



# IM19EE Product Integration Guide

v1.4.1



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v1.4.1	12-2023	LQ
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v1.1	07-2020	LQ
v1.0	01-2019	LQ



The FMI IM19EE 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 IM19EE widespread uses in industrial applications such as tilt RTK surveys (where RTK poles need not be held straight vertical as IM19EE can calculate a virtual digital level at any tilt angles) , agriculture machine automation, and dead reckoning.



## 1. Specifications

IM19EE	
Acceleration range	$\pm 8g$
Gyroscope range	$\pm 1000\text{deg/s}$
Attitude accuracy	$\pm 0.05\text{deg}$
Heading accuracy	$\pm 0.5\text{deg}$
Accelerometer bias accuracy	$\pm 5\text{mg}$
Gyroscope bias accuracy	$\pm 0.2\text{deg/s}$
Tilt survey accuracy	1cm with up to $30^\circ$ tilt angle
Tilt survey initialization time	1 second (95%)
Ag auto steering yaw	$0.5^\circ$



## 2. Hardware Instructions

### 2.1 Electrical

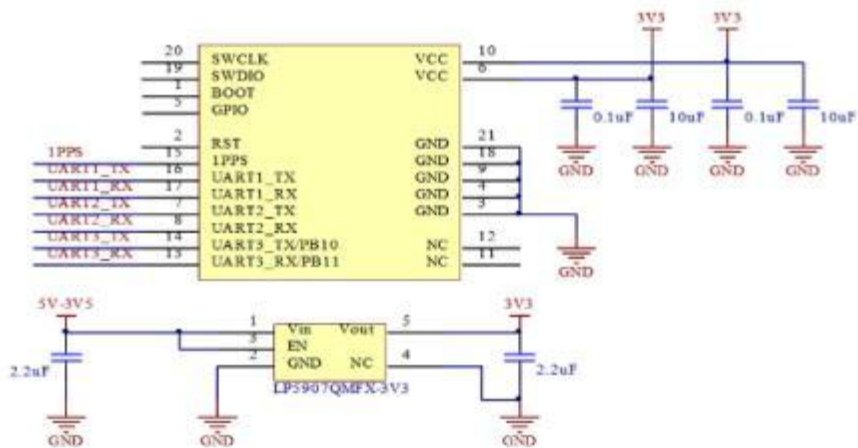
	MIN	TYP	MAX	UNITS
Supply voltage	3.0	3.3	3.6	Volt
Current consumption	120	130	140	mA

### 2.2 Pin assignment

Pin	Name	Description (All ports voltage is 3.3V)
1	BOOT	Start modes High: BOOT mode; 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

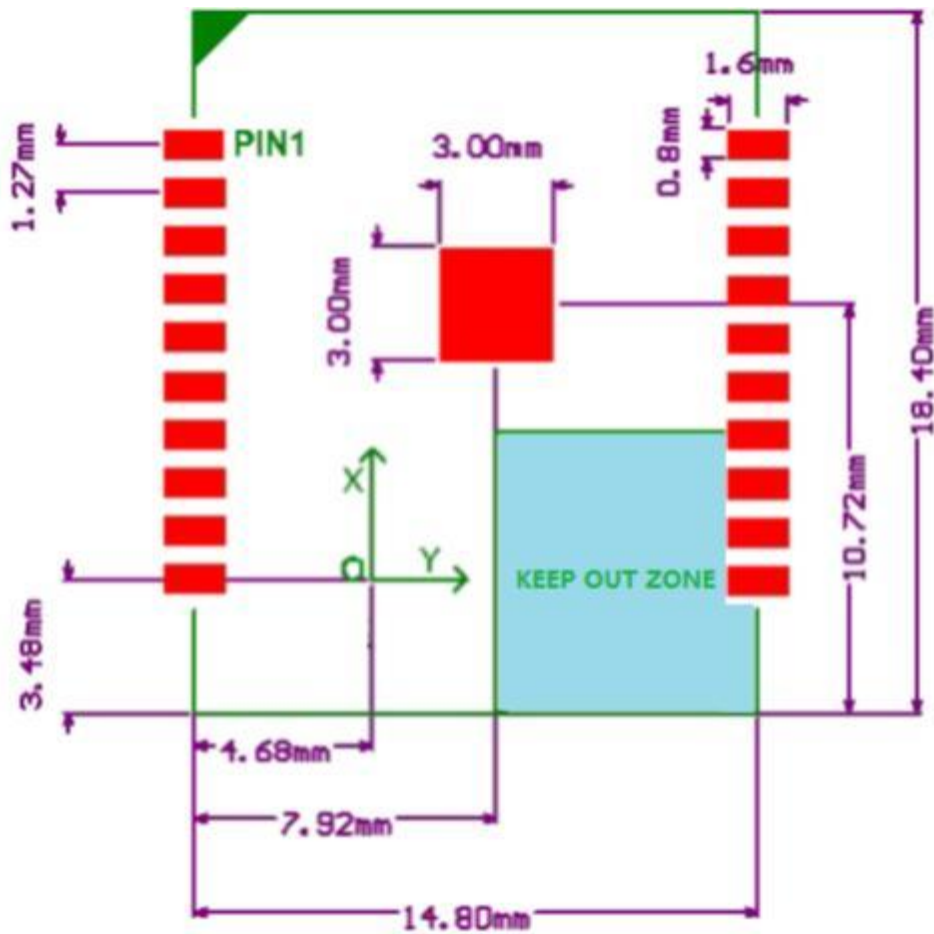
### 2.3 Reference design

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  $3.2 \pm 0.1\text{mm}$ , the size of the edge pad is  $1.6\text{mm} \times 0.8\text{mm}$ , the size of the middle pad is  $3\text{mm} \times 3\text{mm}$ . It is recommended to place the IM19EE module in a stable temperature region to avoid convection with the outside air, and it is strictly forbidden external stress on the module. The coordinate system is defined by the right-hand





### 3. Software development instructions

#### 3.1 Communication protocol

##### 3.1.1 MEMS Raw data protocol

IM19EE 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 IM19EE 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 IM19EE.

	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	Latitude(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

IM19EE 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<sup>2</sup>). 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	<b>STATUS</b>	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 IM19EE.

### 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	FlnitOk	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 IM19EE 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\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 IM19EE 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+OUTPUT_DISABLE=UARTx	Disable the output of all messages over the serial port x
AT+CALIBRATE_MODE2=STEP1/STEP2	Factory calibration command
AT+SET_CHECK_LEVEL=LEVELx	Set check level of calibration parameter
AT+FACTORY_PARA_x=X,Y,Z	Recovery factory calibration parameter
AT+SET_PPS_EDGE=RISING/FALLING	Set PPS edge, accept falling pps edge by default

### 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:

5Hz location data is required at least.

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 IM19EE 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.

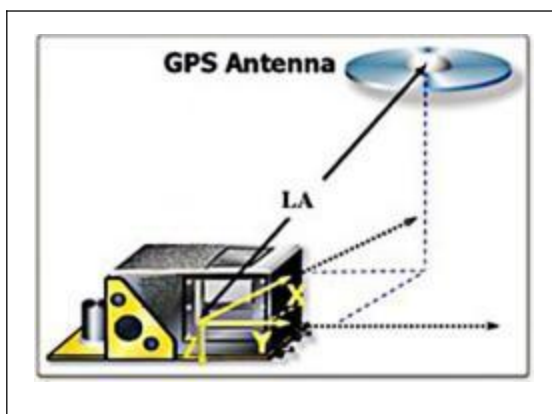
#### (4) AT+LEVER\_ARM=X,Y,Z

#### (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, IM19EE module can enter a suspended mode where the filter initialization is prevented. If the IM19EE 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(default), 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(optional with authorization code), 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(optional with authorization code), 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(optional with authorization code), this mode is used in vehicle DR application.

Heading mode: Set X = 72(optional with authorization code), 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 IM19EE module is mounted on the back of the GNSS receiver (so the IM19EE faces downward instead of upward), before sending the save command.

2. Communication serial port, GNSS receiver type, LEVER ARM and CLUB\_VECTOR (RTK



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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 1 to 2 times. The IM19EE module will alter the positioning status to initialization complete, and the user can start tilt survey.

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 IM19EE to complete the initialization. If the device is used continuously, 90° rotation do not required.



## 6. SMT Precautions

The IM19EE 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°C before SMT. Detailed SMT furnace temperature control see reference document: IM19EE\_P20 SMT requirements.pdf

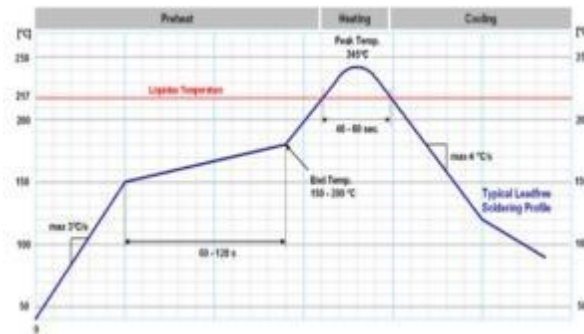


Table 1 smt temperature curve