
|------------|---------|-----------------|

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

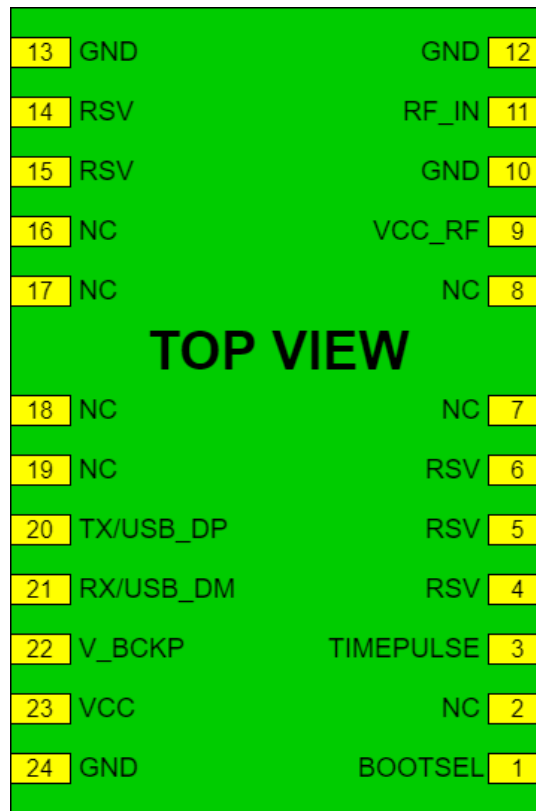


Table 6-1 Pin descriptions

| 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 |

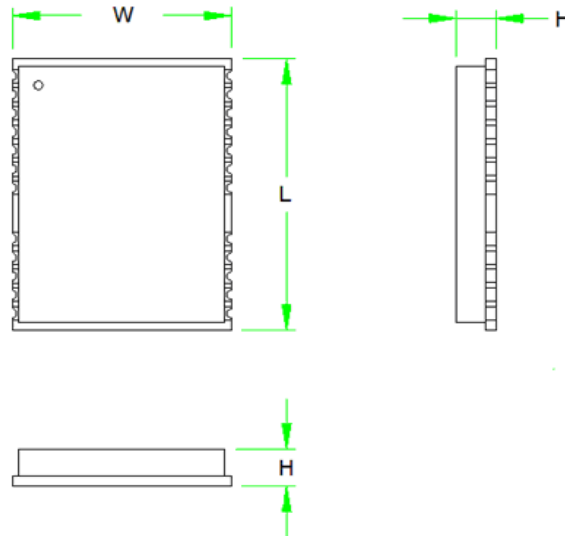
Note 1. Measured for 12 hours when position fix (1Hz) is available and input voltage is 3.3V with UART interface.

7.3 Temperature characteristics

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

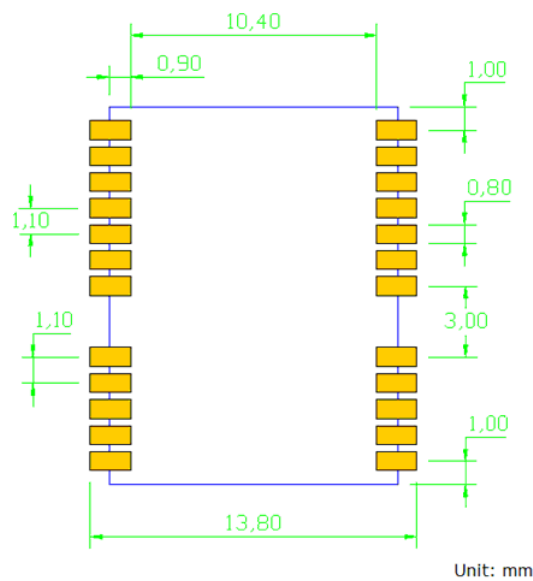
8 Mechanical specification

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

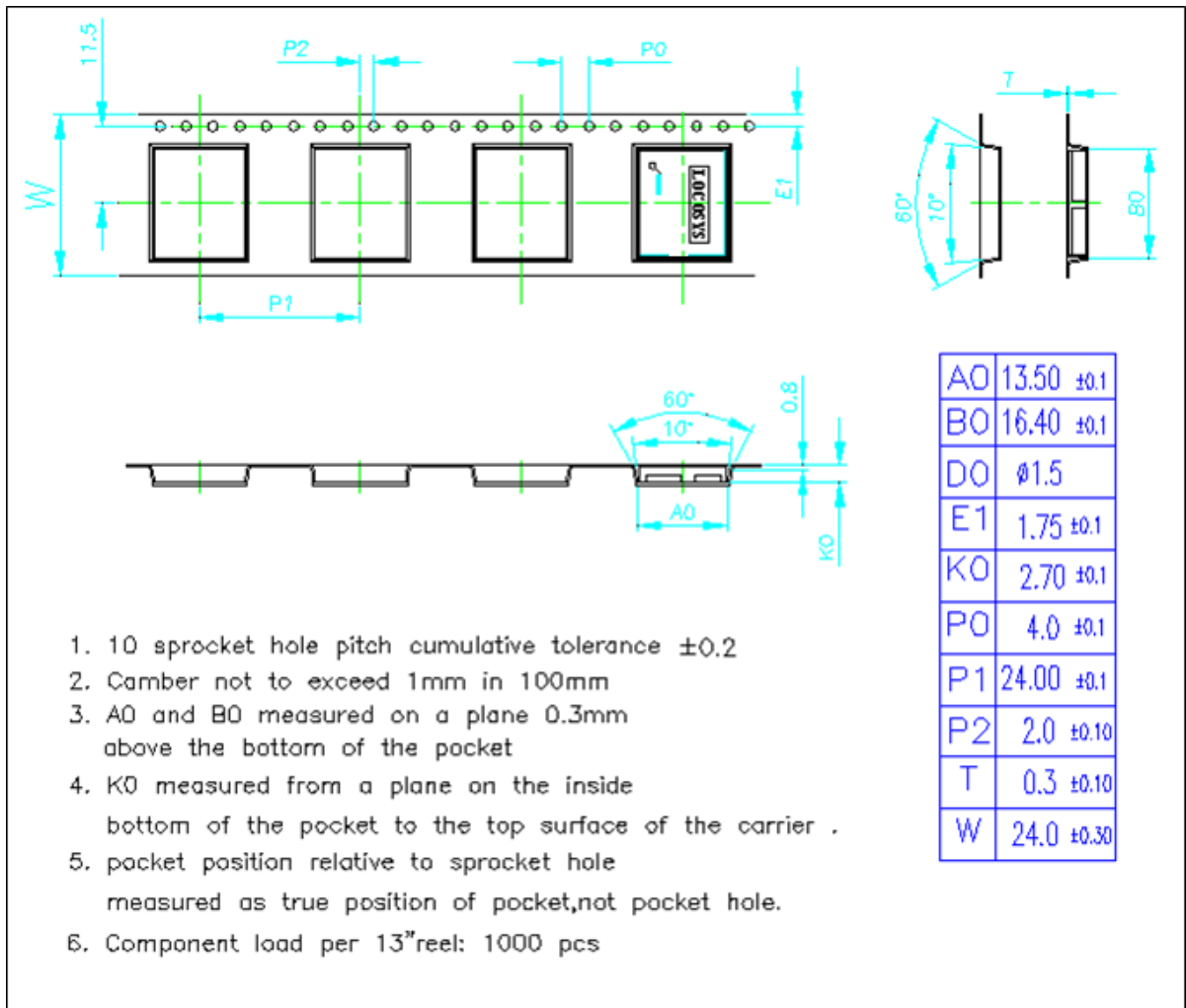
9.1 ESD precaution

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.

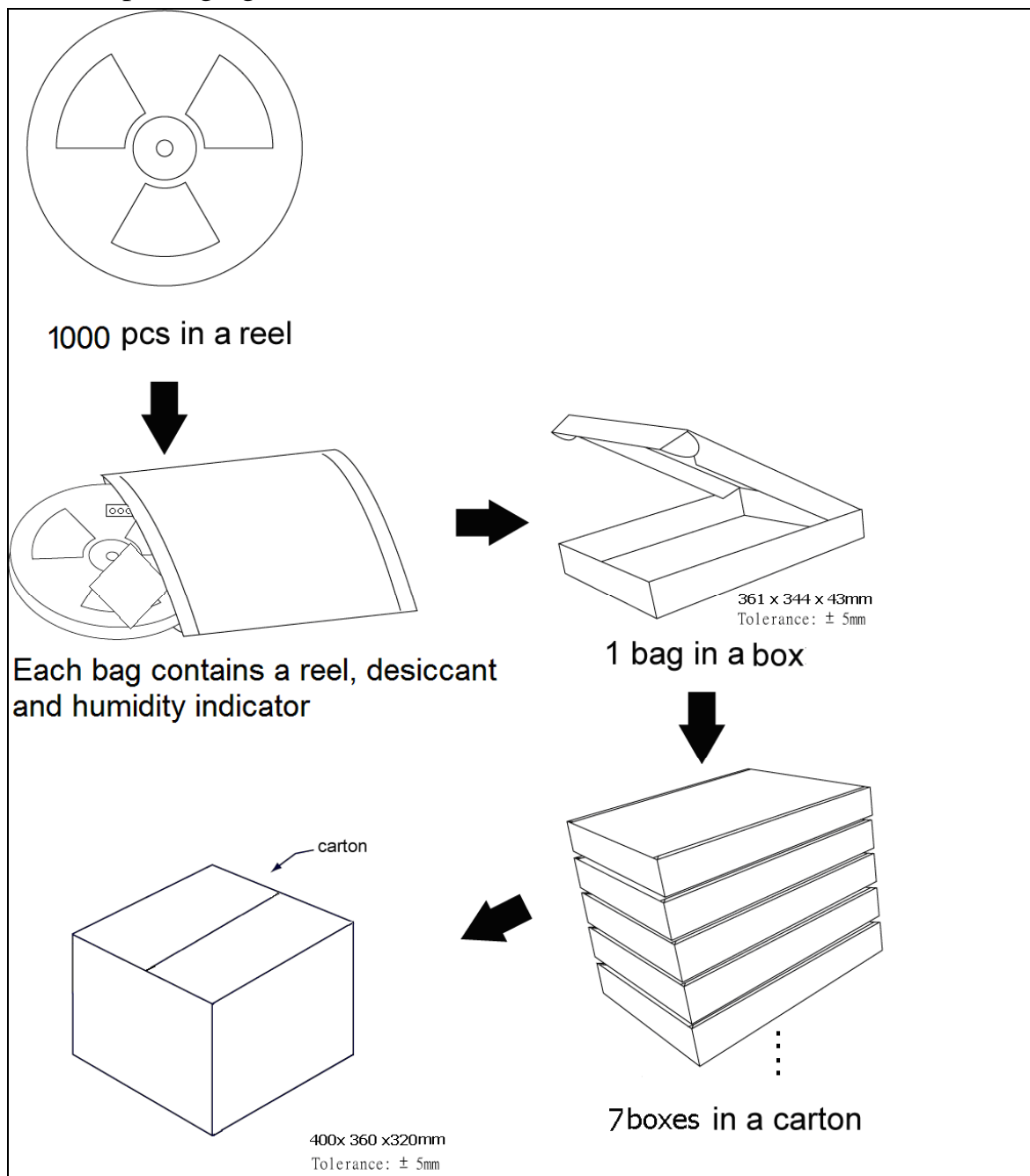
9.2 Packaging

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



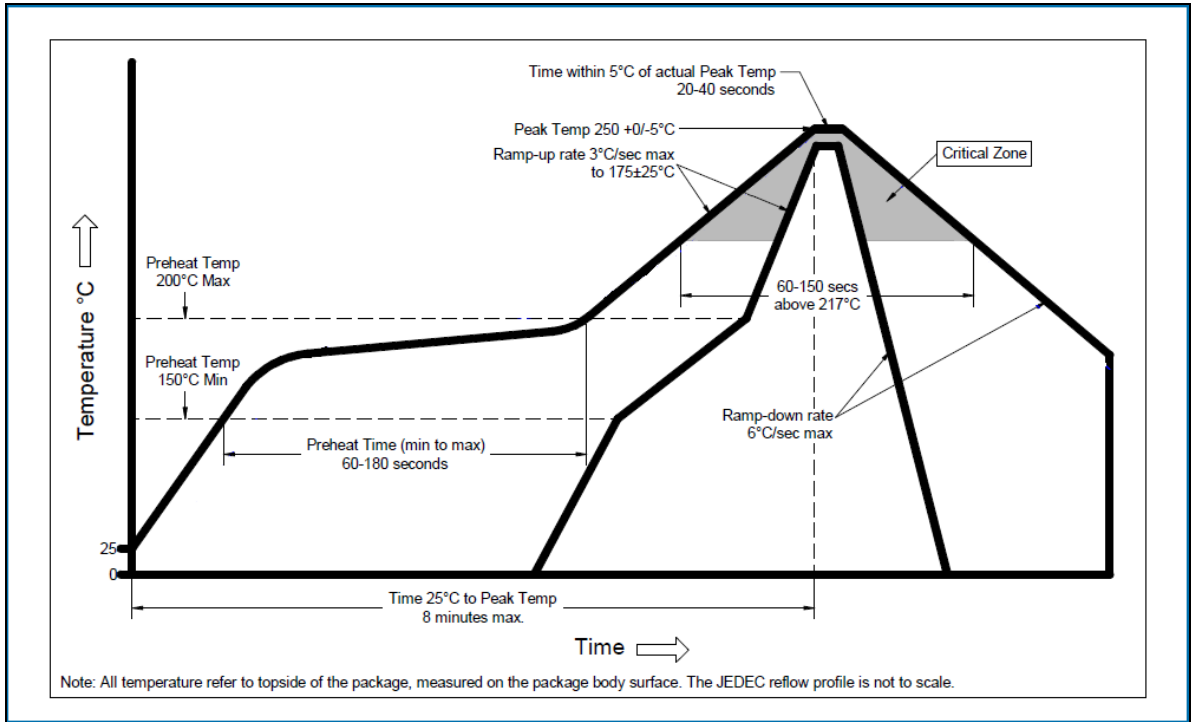
9.3 Moisture sensitivity level

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:

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