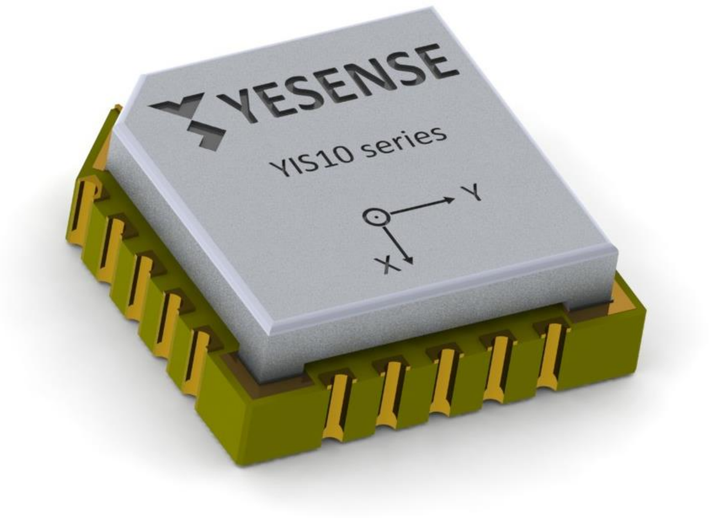
YIS10 series Data sheet

3D AHRS/VRU/IMU module

Document Version 2.0, 30 October 2018



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CONTENT

1. General information

1.1 Description

The YIS10 series is a module outputting 3D orientation, 3D angular rates, 3D accelerations and 3D magnetic field. It is available as an Inertial Measurement Unit (IMU), Vertical Reference Unit (VRU) or Attitude and Heading Reference System (AHRS).
The Robust and accurate orientation algorithm (YFusion®) is embedded in the YIS10, including robust and accurate orientation estimation, online error estimation and active orientation stabilization, providing stable and real time attitude and heading information.
YIS10 is compatible with JEDEC PLCC20 IC-sockets. With a roll/pitch accuracy of 0.5º RMS and yaw accuracy of 1º RMS under dynamic conditions, the output is excellent for control and stabilization of any object and navigation of e.g. unmanned vehicles.

1.2 Features

- Roll/pitch accuracy：0.5 º
- Yaw accuracy：1 º
- Low power and low noise
- Real time dynamic sensing
- YFusion® orientation algorithm
- PLCC20 compatible
- Size：9.5mm × 9.5mm × 2.6mm

1.3 Applications

- Unmanned aerial vehicle control and navigation
- Robotics, pedestrian dead-reckoning
- VR/AR, HMD’s and handheld devices
- Sports science analysis, assistant training

1.4 Frames of reference used in YIS10

The YIS10 series module uses a right-handed coordinate system as the basis of the sensor of frame. The following data is the output in corresponding reference coordinate systems:

Data	Symbol	Reference coordinate system
Acceleration	a_x, a_y, a_z	Sensor-fixed
Angular rate	ω_x, ω_y, ω_z	Sensor-fixed
Magnetic field	m_x, m_y, m_z	Sensor-fixed

Orientation	Pitch, roll and yaw	Local geographic coordinate system (ENU)

The sensor fixed coordinate system is shown in Figure 1:

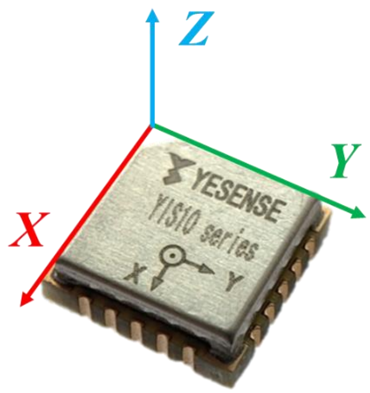

Figure 1. The sensor fixed coordinate system of YIS10

The default local geographic coordinate system is East-North-Up (ENU), and the outputs of YIS10 are default outputted with ENU reference coordinate system.

2. YIS10 series configuration

The YIS10 series is a fully-tested self-contained module that can output 3D orientation data (Euler angles (roll, pitch, yaw) and quaternions), orientation and velocity increments (Δq and Δv) and sensors data (acceleration, rate of turn, magnetic field). The YIS10 series module is available as an Inertial Measurement Unit (IMU), Vertical Reference Unit (VRU) and Attitude and Heading Reference System (AHRS).

2.1 YIS10-U (IMU)

The YIS10-U module is an Inertial Measurement Unit (IMU) that outputs 3D rate of turn, 3D acceleration and 3D magnetic field. The YIS10 also outputs coning and sculling compensated orientation increments and velocity increments (Δq and Δv). Moreover, the testing and calibration over temperature performed by Yesense result in a robust and reliable sensor module.

2.2 YIS10-V (VRU)

The YIS10-V is a 3D vertical reference unit (VRU). Its orientation algorithm (YFusion™) outputs 3D orientation data with respect to a gravity referenced frame: drift-free roll, pitch and unreferenced yaw. In addition, it outputs calibrated sensor data: 3D acceleration, 3D rate of turn and 3D magnetic field data. The YIS10-V is also capable of outputting data of orientation and velocity increments Δq and Δv. The 3D acceleration is also available as so-called free acceleration which has gravity subtracted.

2.3 YIS10-A (AHRS)

The YIS10-A supports all features of the YIS10-U and YIS10-V. It outputs drift-free roll, pitch and true/magnetic North referenced yaw and sensors data: 3D acceleration, 3D rate of turn, as well as 3D orientation and velocity increments (Δq and Δv), and 3D earth-magnetic field data. Free acceleration is also available.

Output data	YIS10-U IMU	YIS10-V VRU	YIS10-A AHRS
Calibrated sensor data	●	●	●
Roll/pitch		●	●
Unreferenced yaw		●	●
North referenced yaw			●

3. 3D Orientation and performance specifications

3.1 3D Orientation specifications

Table 1. Orientation specifications

Parameters		Typ	Unit	Comments
Roll/pitch	Static	0.25	°	1σ RMS
	Dynamic	0.5	°	1σ RMS
Yaw (heading)	VRU	1	°	1σ RMS[1]
	AHRS	1	°	1σ RMS in a homogenous magnetic field
Output data rate		100	Hz	

3.2 Sensors specifications[2]

Table 2. Gyroscope specifications

Parameters	Typ	Unit	Comments
Full range	±2000	°/s	
Non-linearity	±0.1	% FS	
Noise density	0.004	°/s/√Hz	@10Hz
Bias variation vs. temperature	±0.01	°/s/°C	
Sensitivity variation vs. temperature	±2	%	

Table 3. Accelerometers specifications

Parameters	Typ	Unit	Comments
Full range	±16	g	
Non-linearity	±0.3	% FS	
Noise density	100	ug/√Hz	@10Hz
Bias variation vs. temperature	±0.5	mg/°C	X,Y axes
	±1		Z axis
Sensitivity variation vs. temperature	±1.5	%	

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[1] With active orientation stabilization in YFusion®, the yaw error will be less than 1 degree after 60 min in static case, and less than 1 degree per min in moderate dynamics case at room temperature.

[2] These specifications may change as the update of the sensors on the module.

Table 4. Magnetometer specifications

Parameters	Typ	Unit	Comments
Full range	±49	Gauss	
RMS Noise	3	mG	RMS
Sensitivity variation vs. temperature	±0.03	%/°C	

3.3 System specifications

Table 5. System specifications

Parameters	Typ	Unit	Comments
Size	9.5 × 9.5 × 2.6	mm	PLCC20 compatible
Weight	0.5	g	
Input voltage	2.5~3.6	V	
Specified performance operating temperature	0~60	°C	
Operating temperature	-40 ~ +85	°C	
Power consumption	75	mW	@3.3V
Timing accuracy	10	ppm	

3.4 Interface specifications

Table 6. Communication interfaces

Interface		Typ	Unit	Comments
UART	Baud Rates	460800	bps	

4. Sensor calibration

Each YIS is individually calibrated and tested. The (simplified) sensor model of the gyroscopes, accelerometers and magnetometers can be represented as following:

$$\mathbf{u} = \mathbf{H} \cdot \mathbf{y} + \mathbf{b}$$

$\mathbf{u}$ = sensor data of the gyroscopes, accelerometers and magnetometers in °/s, m/s^2 or mGauss, respectively

$\mathbf{y}$ = sensor value before calibration

$\mathbf{H}$ = gain and misalignment matrix

$\mathbf{b}$ = bias

Yesense' calibration procedure calibrates for many parameters, including bias (offset), alignment of the sensors with respect to the module PCB and each other and gain (scale factor). The calibration values are stored in non-volatile memory in the YIS.

5. YFusion® sensor fusion algorithm

The YFusion™ sensor fusion algorithm is based on Kalman Filter, merging the data from 3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer. YFusion includes robust and accurate orientation estimation, online error estimation and active orientation stabilization.

6. Pin configuration

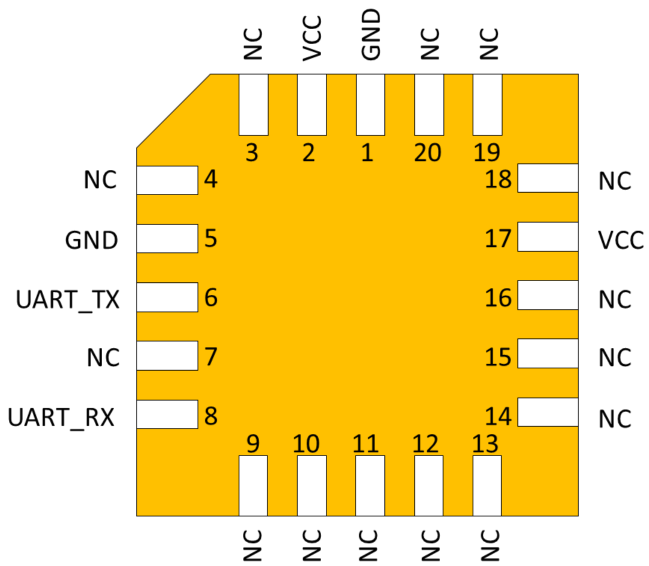

Figure 2. Pin configuration of the YIS10 (top view)

Table 7. Pin map

Pin ID	Pin Name	Description
1	GND	Power Ground
2	VCC	Power Supply
3	NC	Do not connect to this pin
4	NC	Do not connect to this pin
5	GND	Power Ground
6	UART_TX	Transmitter data output
7	NC	Do not connect to this pin
8	UART_RX	Receiver data input
9	NC	Do not connect to this pin
10	NC	Do not connect to this pin
11	NC	Do not connect to this pin
12	NC	Do not connect to this pin
13	NC	Do not connect to this pin
14	NC	Do not connect to this pin
15	NC	Do not connect to this pin

16	NC	Do not connect to this pin
17	VCC	Power Supply
18	NC	Do not connect to this pin
19	NC	Do not connect to this pin
20	NC	Do not connect to this pin

7. Package and handing

Note that this is a mechanical shock (g) sensitive device. Proper handling is required to prevent damage to the part.
Note that this is an ESD-sensitive device. Proper handling is required to prevent damage to the part.
Make sure not to apply force on the components of the YIS10 series module, especially when placing the YIS10 series module in an IC-socket.

7.1 Package drawing

The YIS10 series module is compatible with JEDEC PLCC20 IC-sockets.

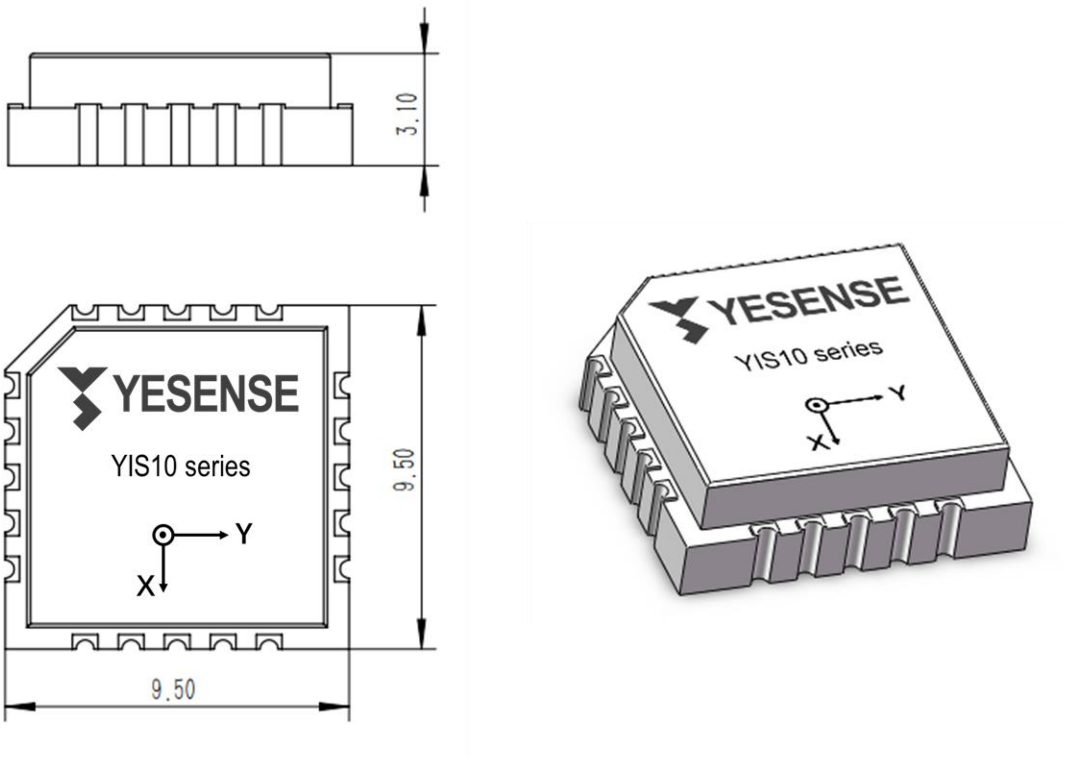

Figure 3. Package drawing (general tolerances are +/- 0.1 mm)

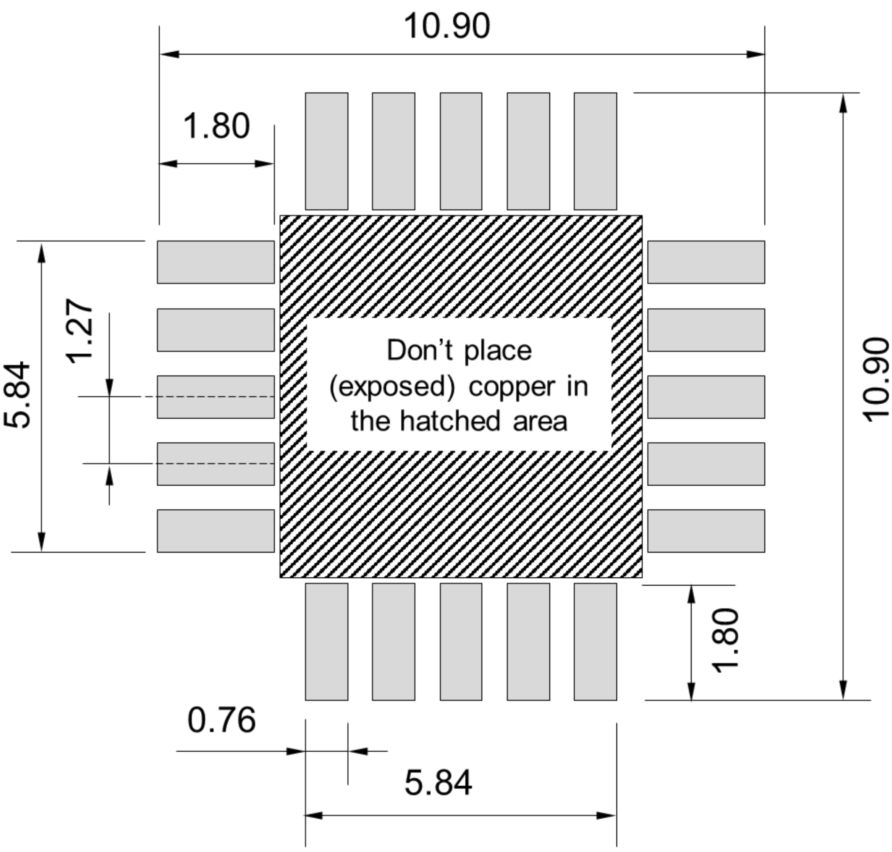

Figure 4. Recommended YIS10 series module footprint

7.2 Mounting considerations

The module contains a MEMS (Micro Electro Mechanical System) chip and is therefore sensitive for stress applied on the PCB. To minimize stress apply the following design rules for the PCB and housing.

Avoid stress on the PCB by screwing/mounting it in a housing, applying unequal or excessive forces to the mounting positions. Ideally the PCB should be mounted using mechanical dampeners.

- Avoid force applied on the PCB by push buttons, connectors etc. close to the YIS10 series module.
- Avoid heat sources close to the YIS10 series
- Avoid vibrations caused by speaker, buzzer etc.

7.3 Soldering

7.3.1 Soldering paste

Use of “No Clean” and “Lead-free” soldering paste is strongly recommended, as it does not require cleaning after the soldering process has taken place.

7.3.2 Reflow soldering

A convection type soldering oven is highly recommended over the infrared type radiation oven.
Convection heated ovens allow precise control of the temperature and all parts will be heated up evenly, regardless of material properties, thickness of components and surface color.

7.3.3 Preheat

Initial heating of component leads and balls. Residual humidity will be dried out. Note that this preheat phase will not replace prior baking procedures.

- Temperature rise rate: max 3° C/s. If the temperature rise is too rapid in the preheat phase it may cause excessive slumping.
- Time: 60 – 120 s. If the preheat is insufficient, rather large solder balls tend to be generated. Conversely, if performed excessively, fine balls and large balls will be generated in clusters.
- End Temperature: 150 – 200° C, 180° C is recommended. If the temperature is too low, non-melting tends to be caused in areas containing large heat capacity.

7.3.4 Heating/Reflow

The temperature rises above the liquidus temperature of 217° C. Avoid a sudden rise in temperature as the slump of the paste could become worse.

- Temperature rise/fall rate: max 2 ° C/s.
- Limit time above 217° C liquidus temperature: 40 – 60 s.
- Peak reflow temperature: 250° C.

7.3.5 Cooling

A controlled cooling avoids negative metallurgical effects (solder becomes more brittle) of the solder and possible mechanical tensions in the products. Controlled cooling helps to achieve bright solder fillets with a good shape and low contact angle.

- Temperature fall rate: max 4° C/s.

7.3.6 Optical inspection

After soldering the YIS10 modules, consider an optical inspection step to check whether:

- The module is properly aligned and centered over the pads.
- All pads are properly soldered.
- No excess solder has created contacts to neighboring pads, or possibly to pad stacks and vias nearby.

7.3.7 Cleaning

In general, cleaning the populated modules is strongly discouraged. Residues underneath the modules cannot be easily removed with a washing process.

The best approach is to use a “no clean” soldering paste and eliminate the cleaning step after the soldering. Note that ultrasonic cleaning will permanently damage the module, in particular the oscillators and MEMS chips.

7.3.8 Repeated reflow soldering

Only single reflow soldering processes are recommended. YIS10 modules should not be submitted to two reflow cycles on a board populated with components on both sides in order to avoid upside down orientation during the second reflow cycle. In this case, the module should always be placed on that side of the board, which is submitted into the last reflow cycle. The reason for this (besides others) is the risk of the module falling off due to the significantly higher weight in relation to other components.

7.3.9 Hand soldering

Hand soldering is allowed. Use a soldering iron temperature-setting equivalent to 350° C. Place the module precisely on the pads. Start with a diagonal fixture soldering (e.g. pins 1 and 11), and then continue in clockwise.

7.3.10 Rework

The YIS10 modules can be unsoldered from the baseboard using a hot air gun. When using a hot air gun for unsoldering the module, a maximum of one reflow cycle is allowed. In general, we do not recommend using a hot air gun because this is an uncontrolled process and might damage the module.

After the module is removed, clean the pads before placing and hand soldering a new module.

In addition to the two reflow cycles, manual rework on particular pins by using a soldering iron is allowed. Manual rework steps on the module can be done several times.

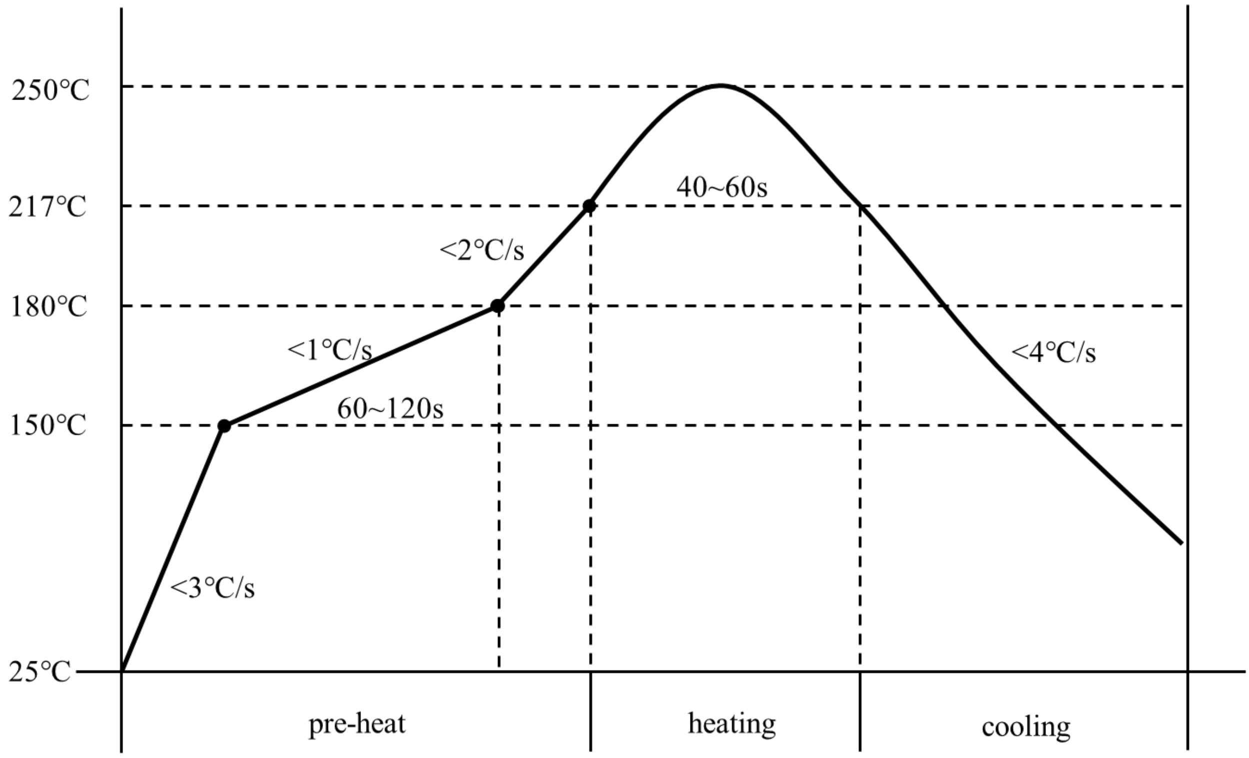

Figure 5 Recommended soldering profile

8. Basic operation

8.1 Communication interface

Interface		Value	Unit
UART	Baudrate	460800	bps

8.2 Message structure

An YIS message contains the following fields：

YS Header	TID	LEN	MESSAGE	CK1	CK2
Dec 89 83 Hex 59 53	2 Bytes Message TID	Length of Message (1 Byte) excluding YS Header, TID	Message size depend on Len filed	two bytes checksum	

Table 8. YIS message structure

Type	LEN(Bytes)	Description
YS Header	2	Indicators of start of YIS message,0x59, 0x53
TID	2	Message identifier，Maximum value is 60000(0xEA60)
LEN	1	Length of YIS message， Maximum value is 255(0xFF)
MESSAGE	0-255	Data bytes
CK1	1	CK1 of checksum
CK2	1	CK2 of checksum

.

Table 9. DATA structure

Packet 1			……	Packet N		
DATA ID	LEN	DATA(LEN Bytes)	……	DATA ID	LEN	DATA(LEN Bytes)

DATA is a list of several packets. Each packet consists of a unique DATA ID, values and the length of values.

Table 10. Packet structure

DATA NAME	DATA ID	LEN	DATA
Acceleration	0x10	12	DATA1 – DATA12
Angular velocity	0x20	12	DATA1 – DATA12
Normalized Magnetic field	0x30	12	DATA1 – DATA12
Magnetic field	0x31	12	DATA1 – DATA12
Euler angles	0x40	12	DATA1 – DATA12
Quaternion	0x41	16	DATA1 – DATA16

Table 11. Value and conversion

Type	Value	Conversion	Unit
Acceleration	DATA1(DATA[7:0])	ax = DATA × 0.000001	m/s^2
	DATA2(DATA[15:8])		
	DATA3(DATA[23:16])		
	DATA4(DATA[31:24])		
	DATA5(DATA[7:0])	ay = DATA × 0.000001	
	DATA6(DATA[15:8])		
	DATA7(DATA[23:16])		
	DATA8(DATA[31:24])		
	DATA9(DATA[7:0])	az = DATA × 0.000001	
	DATA10(DATA[15:8])		
	DATA11(DATA[23:16])		
	DATA12(DATA[31:24])		
Angular velocity	DATA1(DATA[7:0])	wx = DATA × 0.000001	deg/s
	DATA2(DATA[15:8])		
	DATA3(DATA[23:16])		
	DATA4(DATA[31:24])		
	DATA5(DATA[7:0])	wy = DATA × 0.000001	
	DATA6(DATA[15:8])		
	DATA7(DATA[23:16])		
	DATA8(DATA[31:24])		
	DATA9(DATA[7:0])	wz = DATA × 0.000001	
	DATA10(DATA[15:8])		
	DATA11(DATA[23:16])		
	DATA12(DATA[31:24])		
Normalized Magnetic field	DATA1(DATA[7:0])	mx = DATA × 0.000001	
	DATA2(DATA[15:8])		
	DATA3(DATA[23:16])		
	DATA4(DATA[31:24])		
	DATA5(DATA[7:0])	my = DATA ×0.000001	

	DATA6(DATA[15:8])		
	DATA7(DATA[23:16])		
	DATA8(DATA[31:24])		
	DATA9(DATA[7:0])	mz = DATA ×0.000001	
	DATA10(DATA[15:8])		
	DATA11(DATA[23:16])		
	DATA12(DATA[31:24])		
Magnetic field	DATA1(DATA[7:0])	mx = DATA × 0.001	mGauss
	DATA2(DATA[15:8])		
	DATA3(DATA[23:16])		
	DATA4(DATA[31:24])		
	DATA5(DATA[7:0])	my = DATA × 0.001	
	DATA6(DATA[15:8])		
	DATA7(DATA[23:16])		
	DATA8(DATA[31:24])		
	DATA9(DATA[7:0])	mz = DATA × 0.001	
	DATA10(DATA[15:8])		
	DATA11(DATA[23:16])		
	DATA12(DATA[31:24])		
Euler angles	DATA2(DATA[15:8])	pitch = DATA × 0.000001	deg(°)
	DATA3(DATA[23:16])		
	DATA4(DATA[31:24])		
	DATA5(DATA[7:0])		
	DATA6(DATA[15:8])	roll = DATA × 0.000001	
	DATA7(DATA[23:16])		
	DATA8(DATA[31:24])		
	DATA9(DATA[7:0])		
	DATA10(DATA[15:8])	yaw = DATA × 0.000001	
	DATA11(DATA[23:16])		
	DATA12(DATA[31:24])		
	DATA12(DATA[31:24])		
Quaternion	DATA1(DATA[7:0])	q0 = DATA × 0.000001	
	DATA2(DATA[15:8])		
	DATA3(DATA[23:16])		
	DATA4(DATA[31:24])		
	DATA5(DATA[7:0])	q1 = DATA × 0.000001	
	DATA6(DATA[15:8])		
	DATA7(DATA[23:16])		
	DATA8(DATA[31:24])		
	DATA9(DATA[7:0])	q2 = DATA × 0.000001	
	DATA10(DATA[15:8])		
	DATA11(DATA[23:16])		
	DATA12(DATA[31:24])		

	DATA13(DATA[7:0])		
	DATA14(DATA[15:8])		
	DATA15(DATA[23:16])		
	DATA16(DATA[31:24])	q3 = DATA × 0.000001	
	DATA10(DATA[15:8])		
	DATA11(DATA[23:16])		
	DATA12(DATA[31:24])		

8.3 Checksum

The checksum is calculated over the Message, starting and including the TID field, up until, but excluding, the Checksum Field:

YS Header	TID	LEN	MESSAGE	CK1	CK2

Range over which the checksum is to be caculated

The checksum algorithm used is the 8-Bit Fletcher Algorithm, which is used in the TCP standard. This algorithm works as follows:

Buffer[N] contains the data over which the checksum is to be calculated.

The two CK_ values are 8-Bit unsigned integers, only! If implementing with larger-sized integer values, make sure to mask both CK_1 and CK_2 with 0xFF after both operations in the loop.

```
CK1 = 0; CK2 = 0;
For(i=0;i<N;i++)
{
   CK1 = CK1 + buffer[i];
   CK2 = CK2 + CK1;
}
```

9. Revisions

Revision	Date	By	Changes
1.0	2016-05-20	Z. L.	• Initial release
1.1	2016-09-20	Z. L.	• Update communication interface
1.2	2016-10-20	Z. L.	• Add YIS10 series configuration • Add introduction to YFusion™ sensor fusion algorithm
1.3	2017-04-21	Z. L. S. Y.	• Update YIS10 series configuration • Update pin configuration • Update communication interface
1.3.1	2017-05-03	Z. L.	• Update figures of YIS10
1.4	2017-10-26	Z. L	• Update YIS10 series configuration • Update sensors specifications • Update sensor calibration • Update package and handing
1.5	2017-12-12	Z. L	• Update 3D Orientation specifications
1.6	2018-05-10	Z. L	• Update figures of YIS10 • Update package drawing
2.0	2018-10-30	Z. L	• Update the communication protocol