# IM19 Product Integration Guide

v1.3.7

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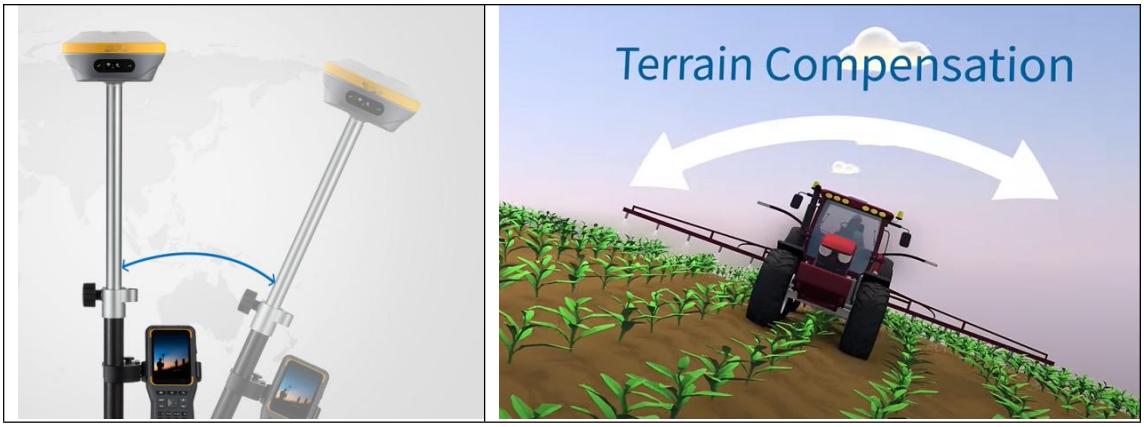
The FMI IM19 inertial module fuses MEMS sensor and GNSS RTK positioning data to deliver low cost, high-precision attitude measurement, with roll and pitch accurate to within 0.05 degrees. This kind of superb accuracy has found IM19 widespread uses in industrial applications such as tilt RTK surveys (where RTK poles need not be held straight vertical as IM19 can calculate a virtual digital level at any tilt angles) , agriculture machine automation, and dead reckoning.




## 1. Specifications

| IM19 | |
|---|---|
| Acceleration range | ±8g |
| Gyroscope range | ±1000deg/s |
| Attitude accuracy | ±0.05deg |
| Heading accuracy | ±0.5deg |
| Accelerometer bias accuracy | ±5mg |
| Gyroscope bias accuracy | ±0.2deg/s |
| Tilt survey accuracy | 1cm with up to 30° tilt angle |
| Tilt survey initialization time | 1 second (95%) |
| Ag auto steering yaw | 0.5° |

# 2. Hardware Instructions

## 2.1 Electrical

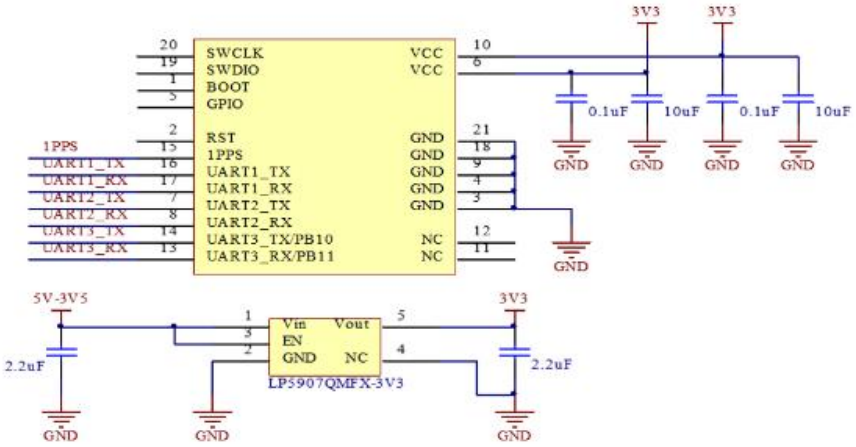
| | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|
| **Supply voltage** | 3.0 | 3.3 | 3.6 | Volt |
| **Current consumption** | 120 | 130 | 140 | mA |

## 2.2 Pin assignment

| Pin | Name | Description（All ports voltage is 3.3V） |
|---|---|---|
| 1 | BOOT | Start modes<br>High: BOOT mode;<br>NC or low: normal working mode |
| 2 | RESET | Hardware reset pin (pull low 10ms to reset module) |
| 3 | GND | Ground |
| 4 | GND | Ground |
| 5 | GPIO | Output IO, Active buzzer can be connected |
| 6 | 3V3 | Voltage supply |
| 7 | UART2_TX | Uart2 output, connect GNSS board RX |
| 8 | UART2_RX | Uart2 input, connect GNSS board TX |
| 9 | GND | Ground |
| 10 | 3V3 | Sensor power supply |
| 11 | NC | Reserved |
| 12 | NC | Reserved |
| 13 | UART3_RX | Uart3 input, used for configuration, message output and firmware upgrade |
| 14 | UART3_TX | Uart3 output, used for configuration, message output and firmware upgrade |
| 15 | 1PPS | 1PPS pin，Connect to GNSS board 1PPS |
| 16 | UART1_TX | Uart1 output, used for configuration, message output and firmware upgrade |
| 17 | UART1_RX | Uart1 input, used for configuration, message output and firmware upgrade |
| 18 | GND | Ground |
| 19 | SWDIO | Debug IO, Reserved |
| 20 | SWCLK | Debug IO, Reserved |
| 21 | GND | Ground |

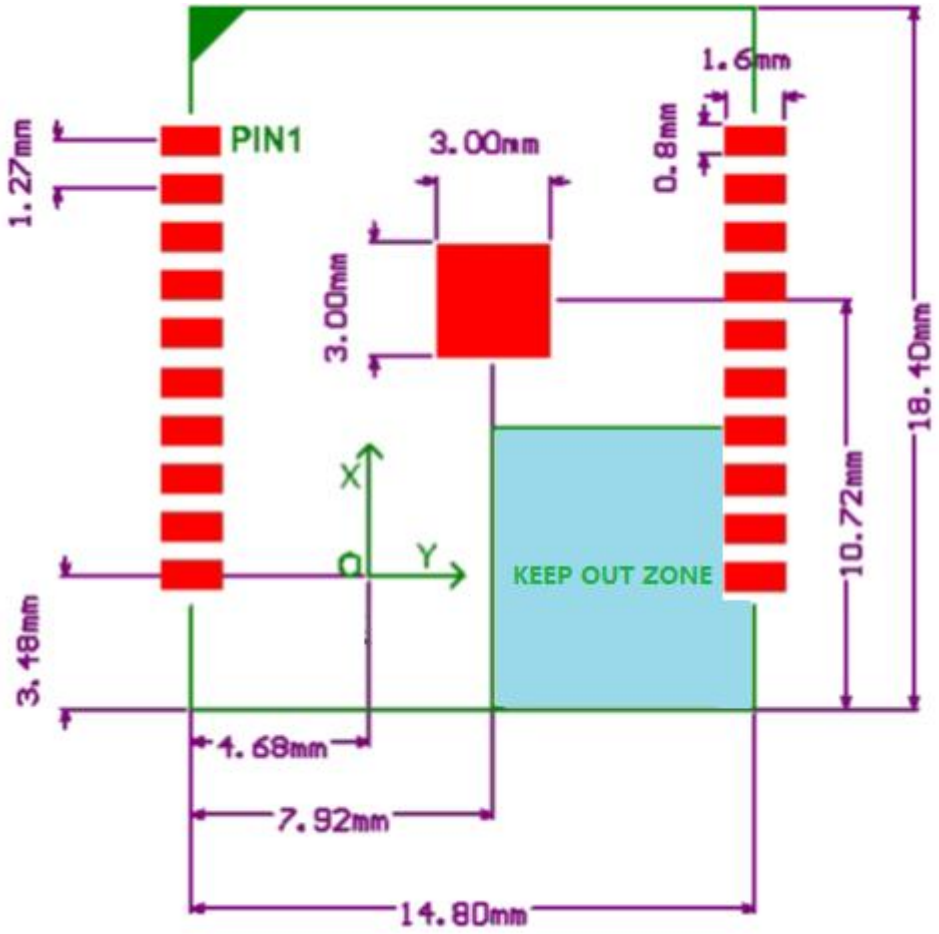
## 2.3 Reference design

UART ports 1 and 3 have the same functions. One of them can be connected to the main processor and the other can be used as a debugging interface. In addition, BOOT pins are recommended to be used for backup. Buzzer can be used for status indicators, such as: power on, completion of installation angle estimation etc.




## 2.4 Mechanical

The height of the module is 3.2±0.1mm, the size of the edge pad is 1.6mm-0.8mm, the size of the middle pad is 3mm-3mm. It is recommended to place the IM19 module in a stable temperature region to avoid convection with the outside air. The coordinate system is defined by the right-hand system, as shown in the figure below.



# 3. Software development instructions

## 3.1 Communication protocol

### 3.1.1 MEMS Raw data protocol

IM19 module can output 100Hz MEMS raw data in little endian mode (low byte in low address for storage, low byte in priority transmission), where the accelerometer unit is: g, gyroscope data unit is: rad/s.

| | Data | Type | Relative position |
|---|---|---|---|
| Header | f | char | 1 |
| Header | m | char | 2 |
| Header | i | char | 3 |
| Data Type | m | char | 4 |
| Field 1 | hhmmss.ss | double | 5 |
| Field 2 | Acceleration X-axis | float | 13 |
| Field 3 | Acceleration Y-axis | float | 17 |
| Field 4 | Acceleration Z-axis | float | 21 |
| Field 5 | Gyroscope X-axis | float | 25 |
| Field 6 | Gyroscope Y-axis | float | 29 |
| Field 7 | Gyroscope Z-axis | float | 33 |
| Field 8 | Reserved | float | 37 |
| Field 9 | Reserved | float | 41 |
| Field 10 | Reserved | float | 45 |
| Check sum | 1-48Byte sum | uint16_t | 49 |
| End | e | char | 51 |
| End | d | char | 52 |

### 3.1.2 GNSS Raw data protocol

The raw GNSS data output by IM19 module is derived from the output data of GNSS receiver, so its data frequency is consistent with the output frequency of GNSS receiver, generally 5Hz. The protocol also uses the little-endian mode. Note: when the real time raw GNSS data is required, the data should be requested directly from the GNSS receiver, instead of IM19.

| | Data | Type | Relative position |
|---|---|---|---|
| Header | f | char | 1 |
| Header | m | char | 2 |
| Header | i | char | 3 |
| Data Type | g | char | 4 |
| Field 1 | hhmmss.ss | double | 5 |
| Field 2 | Altitude(DEG) | double | 13 |
| Field 3 | Longitude(DEG) | double | 21 |
| Field 4 | Height | double | 29 |
| Field 5 | North velocity | float | 37 |

| | | | |
|---|---|---|---|
| Field 6 | East velocity | float | 41 |
| Field 7 | Downward velocity | float | 45 |
| Field 8 | Northbound position variance | float | 49 |
| Field 9 | Eastbound position variance | float | 53 |
| Field 10 | Height position variance | float | 57 |
| Field 11 | Reserved | float | 61 |
| Field 12 | Reserved | float | 65 |
| Field 13 | Heading | float | 69 |
| Field 14 | HRMS | float | 73 |
| Field 15 | VRMS | float | 77 |
| Field 16 | HDOP | float | 81 |
| Field 17 | VDOP | float | 85 |
| Field 18 | Satellite number | uint8_t | 89 |
| Field 19 | Fix state | uint8_t | 90 |
| Field 20 | Diff age | uint8_t | 91 |
| Check sum | 1-91Byte Sum | uint16_t | 92 |
| End | e | char | 94 |
| End | d | char | 95 |

### 3.1.3 Binary NAVI positioning data protocol

IM19 runs multiple parallel Kalman filters internally to fuse the MEMS IMU raw data and the GNSS data. The fusion result is output in the NAVI message protocol. The message includes estimated latitude, longitude and height, NED (north-east-down) velocity (m/s), Euler angle (RAD), gyroscope biases (RAD /s), and accelerometer biases (m/s^2). The final coordinates can be mapped to any point on the RTK pole according to Euler angles and specified RTK pole vector to accomplish functions such as tilt measurement. The protocol uses the little-endian mode.

| | Data | Type | Relative position |
|---|---|---|---|
| Header | f | char | 1 |
| Header | m | char | 2 |
| Header | i | char | 3 |
| Data Type | n | char | 4 |
| Field 1 | hhmmss.ss | double | 5 |
| Field 2 | Latitude | double | 13 |
| Field 3 | Longitude | double | 21 |
| Field 4 | Height | double | 29 |
| Field 5 | North velocity | float | 37 |
| Field 6 | East velocity | float | 41 |
| Field 7 | Downward velocity | float | 45 |
| Field 8 | Roll | float | 49 |
| Field 9 | Pitch | float | 53 |

| | | | |
|---|---|---|---|
| Field 10 | Yaw | float | 57 |
| Field 11 | Position quality | float | 61 |
| Field 12 | Acceleration X-axis bias | float | 65 |
| Field 13 | Acceleration Y-axis bias | float | 69 |
| Field 14 | Acceleration Z-axis bias | float | 73 |
| Field 15 | Gyroscope X-axis bias | float | 77 |
| Field 16 | Gyroscope Y-axis bias | float | 81 |
| Field 17 | Gyroscope Z-axis bias | float | 85 |
| Field 18 | Sensor temperature | float | 89 |
| Field 19 | **STATUS** | uint32_t | 93 |
| Check sum | 1-96Byte Sum | uint16_t | 97 |
| End | e | char | 99 |
| End | d | char | 100 |

### 3.1.4 ASCII format NAVI Inertial positioning data protocol

Besides the previously mentioned binary format, NAVI message can also be output in the following ascii format:

$GPFMI,UTC, Lat, Lon, HGT, ROLL, PITCH, YAW, HRMS, NSAT, AGEDIFF, NAVMOD, STATUS*CHECKSUM

The ASCII format message has the same meaning with 3.1.3. The checksum calculation is consistent with NMEA 0813 checksum algorithm. HRMS, NSAT, AGEDIFF, NAVMOD are GNSS location information acquired by IM19.

### 3.1.5 Detailed description of Status in NAVI message

In both 3.1.3 and 3.1.4, the STATUS word is defined with the following meanings:

| NAVI DATA STATUS LIST | | | |
|---|---|---|---|
| NO | Name | Location | Description |
| 1 | Finit | 0X00000001 | Filter uninitialized flag |
| 2 | Ready | 0X00000002 | Filter convergence completion flag |
| 3 | Inaccurate | 0X00000004 | Filter convergence process |
| 4 | TiltReject | 0X00000008 | Tilt angle over threshold |
| 5 | GnssReject | 0X00000010 | RTK data poor quality |
| 6 | FReset | 0X00000020 | Filter reset flag |
| 7 | FixRlsStage1 | 0X00000040 | Installation angle estimation stage 1 |
| 8 | FixRlsStage2 | 0X00000080 | Installation angle estimation stage 2 |
| 9 | FixRlsStage3 | 0X00000100 | Installation angle estimation stage 3 |
| 10 | FixRlsStage4 | 0X00000200 | Installation angle estimation stage 4 |
| 11 | FixRlsOK | 0X00000400 | Installation angle estimation complete |
| 12 | Direction1 | 0X00002000 | Shake RTK pole to initialize direction 1 |
| 13 | Direction2 | 0X00004000 | Shake RTK pole to initialize direction 2 |

| | | | |
|---|---|---|---|
| 14 | GnssLost | 0X00010000 | Invalid RTK data or RTK data missing |
| 15 | FInitOk | 0X00020000 | Filter initialization completed |
| 16 | PPSReady | 0X00040000 | PPS signal detected |
| 17 | SyncReady | 0X00080000 | Module time synchronized with PPS |
| 18 | GnssConnect | 0X00100000 | Serial connection with RTK established |

NOTICE:

7-11: The module supports the calibration compensation function of the RTK pole, indicating the calibration status through fields 7 to 11.

12-13:The pole shaking direction field is used during the initialization phase to indicate that the user needs to turn the RTK pole 90°. Here is how it works:
If the device has not been factory calibrated, after IM19 time synchronization and RTK fixed solutions, shake the RTK pole forward and backward for 3-5 seconds, rotate the RTK pole by 90° and shake again forward and backward for another 3-5 seconds to complete the initialization.

16-18: IM19 module requires time synchronization with RTK receiver. This is done by the host MCU configuring the RTK receiver to output 1PPS signal (falling edge is assumed by default) and corresponding RTK data.

### 3.2 Configuration instruction sets

The module can be configured through serial port 1 or 3. The command structure is as follows:

AT+COMMAND[=][PARA1],[PARA2],[PARA3]\r\n

Where, all letters are uppercase, [] is an optional parameter inside. Configuration will be lost after power cycle unless explicitly saved. The default baud rate is 115200bps. The basic response to the command is:

\r\n OK\r\n\r\n\r\n or Error\r\n\r\n

### 3.3 Configuration instruction set overview

| Instruction overview | |
|---|---|
| AT+SYSTEM_RESET | System reset |
| AT+SAVE_ALL | Save the parameters |
| AT+UPDATE_APP | Update module firmware, see attachment for protocols |
| AT+UPDATE_BOOT | Update Bootloader, see attachment for protocols |
| AT+GNSS_CARD=OEM | Set the GNSS RTK receiver type |
| AT+READ_PARA=SYSTEM/ALL | Read parameters (SYSTEM/ALL) |
| AT+LOAD_DEFAULT | Loading default parameters |
| AT+AUTO_FIX=ENABLE/DISABLE | Installation angle estimation in tilt measurement applications |
| AT+CLUB_VECTOR=X,Y,Z | Set the RTK pole vector to map the position to the end of the RTK pole |

| | |
|---|---|
| AT+NAVI_OUTPUT=UART1,ON/OFF | Binary NAVI positioning output |
| AT+NASC_OUTPUT=UART1,ON/OFF | Ascii type NAVI positioning output |
| AT+MEMS_OUTPUT=UART1,ON/OFF | MEMS raw output |
| AT+GNSS_OUTPUT=UART1,ON/OFF | GNSS raw output |
| AT+LEVER_ARM =X,Y,Z | Set the lever arm |
| AT+LEVER_ARM2 =X,Y,Z | Set the lever arm, the input value will be automatically adjusted according to the estimated installation angle |
| AT+CHECK_SYNC | Query whether time is synchronized between MEMS and GNSS |
| AT+HIGH_RATE=ENABLE/DISABLE | High-rate mode setting |
| AT+ACTIVATE_KEY=KEY | Module activation |
| AT+ALIGN_VEL=1.0 | Set the initial alignment speed threshold |
| AT+VERSION | Query the Firmware version |
| AT+GNSS_PORT=PHYSICAL_UART2 | Set the physical serial port for communicating with the GNSS RTK receiver. Save the Settings and restart to take effect |
| AT+WORK_MODE=X | Set the module working mode |
| AT+INSTALL_ANGLE=X,Y,Z | Set the module installation angle |
| AT+THIS_PORT | Query the serial port number |
| AT+FILTER_STOP=ENABLE/DISABLE | Causes the filter to enter or exit stop mode |
| AT+LOOP_BACK=UARTn/NONE | UART n enters or exits the loopback mode |
| AT+FILTER_RESET | Filter Reset |
| AT+CHECK_CRC=N | The IM19 firmware CRC is calculated for checking the firmware, where N is the firmware size |
| AT+CORRECT_HOLDER= ENABLE/DISABLE | Turn on or off RTK pole length compensation |
| AT+DISABLE_OUTPUT=UARTx | Disable the output of all messages over the serial port x |
| AT+CALIBRATE_MODE2=STEP1/STEP2 | Factory calibration command |

### 3.4 Instruction details

#### (1) AT+GNSS_CARD=OEM

Set the type of GNSS RTK receiver. There are four types: Hemisphere board, NOVTEL board, UNICORE board, and Universal board OEM.

Set it to HEMI board, input the Bin3 message.

Set it to UNICORE board, input BESTPOSB, PSRVELB and GPGGA.

Set it to OEM board, input GPGGA, GPRMC, and GPGST.

Set it to NOVTEL board, input BESTPOSB, BESTVELB and GPGGA, set the velocity to Doppler velocity.

NOTICE:

The doppler derived velocity is required from the rtk receiver.

The leap second compensation of time in NAVI positioning data protocol is 18 s, when the GNSS board is hemi, unicore, novtel and all other GNSS type, besides OEM type.

**(2) AT+AUTO_FIX=ENABLE**

In tilt RTK surveys, angle misalignment of installation can be estimated by this command. Note that this command will only work when the filter is in the Ready state after the filter has converged and stabilized. Automatically return to DISABLE state when estimation is complete.

**(3) AT+CLUB_VECTOR= X,Y,Z**

The IM19 module supports mapping position of GNSS antenna phase center to any specified position according to the current attitude. When mapping, you need to set the mapping vector. The origin of the vector coordinate system is at the center of the antenna phase, and the direction of the coordinate axis is defined in section 1.4.

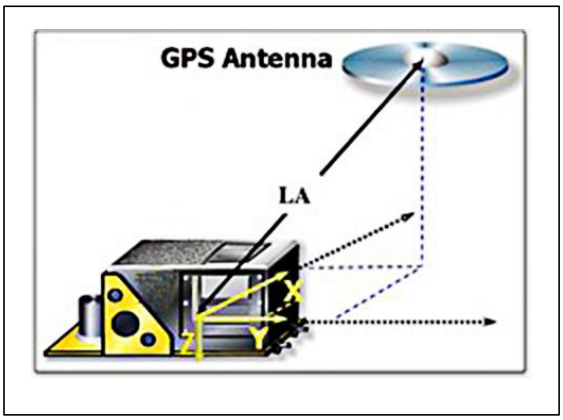
**(4) AT+LEVER_ARM=X,Y,Z**

**(5) AT+LEVER_ARM2=X,Y,Z**

Generally speaking, the phase center position of the GNSS antenna does not coincide with the origin of the MEMS sensor coordinate. When moving, the position and velocity measured by GNSS RTK are not same as measurement value by the MEMS sensor. Therefore, it is necessary to carry out a mapping to solve this problem. The origin of coordinate and direction of the coordinate axis are defined as section 1.4.

As shown in the figure below, User need set the 3D coordinates (X, Y, Z) of the RTK antenna phase center in IMU coordinate system, which can be set by this command.

Note: If the antenna is above the IMU, the Z value is negative, otherwise, the Z value is positive.




When setting the lever arm parameters by AT+LEVER_ARM2, the lever arm parameters will be internally rotated according to the currently installation angle. Therefore, the lever arm parameters should be measured in the default coordinate system of the module.

**(6) AT+HIGH_RATE=ENABLE**

High-rate mode enables NAVI data output at 100Hz for high dynamics and low latency applications. Accuracy can be degraded in this mode for better dynamics performance. It is recommended to set high-rate mode only in applications with high real-time requirements, and do NOT use high-rate mode in applications where accuracy is paramount, such as RTK surveying.

### (7) AT+LOOP_BACK=UART1

You can use this command to make the serial port enter loopback mode, and the serial port will return the received data to test whether the serial port is connected. This configuration will not be saved, and disappeared after power reset.

### (8) AT+FILTER_STOP=ENABLE

By issuing this command, IM19 module can enter a suspended mode where the filter initialization is prevented. If the IM19 filter is already running, the filter is reset and then goes into suspended state. This feature can be used to wait for a specific user input before starting the normal operation of the module.

### (9) AT+WORK_MODE=X

Config the work mode of module, the default work mode is tilt mode 1.

Tilt mode 1: Set X = 152, initialize tilt survey by shaking the RTK pole back and forth with the end of pole fixed on the ground.

Tilt mode 2: Set X = 408, initialize by shaking the RTK pole back and forth or by simply walking. Shaking initialization (same as mode 1) is required when the RTK tilt survey is used for the first time （as an calibration）.

Tilt mode 3: Set X = 410, initialize by shaking or walking. Shaking initialization is required (first time tilt survey is used), however in this mode a RTK pole is not required, you can shake the integrated product by hand within a relatively large spatial distribution.

Vehicle Mode: Set X = 13, this mode is used in vehicle DR application.

Heading mode: Set X = 72, this mode is used in agriculture machine automation.

## 4. Tilt survey mode configuration flow

Please send the following commands after booting. The commands listed below set the

1. AT+NAVI_OUTPUT=UART1,ON
2. AT+LEVER_ARM=0,0,0
3. AT+CLUB_VECTOR=0,0,1.855
4. AT+GNSS_CARD=HEMI
5. AT+WORK_MODE=152
6. AT+SAVE_ALL

**Note**:

1. Send AT+INSTALL_ANGLE=180,0,0 If the IM19 module is mounted on the back of the GNSS receiver (so the IM19 faces downward instead of upward), before sending the save command.

2. Communication serial port, GNSS receiver type, LEVER ARM and CLUB_VECTOR (RTK pole) should be set according to the specific hardware implementation.

## 5. The actual use flow of the tilt measurement mode

When the RTK tilt survey system is powered on, the GNSS receiver outputs an integer-fixed solution and a 1PPS signal. Make sure the end of the RTK pole is placed on the

ground and does not move. Shake the RTK pole back and forth for 2 to 3 times. The IM19 module will alter the positioning status to initialization complete, and the user can start tilt survey.

Notice:

If the installation angle has not been calibrated in the factory, when initializing in the first time, you need to rotate the RTK pole by 90°according to the prompt given by IM19 to complete the initialization. If the device is used continuously, 90° rotation do not required.

## 6. SMT Precautions

The IM19 modules need to be baked at a low temperature to remove water vapor before SMT. It takes at least 24 hours to bake at 60℃ before SMT. Detailed SMT furnace temperature control see reference document: IM19_P20 SMT requirements.pdf

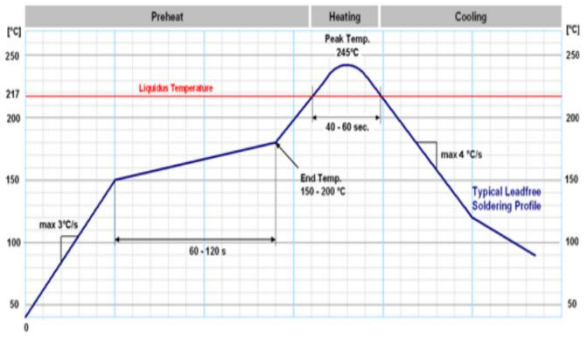



Table 1 smt temperature curve