

## Ultra-light Star Sensor (380g)

**Abstract:**

This instruction describes the appearance features, technical specifications, interface definitions and communication protocols of Ultra-light Star Sensor (380g).

Key words: satellite, ultra-light, star sensor, electro-mechanical-thermal interface, communication protocol.

## 1. Appearance

The appearance of Ultra-light Star Sensor is shown as figure1.



Fig1. Ultra-light Star Sensor (380g)

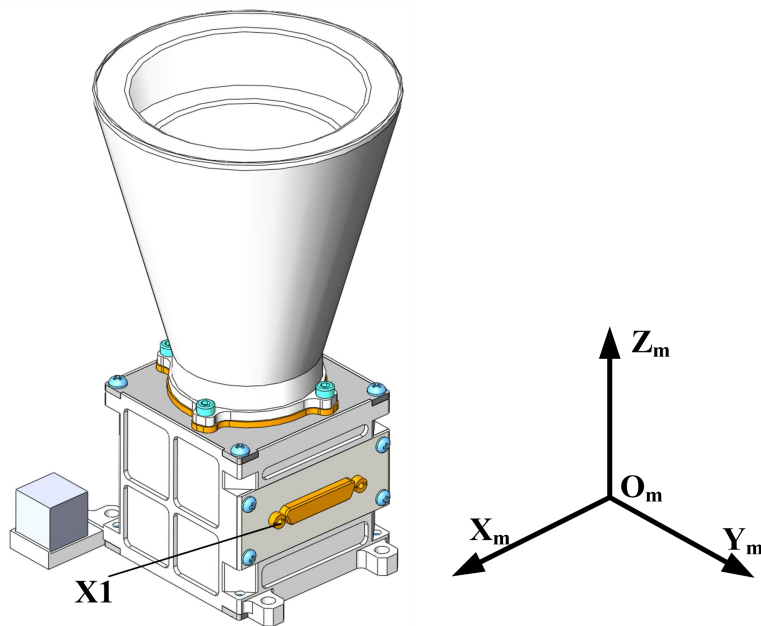


Fig2. Ultra-light Star Sensor (380g)

Where,  $O_m$  is the origin of the coordinate system and cross point of light axis with the photosensitive side of image sensor; generally, it can be considered as the center of photosensitive side of image sensor.  $Z_m$  points to light axis direction,  $Y_m$  points to external connector( $X1$ ),  $X_m$  is determined by right hand rule.  $X_m$ ,  $Y_m$  is parallel to the vertical/horizontal direction of image sensor pixel layout.

## 2. Specifications

Table1 Specifications

technical specification	parameter	remark
field of view	25°×25°	
accuracy	static x, y <3"(3σ) z < 20"(3σ)	
	0.1°/s x, y <6"(3σ) z < 36"(3σ)	
	0.5°/s x, y <18"(3σ) z < 100"(3σ)	
	1.0°/s x, y <30"(3σ) z < 150"(3σ)	
dynamic performance	2°/s traceable	
data update rate	5Hz	
star magnitude sensitivity	5	
spherical capture time for full-time	≤0.2s	
suppression angle of sun light	35°	
power consumption	<3W	
life time	≥1 year	
operating temperature	-20°C to +50°C	
storage temperature	-40°C to to +70°C	

3. Mechanical Interfaces

Table2 Specifications

technical specification	parameter	remark
outline size	(60±0.5)mm×(60±0.5)mm× (55±0.5)mm	
Envelope size (includes baffle and reference mirror )	(97.4±1)mm×(92.8mm±1) ×(157±1)mm	
weight	377g(include reference mirror) 350g( exclude reference mirror)	
mounting size	(92.8±1)mm x (97.4±1)mm	
mounting aperture	4-Φ(4.5±0.1) mm	

4. Power Requirements

28V DC power supply.

Table 3 power supply requirements

technical specification	parameter	remark
Power supply	+28V (+20V to +35V)	
power ripple	<500mV	

Inrush current	<0.5 A/5 ms	
steady power consumption	2.18W	
insulation resistance	>20 MΩ	

## 5. Interface Definitions and Communication Protocols

The connector X1 is J30J-37ZKNP4-J, and its pin definitions are shown in table 4.

Table 4 The definition of connector X1 pins

No.	function	description
1, 20	+28V	+28V power supply
3, 22	GND	ground
9, 28	PPS_H	pulse per second +
10, 29	PPS_L	pulse per second-
11, 30	CANA_H	CAN A+
12, 31	CANA_L	CAN A-
13, 32	CANB_H	CAN B+
14, 33	CANB_L	CAN B-
18, 37	connects to shell	connects to shell
2,4,15,16,19,21,23,34,35	Debug JTAG	Debug JTAG
5~8,17,24~27, 36	reserved	reserved

### 5.1 communication interface

Star sensor communicates with onboard computer (OBC) via AB dual-redundant CAN bus with the communication rate of 500Kbps. Pin 6,7 (CANL, CANH) of interface chip TJA1040T are connected to CANL, CANH of CAN bus respectively, as shown in figure 2. There is no matched resistor for the joint, and matched resistors are added at the two terminals of bus by cable network.

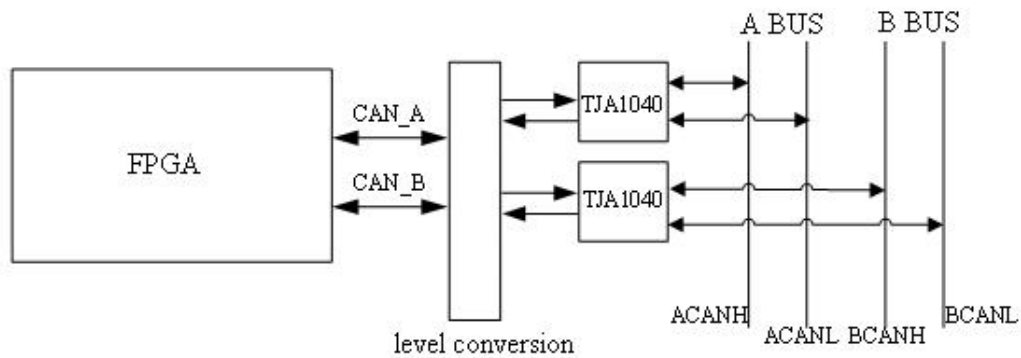


Fig 2. CAN interface schematic

OBC adopts pulse per second (PPS) to realize time synchronous with star sensor. PPS signal uses 422 differential level with the direction of OBC to star sensor. it is negative pulse (high level in normal), pulse falling edge is aligned with the satellite system time full-seconds, the pulse duration is no less than 1 $\mu$ s. Figure 3 shows its interface, and ETR signal is PPS.

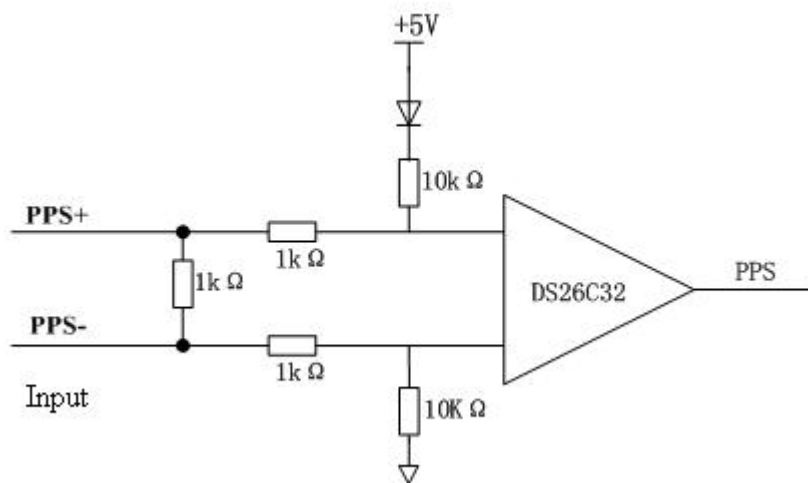


Fig 3. PPS interface circuit schematic

## 5.2 communication protocol

(1) The communication protocol of star sensor includes eleven commands in total, as shown in table 5. All commands implementation are that OBC sends command sequence to star sensor, then the sensor gives response. The numbers in command and response sequences below are hex unless otherwise specified.

Table 5. List of star sensor commands

No.	command name	command sequence(hex )	Response sequence(hex)	Response/execute mode	remark
C0	reset	A1 51 00 00 00 00	A1 51 80 00 00 00	respond immediately  execute immediately	
C1	self-test	A1 1A 00 00 00 00	A1 1A xx yy zz ww	delay execute  respond after execute	xx, yy, zz, ww are the results of self-test
C2	enter into standby mode	1A 01 00 00 00 00	1A 01 80 00 00 00	respond immediately  delay execute	
C3	Enter into attitude measureme nt mode	1A 10 00 00 00 00	1A 10 80 00 00 00	respond immediately  delay execute	
C4	Parameter configuratio n command	14 15 cc xx yy zz	14 15 80+cc xx yy zz	respond immediately  delay execute	cc represents code of parameter, xx yy zz represent the value of parameter
C5	data simple package request	22 01 00 00 00 00	Data request simple package	execute immediately  Respond after execute	
C6	data	22 10 00 00 00	Data request	delay execute	

No.	command name	command sequence(hex )	Response sequence(hex)	Response/execute mode	remark
	detailed package request	00	detailed package	Respond after execute	
C7	Star map download	22 55 xh xl yh yl wh wl	Star map data package	delay execute Respond after execute	xh, xl, yh, yl, wh, wl represent locations parameters
C8	Program update	AA 55 .....	AA 55 80 00 00 00	execute immediately Respond after execute	
C9	Set time	53 74 s1 s2 s3 s4 ms1 ms2	53 74 80 00 00 00	respond immediately Execute immediately	s1, s2, s3, s4 are second, ms1, ms2 are millisecond
C10	Parameter download	22 AA 00 00 00 00	Parameter data package	delay execute Respond after execute	

If star sensor receives commands not in table 5, it will filter the commands automatically without response; If the operating mode of star sensor can't execute the current command, it will respond with an invalid command frame in the format of table 6.

Table 6 invalid command response frame

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6
42	43	XX	YY	00	00

(1) After OBC sends the command, star sensor will return a telemetry data package consisting of sixty-one bytes with the delay time no more than 10ms.

Table 7 format of data simple package request command

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6
22	01	00	00	00	00

Format of response frame is shown in table 8.

Table 8 format of data simple package

Offset	Parameter	Type	Description
0	frame header	—	2 bytes, fixed F1 90
2	length	Unsigned integer	2 bytes, big end alignment, represent number of byte from “length” to “checksum”.
4	reserved	—	3 bytes
7	type of command	Unsigned integer	2 bytes, represent response command code, fixed 22 01.
9	second timestamp	Unsigned integer	4 bytes, big end alignment, represent the second of current frame exposure center time
13	millisecond timestamp	Unsigned integer	2 bytes, big end alignment, represent the millisecond of current frame exposure center time
15	strong light flag	Unsigned integer	2 bytes, big end alignment
17	Quaternion 0	Integer	4 bytes, big end alignment, calculation method as following
21	Quaternion 1	integer	4 bytes
25	Quaternion 2	integer	4 bytes
29	Quaternion 3	integer	4 bytes
33	Angular velocity x	integer	4 bytes, big end alignment, calculation method as following
37	Angular velocity y	integer	4 bytes
41	Angular velocity z	integer	4 bytes
45	Work state A	Unsigned integer	4 bytes, refer to table 9 for meaning
49	Work state B	Unsigned integer	4 bytes, refer to table 10 for meaning
53	Work state C	Unsigned integer	4 bytes, refer to table 11 for meaning
57	Reserved	—	3 bytes



60	Checksum	Unsigned integer	1 byte, represent the sum of all bytes from “length” to the one before “checksum”.
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The type of quaternion output value is integer; the relationship with real quaternion is: real Quaternion = (output value)/2<sup>30</sup>, real Quaternion is the rotation matrix from J2000 celestial coordinate to sun sensor coordinate, where, the scalar is Quaternion 0, the vector is Quaternion 1, Quaternion 2, and Quaternion 3. For example, the output of (0x20000000, 0x20000000, 0x20000000, 0x20000000) represents the real Quaternion (0.500000000, 0.500000000, 0.500000000, 0.500000000).

The output type of angular velocity is integer, it represents in rad/seconds. The relationship between the output and real angular is: real angular velocity = (output value)/2<sup>30</sup>. The angular velocity is calculated from attitude data differential of star sensor.

Work state of A, B, C are 32bit unsigned integer, definitions of each bit are shown in table 20 to table 22.

Table 9 definition of work state of A

<b>31 to 29</b>	work mode	001 standby
		010 full-time
		011 tracking
<b>28</b>	the flag of attitude valid 1 valid, 0 invalid	
<b>27</b>	the flag of anti-stray-light function start 1 on, 0 off	
<b>26</b>	the flag of abnormal extraction of star point mass center 1 abnormal, 0 normal	
<b>25 to 20</b>	Number of observed stars: 0 to 63	
<b>19 to 14</b>	Number of recognized stars: 0 to 63	
<b>13 to 0</b>	Current frame process time (ms)	

Table 10 definition of work state of B

<b>31 to 24</b>	the temperature of imaging part
<b>23 to 14</b>	image gray mean value
<b>13</b>	the flag of valid timestamp 0: OBC represents OBC hasn't set timestamp. 1: OBC represents OBC has set timestamp.
<b>13 to 10</b>	reserved
<b>9 to 8</b>	the flag of imaging part state 11 is normal, the others are abnormal.
<b>7 to 0</b>	exposure time

Table 11 definition of work state of C

<b>31 to 24</b>	analogue gain
<b>23 to 16</b>	Gray offset
<b>15 to 8</b>	digital gain
<b>7 to 0</b>	reserved

(1) data detailed package request

The command of data request detailed package is used by onboard computer for obtaining attitude data, work state and center of mass from star sensor. Compared to data simple package, the detailed package adds data package of mass center, including 63 stars information at most, with 20 bytes for each star and totally  $20 \times N$  bytes (N represents the number of observed stars)

After the command is sent by onboard computer, star sensor will execute it after a time delay. The interval from star sensor receiving the command to returning the detailed package will be no more than 200ms. If star sensor receives this command in standby mode, it will respond an invalid command frame (as shown in table 5).

The format of data detailed package request command is as following.

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6
22	10	00	00	00	00

The format of response frame is similar to simple package, as shown in table 12. The format of star point mass center is shown in table 12.

Table 12 the format of data detailed package

Offset	parameter	types	description
0 to 6	same to simple package	same to simple package	same to simple package
7 to 8	Type of command	Unsigned integer	2 bytes, represent response command code, fixed 22 10
9 to 59	same to simple package	same to simple package	same to simple package
60 to 59+20×N	star point mass center data	—	For details, refer to table 23.
60+20×N	checksum	Unsigned integer	1 byte, represent the sum of all bytes from “length” to the one before “checksum”.

Table 13 format of star point mass center data

parameter	types	description
X-coordinate	32 bits of floating point	4 bytes IEEE floating point, star point X-coordinate
Y-coordinate	32 bits of floating point	4 bytes IEEE floating point, star point Y-coordinate
brightness	Unsigned integer	2 bytes IEEE floating point, the sum of gray value of all pixels of star point.
reserved	—	10 bytes

(2) star map download

The command of star map download is used to download the local area of star map collected by star sensor to OBC, with each pixel of 8bit, and the position and size of that area are determined by parameters.

After the commands are sent by onboard computer, star sensor will

execute it after a time delay time. The interval from star sensor receiving the command to returning star map data will be no more than 1s. During star map downloading, star sensor will stop star map processing and not respond to any other commands. If star sensor receives the command in standby mode, it will respond an invalid command frame (as shown in table 5).

Frame format of star map download command is shown as following.

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8
22	55	xh	xl	yh	yl	wh	wl

Where, the top left corner coordinate  $x=xh \times 256 + xl$ , top left corner coordinate  $y=yh \times 256 + yl$ , the size of window  $w=wh \times 256 + wl$ .

Frame format of response is shown as the following.

byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9~
22	55	xh	xl	yh	yl	wh	wl	P1, P2, P3.....

Where, P1, P2, P3 and the others record the 8bit gray value of pixel respectively in turn. The pixel output sequence takes the top left corner as the origin, from left to right, from top to bottom.

## 6 Maintenance

(1)Star sensor should be stored in the conditions of constant temperature (room temperature) and constant humidity (20%RH to 35%RH).

(2)When the equipment is in storage or not being used, baffle cover, reference mirror cover, and connector cover should be checked for protection state. These covers should be removed when utilizing or mounting star sensor on the satellite.

(3)Star sensor should be protected from ESD during handling.