OrigamiSat-1

CW Downlink Data Format

(English version)

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ORIGAMI PROJECT

Revision History

Date	Version #	Contents
2019/01/09	1.0, 1.1	Translated from Japanese document OP-S1-0109, ver. 2.2. (Sakamoto, Nakatsuka)
2019/01/18	2.0	"Battery voltage 2" explanation updated.
2019/01/20	2.1	In "2.2 satellite mode error status," Table 7 is updated. In "2.11 selected data," Table 11 is updated. TX/RX subpower status values were incorrect. (Corresponding to Ver. 3.1 of Japanese version)
2019/01/25	2.2	2.5.2. Battery voltage 2; calculation is corrected. 2.6.2. 3.3V bus voltage; calculation is corrected. Updates are shown in red.

1. Overview

This document specifies the CW (Constant Wave, Continuous Wave) downlink data (telemetry) format for 3U Cubesat OrigamiSat-1 (JS1YAX). In OrigamiSat-1, ON/OFF of CW downlink, data update, and contents of data items change according to the satellite mode, as well as commands sent from the Tokyo Tech ground station.

2. Data format

This section explains the CW data format. Table 1 shows the overview of CW downlink data. Between the call sign, the satellite name, and the data part, there is approximately 1 second interval. The transmission speed is 20 wpm.

Please note that, when the OrigamiSat-1 starts the FM (Frequency Modulation) transmission, CW transmission stops even in the middle of sending data. Then, once the FM transmission finishes, CW transmission is restarted from the call sign. To compete the CW transmission from the beginning of call sign to the end of the data part, it takes approximately 50-60 seconds.

The detailed data items and size of each items in the data part are shown in Table 2. All the data are in hexadecimal number (HEX).

Table 1 Overview of CW downlink data format

Satellite's call sign	Satellite's name	**Data part**
JS1YAX	ORIGAMI	24byte

Table 2 Data items and sizes of "Data part"

Data items	Data size	Satellite's component, which updates the data item
Satellite mode	1 byte	CIB[1]
Satellite mode error status	1 byte	
Battery temperature	2 byte	
Latest executed command ID (RXPIC[2])	1 byte	
Latest executed command ID (TXPIC[3])	1 byte	
Battery voltage 1	2 byte	
5V bus voltage	2 byte	CIB/OBC

[1] CIB: Communication and Inhibit control Board.
[2] PIC microcomputer, which controls the transmitter (TX)
[3] PIC microcomputer, which controls the receiver (RX)

3.3V bus voltage	2 byte	OBC
Battery voltage 2	1 byte	
Latest executed command ID (OBC[4])	1 byte	
OBC command status	1 byte	
Battery current	2 byte	
EPS[5] switch status	2 byte	
Temperature of TX	1 byte	
Temperature of RX	1 byte	
Selected data 1	1 byte	Selected by commands
Selected data 2	1 byte	

All data are big-endian.

Configurations of EPS, OBC, TX, and other components are shown in Figure 1.

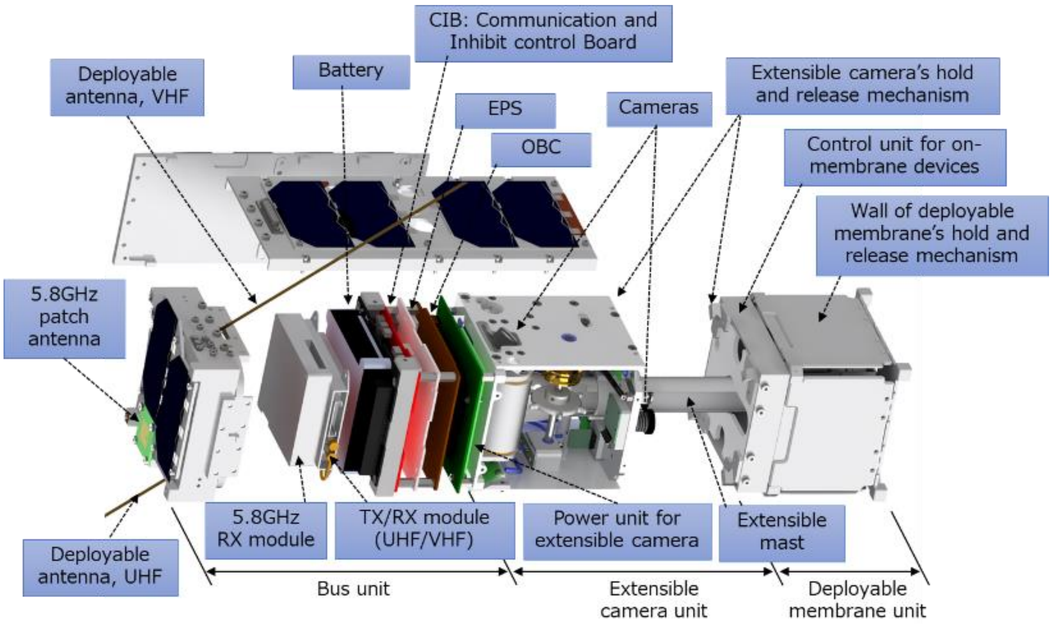

Figure 1　OrigamiSat-1 component configuration

The subsections below describe each of the data items in the **Data part** in detail.

2.1. Satellite mode

Table 3 shows the information in this data section. There are three satellites modes, depending upon battery voltage. Table 4 explains each modes in detail.

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[4] OBC: On Board Computer

[5] EPS: Electrical Power Subsystem

Table 3　Data contents of "satellite mode"

7bit(MSB)	6bit	5bit	4bit	3bit	2bit	1bit	0bit(LSB)
Satellite mode				SEP switch status		RBF switch status	

Table 4　Explanation of each satellite mode

Satellite mode	Satellite mode contents
Nominal mode	Mode for nominal operation.
Saving mode	This mode is used when battery voltage is relatively low. To reduce power consumption, only minimal communication functions are active, and the battery voltage is resumed. CW downlink data format is unchanged from the nominal mode; however, OBC is turned off in this mode. As a result, the data from OBC are not updated in this mode.
Survival mode	This mode is used when battery voltage is critically low. Only PIC microcomputers are active and all most all the other devices are turned off. In this mode, CW data transmission is not implemented. This mode concentrates charging the battery.

Table 5 shows the data representation for "satellite mode" in Table 3.

Table 5　Satellite mode representation

Satellite mode	7 bit	6bit	5bit	4bit
Nominal mode	0	1	0	1
Saving mode	0	1	1	0
Survival mode	1	0	1	0

"SEP" and "RBF" in Table 3 are the switches, switched according to the satellite mode. SEP switches ON/OFF of the bus power line from EPS. RBF switches ON/OFF between EPS and battery. Therefore, if the switches function normally, both SEP/RBF are ON in Nominal mode; whereas only SEP is on in Saving mode and Survival mode. In binary number (BIN), the switch status is 0b10 when a switch is ON; and it is 0b01 when a switch is OFF. Table 6 summarizes this.

Table 6　Summary of "satellite mode" data

Satellite mode	SEP	RBF	Data (BIN)	Data (HEX)
Nominal mode	ON	ON	0b01011010	0x5A
Saving mode	OFF		0b01100110	0x66
Survival mode			0b10100110	0xA6

2.2.　Satellite mode error status

"Satellite mode error status" shows the error information when satellite mode changes. "0x00" shows normal. If there is an error, the corresponding bit in Table 7 becomes "1."

Table 7　Contents of "satellite mode error status"

7bit (MSB)	6bit	5bit	4bit	3bit	2bit	1bit	0bit (LSB)
Satellite mode switching error		Error in reading previous satellite mode		Error in reading threshold voltage		Error in reading battery voltage	

In addition to the errors in Table 7, there is "abnormal termination during switching satellite mode." In this case, the satellite mode error status becomes "0x55." Besides this "0x55" error, the other errors will be resolved automatically using redundant algorithms to complete a change satellite mode normally.

2.3.　Battery temperature

Battery temperature in analog (BTA, hereafter) is converted to decimal number (DEC) from the received HEX number, using the following equation.

$$\mathrm{BTA} = \frac{330 \times \mathrm{data\ \ (DEC)}}{1024 - \mathrm{data\ \ (DEC)}} \tag{1}$$

Then, the actual battery temperature [°C] is obtained from BTA by:

$$\mathrm{Battery\ \ temperature\ \ [°C]} = \frac{1}{\left\{\frac{1}{4390} \times \log\left(\frac{\mathrm{BTA}}{100}\right) + \frac{1}{298.15}\right\}} - 273.15 \tag{2}$$

2.4.　Latest executed command ID (TXPIC, RXPIC, OBC)

When a command is transmitted from the Tokyo Tech ground station, each command has a consecutive number from 0x00 to 0xFF (command ID). Latest executed command

ID shows the final command ID executed by TXPIC, RXPIC, and OBC respectively.

2.5. Battery voltage

There are two Battery voltages.

2.5.1. Battery voltage 1

Battery voltage 1 shows the value obtained by PIC microcomputer through AD converter. The received data (HEX) is converted to DEC first, then the actual voltage is calculated as follows.

$$\text{Battery voltage } 1[\text{V}] = 0.01386 \times \text{data (DEC)} \quad (3)$$

2.5.2. Battery voltage 2

Battery voltage 2 shows the value obtained by OBC from EPS telemetry. The received data (HEX) is converted to DEC first, then the actual voltage is calculated as follows.

$$\text{Battery voltage } 2[\text{V}] = 0.009 \times \text{data (DEC)} \quad (4)$$

Please note that this "Battery voltage 2" is not updated in the Survival mode, as shown in Table 4.

** Because of a software error, only the upper 1 byte bits of the 2 byte data is transmitted from the satellite.

2.6. Bus voltage (5V/3.3V)

2.6.1. 5V bus voltage

"5V bus voltage" is updated by OBC in the Nominal mode; whereas it is update by CIB in the Saving mode. As a result, different conversion formula is required. In the Nominal mode, the received data (HEX) is converted to DEC first, then the actual voltage is calculated as follows.

$$\text{5V bus voltage (nominal mode) [V]} = 0.005865 \times \text{data (DEC)} \quad (5)$$

In the Saving mode, the received data (HEX) is converted to DEC first, then the actual voltage is calculated as follows.

$$\text{5V bus voltage (saving mode)[V]} = 0.00645 \times \text{data (DEC)} \quad (6)$$

2.6.2. 3.3V bus voltage

As for "3.3V bus voltage", the received data (HEX) is converted to DEC first, then the actual voltage is calculated as follows.

$$\text{3.3V bus voltage [V]} = 0.004311 \times \text{data (DEC)} \quad (7)$$

2.7. OBC command status

"OBC command status" shows the results of OBC's command execution. Table 8 shows the values and respective contents.

Table 8 Values of OBC command status

Status value (HEX)	Status contents
0x00	Normal
0x02	SD card processing error (undefined parameter)
0x03	SD card processing error (file open)
0x04	SD card processing error (too many parameters)
0x05	SD card processing error (I2C)
0x0F	Other error
0x3A	5.8GHz com module enable/disable check, enable
0x55	5.8GHz com module enable/disable check, disable
0xF0	Time out error
0xF2	Command format error
0xF3	EEPROM address page error
0xF4	Over flow error
0xF5	Status error of module
0xF6	File open error
0xF8	Undefined parameter error
0xFC	Too many parameter error

2.8. Battery current

"Battery current" is calculated as follows, after the received data (HEX) is converted to DEC.

$$\text{Battery current [A]} = 0.005237 \times \text{data (DEC)} \tag{8}$$

2.9. EPS switch status

EPS switch status shows whether the voltage and current values for each of EPS switches are normal or not. "0" is normal, and "1" shows error. Table 9 shows the meaning of each bit.

Table 9 EPS switch status

15bit (MSB)	14bit	13bit	12bit	11bit	10bit	9bit	8bit
switch 1 voltage	switch 1 current	switch 2 voltage	switch 2 current	switch 5 voltage	switch 5 current	switch 6 voltage	switch 6 current

7bit	6bit	5bit	4bit	3bit	2bit	1bit	0bit (LSB)
switch 7 voltage	switch 7 current	switch 8 voltage	switch 8 current	switch 9 voltage	switch 9 current	switch 10 voltage	switch 10 current

Additionally, Table 10 shows the components connected to each EPS switch.

Table 10 Details of EPS switches

EPS Switch#	Connected component	EPS Switch#	Connected component
1	Motor for extensible mast (12V 1.5A)	6	LED for cameras (5V)
2	12V power supply	7	5.8GHz transmitter power (5V)
3	Battery voltage	8	MDC power (3.3V, 4A)
4	Battery voltage	9	Nichrome cutter in Deployable membrane unit (3.3V, 4A)
5	Extensible camera unit power (5V, 4A)	10	Nichrome cutter for UHF/VHF deployable antenna (3.3V, 4A)

2.10. Temperature of TX/RX

Temperature of TX/RX in Analog (TTA, hereafter) can be calculated as follows, after the received data in HEX is converted to DEC.

$$\mathrm{TTA} = \frac{330 \times \mathrm{data\ (DEC)}}{255 - \mathrm{data\ (DEC)}} \tag{9}$$

Then, the actual temperature [°C] is obtained as

$$\mathrm{Temperature}\ \left[{}^{\circ}\mathrm{C}\right] = \frac{1}{\left\{\frac{1}{4390} \times \log\left(\frac{\mathrm{TTA}}{100}\right) + \frac{1}{298.15}\right\}} - 273.15 \tag{10}$$

2.11. Selected data

In Selected data 1 and 2, any 1 byte data, respectively, required by a command from the ground station can be stored.

In the initial setting (right after the launch and release), Selected data 1 shows the Nichrome cutter status, and Selected data 2 shows the TX/RX subpower supply status. The Nichrome cutter status shows whether the Nichrom cutter for fishing cable in the UHF/VHF deployable antenna is turned off or not. The TX/RX subpower supply status shows whether the redundant power supply line for the TX/RX is turned on or off. Table 11 shows these initial settings of Selected data 1 and 2.

Table 11 Initial data format for "Selected data 1" and "2"

Data item	Status	Value (HEX)
Nichrome cutter status	Still cutting	0x10
	Finished cutting	0x7E
TX/RX subpower status	Subpower OFF	0x07
	Subpower ON	0x3F

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