BIRDS Platform

Interface Control Document

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Contents

1 Scope

This document defines interface of the BIRDS CubeSat platform.

The interface requirements are based on the relevant documents (Ref.(1)) CubeSat Design Specification, (2) JEM Payload Accommodation Handbook.

2 Related documents

(1) ISO 17770:2017, Space Systems – Cube satellites

(2) JEM Payload Accommodation Handbook, Vol.8 Rev. D, May 2020.

(3) BIRDS platform Vibration Test Report.

(4) BIRDS platform Thermal Vacuum Test Report.

(5) BIRDS platform Assembly Procedure.

(6) ISO/TC20/SC14/WG1 "Space Systems – CubeSat Interface", Working Draft, November, 2020.

(7) CubeSat bus interface with Complex Programmable Logic Device, Acta Astronautica, **160**(2019), 331−342.

(8) BIRDS platform Battery Charging Procedure.

(9) ISO 16290, Space systems — Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment

(10) ISO 19683:2017, Space Systems – Design qualification and acceptance tests of small spacecraft and units

3 Mechanical interfaces

3.1 Coordinate system

The coordinate system of the BIRDS platform conforms to the CubeSat deployment system (J-SSOD-R, E-SSOD, etc.) and defines the following:

- The coordinate system of the platform: (X, Y, Z)
- The origin is at the geometric center in the nominal dimensions of the platform.

Figure 3.1 shows the coordinate system of the platform.

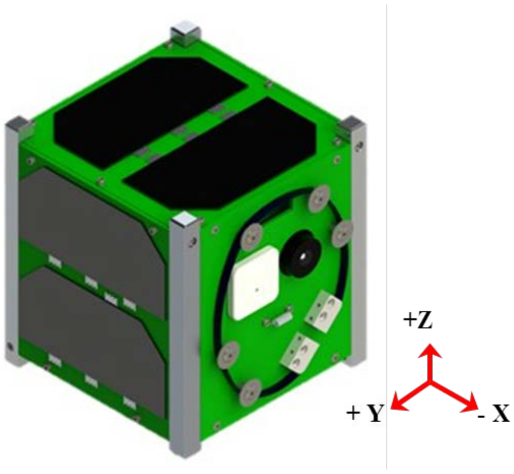


Figure 3.1 Platform Coordinate System

3.2 BIRDS platform outline

The dimension of the BIRDS platform is shown in Table 3.2 and Figure 3.2 Detailed CAD information of the structure is provided as a STEP file. The dimension of the platform conforms to CubeSat standard (Ref.(1),(2)). The ± Z rail ends and the edges of the rail sides are rounded at 1 mm radius of curvature. Also, the rail surface conforms to MIL-A-8625 Type3; hard anodized coating has been made at 10 µm or more.

Table 3.2 Satellite dimension

Size	Platform dimension [mm]*	Rail dimension [mm]	Tolerance [mm]
1U	(X, Y, Z) : (100, 100, 113.5)	8.5 x 8.5	±0.1

* Nominal dimensions including rails

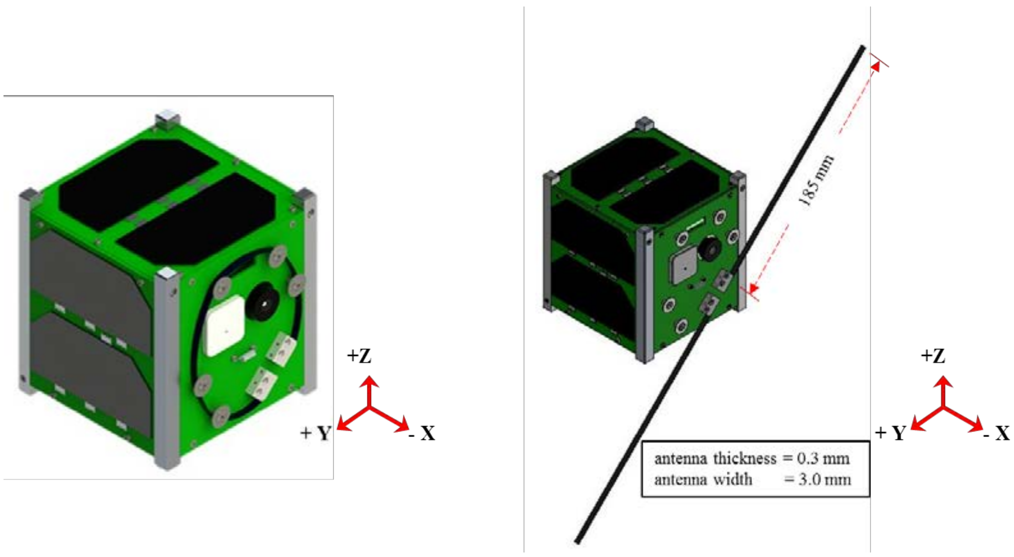


Figure 3.2 BIRDS Platform External Structure

The mass of the BIRDS platform, excluding the payload, is 0.95 kg. In addition, the center of mass is at (X, Y, Z) : (3.75 mm, -0.15 mm, -1.91 mm) from the center of geometry when 100 g is added to each mission section substrates.

3.3 Platform internal structure

Figure 3.3 shows the internal structure of the BIRDS platform. The platform uses a backplane interface. As a standard, two 50-pin female connectors (A3C-50DA-2DSA) are available on the backplane for payload. The allowable thickness of the payload unit is up to 22.35 mm and the size of the board is 83 mm x 86 mm.

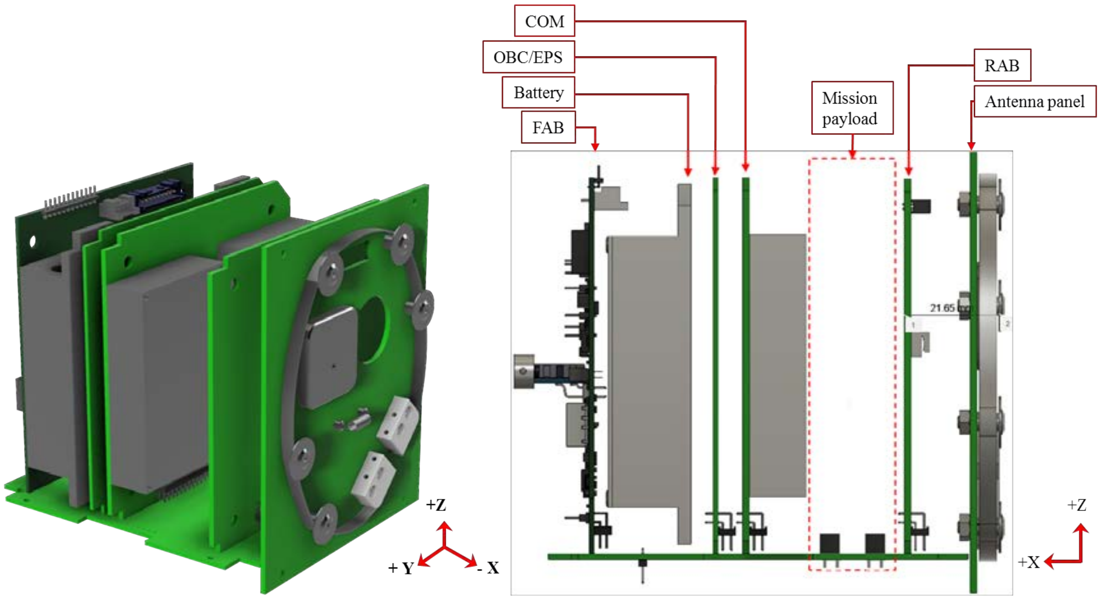


Figure 3.3 BIRDS Platform Internal Structure

3.4 Payload requirements

Figure 3.4 shows the payload size requirements on the BIRDS platform. The size of the payload board is 90 mm x 86 mm and must use a 50-pin male connector (NRPN252PARN-RC, LPC-50M2LG, or equivalent) for connection with the backplane board (BPB). In addition, the platform secures each board with four long bolts. Therefore, 3.8mm diameter holes should be provided at the four corners of the board for passing the long bolts. It is possible to customize the backplane board to reduce the number of 50-pin female connector to one and shift its position. The maximum thickness that the payload board can be stored is 22.35 mm. See Figure 3.4 for the position of connector and holes.

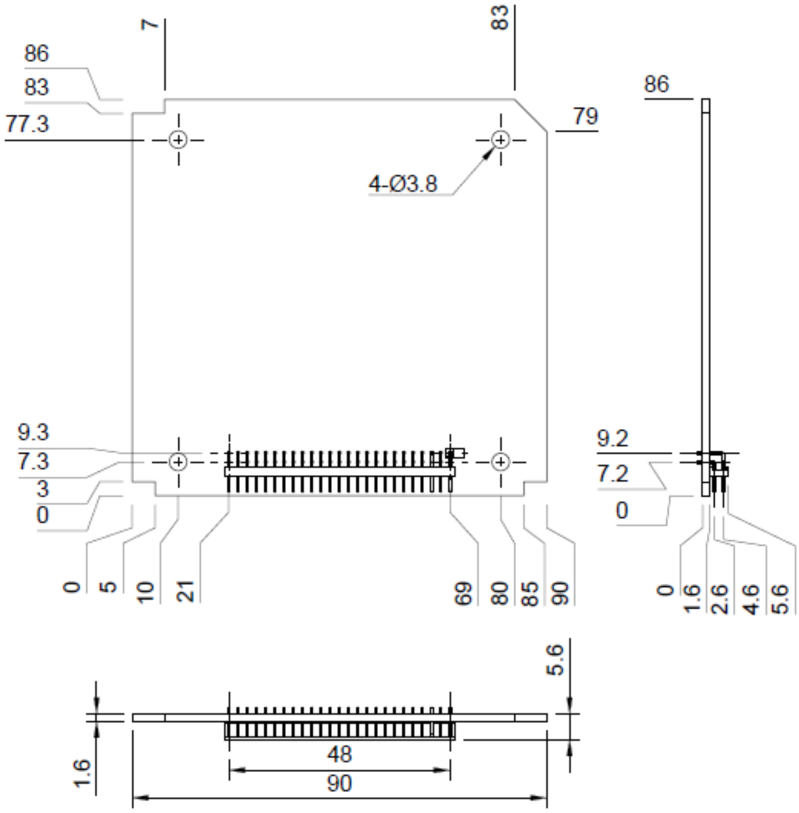


Figure 3.4 Payload board size requirements

The payload can access to space across RAB and the antenna panel. Fig.3.6 shows RAB and Antenna panel of BIRDS-3. There are already holes in both panels so that a camera mounted on the payload board can see the outside. If the user does not need GPS antenna, the part marked by red in Fig. 3.6 (left) can be further removed, although it needs to change some routing on RAB. The height of camera and lens can be 28.15 mm considering the volume height of RAB, Antenna Panel and +6.5mm extra space allowed outside the satellite. By adjusting the position of the payload board, the height can be further extended.

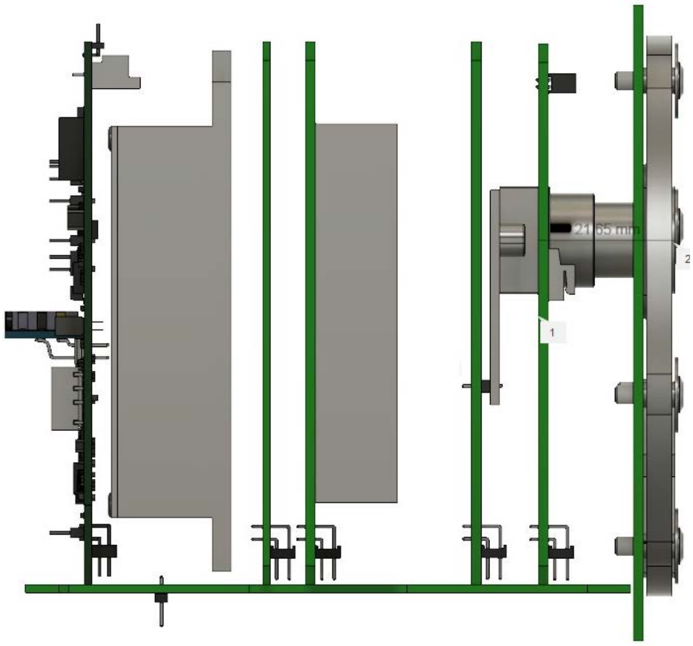


Figure 3.5 Payload board size requirements (Camera Height)

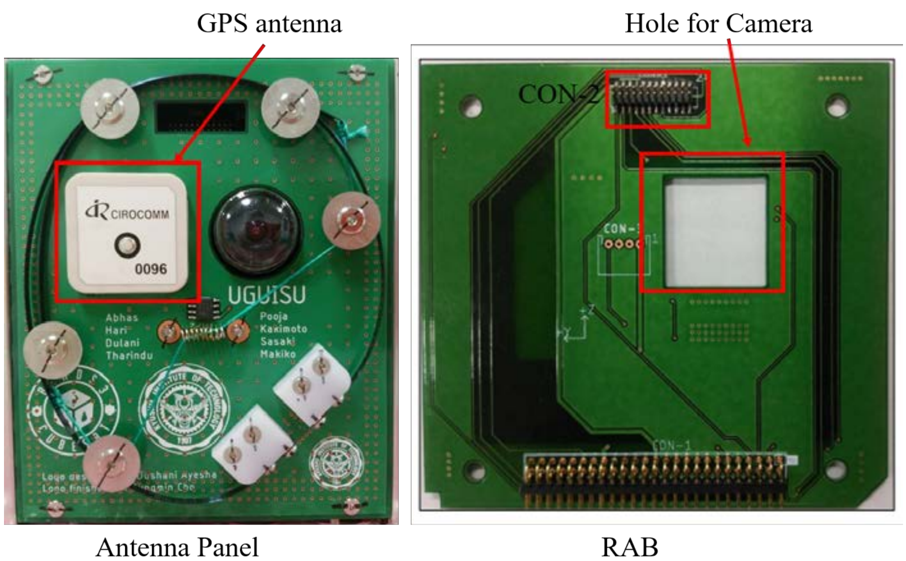


Figure 3.6 Antenna Panel and RAB

4 Electrical interfaces

4.1 Umbilical connector specification

The BIRDS platform has access ports on the +X side as shown in Figure 4.1-1. There are five access ports and two RBF (Remove Before Flight) pins. Table 4.1-1 shows the access connectors pinout.

J1 is a 4 x 2 female connector (model number: SFMC-104-01-SD) which provides access to program micro-controllers in Front Access Board (FAB PIC) and On-Board Computer board (Main PIC, Reset PIC, COM PIC). To program a micro-controller, PGC, PGD, 3V3_FAB, GND, and MCLR pins are used. Each micro-controller has its own MCLR pin, the rest are common pins to all micro-controllers.

J2 is a 2 x 2 female connector (model number: SFMC-102-01-SD) which provides access to the serial lines of the Main PIC. This port can be used to monitor and send data directly to Main PIC when debugging.

J3 is a 5 x 2 female connector (model number: SFMC-105-01-SD) which provides external access to the mission payload. Its access to the mission payload is composed of six hard-wired connections and four configurable connections through CPLD (see Section 4.3).

J4 is a 2 x 2 female connector (model number: SFMC-102-01-SD) which can be used when measuring battery voltage, raw voltage and voltage generated by the solar cells.

J5 is a 2 x 2 female connector (model number: SFMC-102-01-SD) which is used to externally charge the battery. RBF2 pin should be removed when charging the battery externally.

Release Before Flight RBF1 and RBF2 are mechanisms to make sure that power is shutdown when moving the satellite or conducting tests that do not need power. Specifically, RBF1 (FP2 in the EPS block-diagram) is connected to the load side while RBF2 (FP1 in the EPS block-diagram) is connected to the battery side.

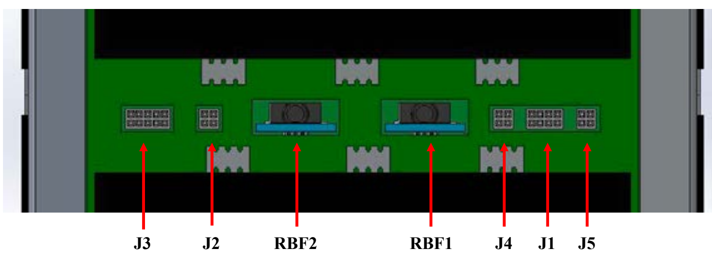


Figure 4.1-1 Access ports on +X panel

Table 4.1-1 Access connectors pinout (+X panel)

digital connection (fixed)

digital connection (configurable by user through CPLD)

power connection

J1 (Programming Main PIC, Reset PIC, COM PIC, FAB PIC)			
PIN	Signal Name	PIN	Signal Name
1	DEV1(PGC)	2	DEV2(PGD)
3	DEV3(MCLR_FP)	4	DEV4(MCLR_RP)
5	DEV5(MCLR_CP)	6	DEV6(MCLR_MP)
7	3V3_FAB	8	GND

J2 (Main PIC debug)			
PIN	Signal Name	PIN	Signal Name
1	FAB2OBC1	2	FAB2OBC2
3	GND	4	GND

J3 (Access to RAB)			
PIN	Signal Name	PIN	Signal Name
1	FAB2RAB1	2	FAB2RAB2
3	FAB2RAB3	4	FAB2RAB4
5	FAB2RAB5	6	FAB2RAB6
7	CPLD4	8	CPLD5
9	CPLD6	10	CPLD7

J4 (Monitor Battery)			
PIN	Signal Name	PIN	Signal Name
1	SRC_V	2	BATT_V
3	RAW_V	4	GND

J5 (Charging line)			
PIN	Signal Name	PIN	Signal Name
1	EXT_PWR	2	GND
2	EXT_PWR	4	GND

It is possible to access the mission payload for programming, debugging, etc. from -X side through the antenna panel and RAB.

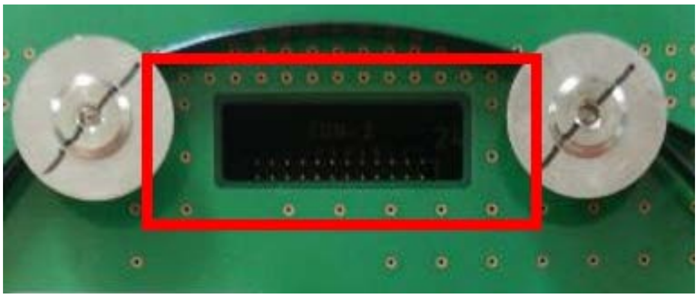


Figure 4.1-2 Access ports on -X panel

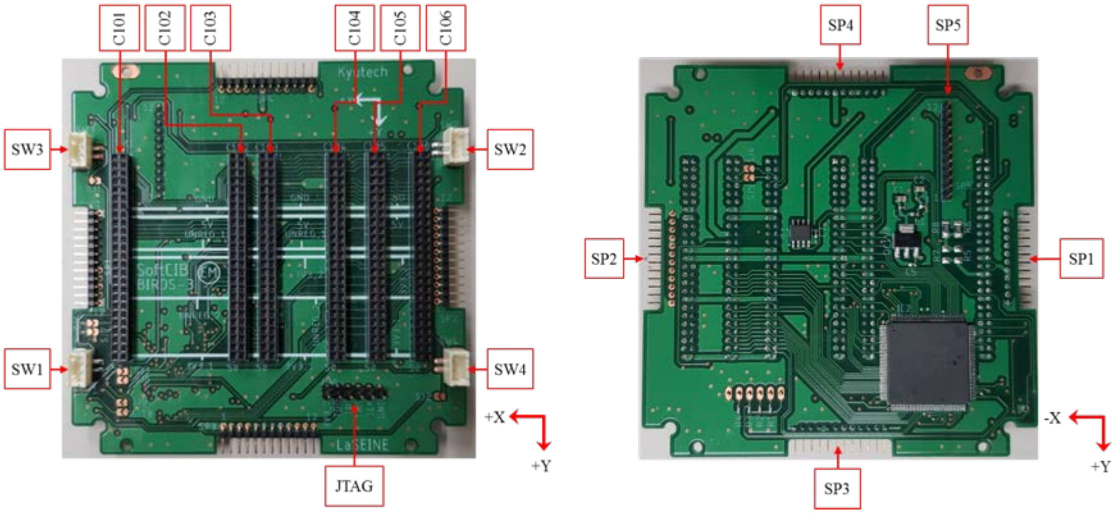
CON-2 is a 12 x 2 male connector (model number: GRPB122VWQS-RC) which provides access to program and debug micro-controllers in the mission boards. To program a micro-controller, PGC, PGD, SUP_3V3_2, GND, and MCLR pins are used. USB lines (Data+, Data- and Data_V_USB) also provide access and debugging of microcontrollers that communicate through USB. UART lines (CAM_RX, CAM_TX and CAM_DTR) also provide access to microcontrollers. This port can be used to monitor and send data directly to payload microcontroller when debugging.

Table 4.1-2 Access connectors pinout (-X panel)

CON-2 (Programming Payload Microcontrollers)			
Pin Number	**Signal Name**	**Pin Number**	**Signal Name**
1	ADCS MCLR	2	SUP_3V3_2
3	ADCS_PGD	4	GND
5	ADCS_PGC	6	GND
7	DATA_V_USB	8	GND
9	DATA+	10	Unassigned
11	DATA-	12	Unassigned
13	CAM_RX	14	Unassigned
15	CAM_TX	16	CAM_DTR
17	Unassigned	18	Unassigned
19	Unassigned	20	Unassigned
21	Unassigned	22	Unassigned
23	Unassigned	24	Unassigned

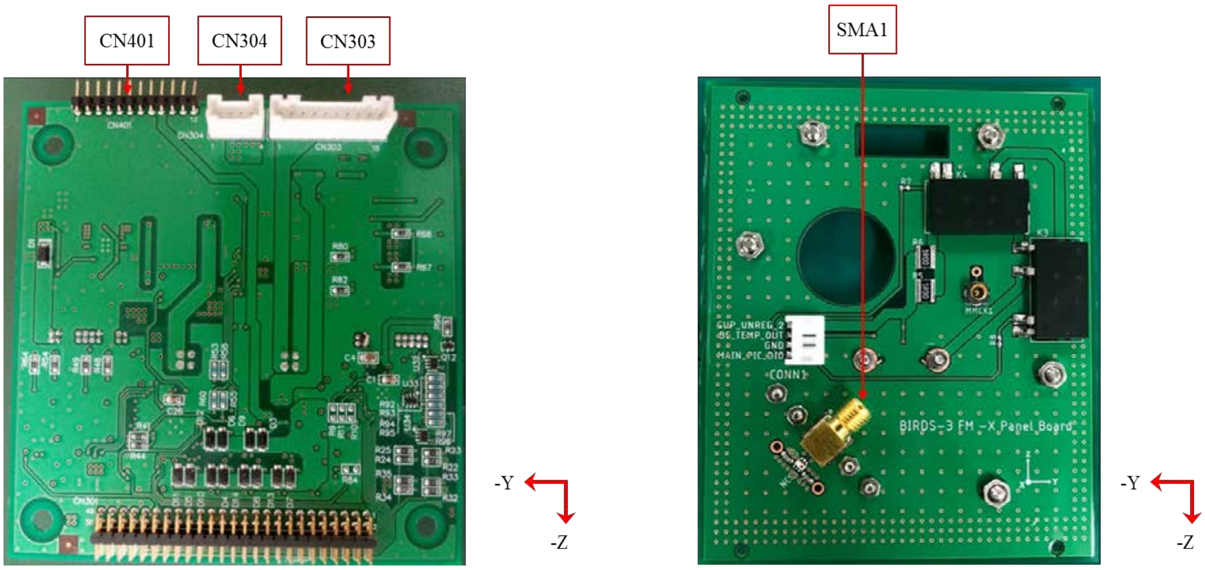
4.2 Connector specification

The BIRDS platform uses multiple connectors to connect each device. Figure 4.2-1 and Figure 4.2-2 show the position of the connectors on BPB, FAB and antenna panel, respectively. Table 4.2-1 shows the specification of the connectors. Connectors 1 to 16 are in backplane board, connectors 17 to 19 are in FAB, and connectors 20 to 21 are in antenna panel board.



(a) (b)

Figure 4.2-1 Connector position on backplane (a) top (b) bottom



(a) (b)

Figure 4.2-2 Connector position on (a) FAB (b) antenna panel

Table 4.2.-1 Connector specification

No.	Connector name	Number of pins	Connector description	Manufacturer	Model No.	Current rating [A[	Voltage rating [V]	Operating Temperature [°C]
1	C101	50	FAB	Hirose	A3C-50DA-2DSA (71)	1	200	-55 to +85
2	C102	50	EPS/OBC	Hirose	A3C-50DA-2DSA (71)	1	200	-55 to +85
3	C103	50	COM	Hirose	A3C-50DA-2DSA (71)	1	200	-55 to +85
4	C104	50	Mission1	Hirose	A3C-50DA-2DSA (71)	1	200	-55 to +85
5	C105	50	Mission2	Hirose	A3C-50DA-2DSA (71)	1	200	-55 to +85
6	C106	50	RAB	Hirose	A3C-50DA-2DSA (71)	1	200	-55 to +85
7	SW1	2	Dep.SW	Molex	0554600272	1.5	125	-40 to +105
8	SW2	2	Dep.SW	Molex	0554600272	1.5	125	-40 to +105
9	SW3	2	Dep.SW	Molex	0554600272	1.5	125	-40 to +105
10	SW4	2	Dep.SW	Molex	0554600272	1.5	125	-40 to +105
11	SP1	12	+X Solar Panel	Hirosugi	PSR-210154-12	1	500	-40 to +105
12	SP2	12	Antenna Panel	Hirosugi	PSR-210154-12	1	500	-40 to +105
13	SP3	12	+Y Solar Panel	Hirosugi	PSR-210154-12	1	500	-40 to +105
14	SP4	12	-Y Solar Panel	Hirosugi	PSR-210154-12	1	500	-40 to +105
15	SP5	12	-Z Solar Panel	Hirosugi	PSS-210204-12	1	500	-40 to +105
16	JTAG	6	Programmer connector	Würth Elektronik	61300411121	3	250	-40 to +105
17	CN303	10	Battery power	JST	B10B-PASK-1 (LF) (SN)	3	250	-25 to +85
18	CN304	4	Battery heater and temp sensor	JST	B04B-PASK-1 (LF) (SN)	3	250	-25 to +85
19	CN401	12	+Z Solar Panel	Hirosugi	PSR-210154-12	1	500	-40 to +105
20	SMA1	1	UHF SMA	Cinch Connectivity Solutions Johnson	142-0711-301	1	335	-65 to +165
21	CON-2	1	RAB	Sullins Connector Solutions	GRPB122VWQS-RC	1	-	-40 to 105

4.3 Connector pin assignment

The pin assignment for the connectors used in BIRDS platform is shown in Table 4.3-1 to Table 4.3-8.

digital connection (fixed)

digital connection (configurable by user through CPLD)

analog connection

power connection

Table 4.3-1 C101 and C102 connector pin assignment

C101 (FAB)			
Signal Name	Pin Number		Signal Name
Prog_GIO_1	1	2	Prog_GIO_2
Prog_GIO_3	3	4	Prog_GIO_4
Prog_GIO_5	5	6	Prog_GIO_6
FAB_to_RAB_GIO_1	7	8	FAB_to_RAB_GIO_2
FAB_to_RAB_GIO_3	9	10	FAB_to_RAB_GIO_4
FAB_to_RAB_GIO_5	11	12	FAB_to_RAB_GIO_6
GND-SYS	13	14	GND-SYS
SUP_5V0	15	16	SUP_5V0
FAB_to_OBC_GIO_1	17	18	FAB_to_OBC_GIO_2
FAB_to_OBC_GIO_3	19	20	FAB_to_OBC_GIO_4
POWERSC_-Y	21	22	TEMP_2 -Y
SUP_UNREG_1	23	24	SUP_UNREG_1
SUP_3V3_2	25	26	SUP_3V3_2
POWERSC_+Y	27	28	TEMP_1 +Y
RAW_POWER	29	30	RAW_POWER
POWERSC_-Y	31	32	TEMP_5 -Y
POWERSC_-Z	33	34	TEMP_3 -Z
SUP_UNREG_2	35	36	SUP_UNREG_2
POWERSC_-X	37	38	TEMP_4 -X
Kill_SW	39	40	DEP_SW_1
DEP_SW_2	41	42	CPLD1/ DEP_SW_3
CPLD2/ DEP_SW_4	43	44	CPLD3/ TEMP_6
CPLD4	45	46	CPLD5
CPLD6	47	48	GND_BAT
SUP_3V3_1	49	50	SUP_3V3_1

C102 (OBC/EPS)			
Signal Name	Pin Number		Signal Name
Prog_GIO_1	1	2	Prog_GIO_2
Prog_GIO_3	3	4	Prog_GIO_4
Prog_GIO_5	5	6	Prog_GIO_6
OBC-COM_1	7	8	OBC-COM_2
FAB_to_RAB_GIO_3	9	10	FAB_to_RAB_GIO_4
FAB_to_RAB_GIO_5	11	12	FAB_to_RAB_GIO_6
GND-SYS	13	14	GND-SYS
SUP_5V0	15	16	SUP_5V0
FAB_to_OBC_GIO_1	17	18	FAB_to_OBC_GIO_2
FAB_to_OBC_GIO_3	19	20	FAB_to_OBC_GIO_4
CPLD8	21	22	CPLD9
SUP_UNREG_1	23	24	SUP_UNREG_1
SUP_3V3_2	25	26	SUP_3V3_2
CPLD10	27	28	CPLD11
RAW_POWER	29	30	RAW_POWER
CPLD12	31	32	CPLD13
CPLD14	33	34	CPLD15
SUP_UNREG_2	35	36	SUP_UNREG_2
CPLD16	37	38	CPLD17
Kill_SW	39	40	DEP_SW_1
DEP_SW_2	41	42	CPLD18
OBC-COM_3	43	44	OBC-COM_4
OBC-COM_5	45	46	OBC-COM_6
OBC-COM_7	47	48	OBC-COM_8
SUP_3V3_1	49	50	SUP_3V3_1

Table 4.3-2 C103 and C104 connector pin assignment

C103 (COM)			
Signal Name	Pin Number		Signal Name
COM_to_RAB_GIO_1	1	2	COM_to_RAB_GIO_2
COM_to_RAB_GIO_3	3	4	COM_to_RAB_GIO_4
COM_to_RAB_GIO_5	5	6	COM_to_RAB_GIO_6
OBC-COM_1	7	8	OBC-COM_2
FAB_to_RAB_GIO_3	9	10	FAB_to_RAB_GIO_4
FAB_to_RAB_GIO_5	11	12	FAB_to_RAB_GIO_6
GND-SYS	13	14	GND-SYS
SUP_5V0	15	16	SUP_5V0
CPLD19	17	18	CPLD20
CPLD21	19	20	CPLD22
CPLD23	21	22	CPLD24
SUP_UNREG_1	23	24	SUP_UNREG_1
SUP_3V3_2	25	26	SUP_3V3_2
CPLD25	27	28	CPLD26
CPLD27	29	30	CPLD28
CPLD29	31	32	CPLD30
CPLD31	33	34	CPLD32
SUP_UNREG_2	35	36	SUP_UNREG_2
CPLD33	37	38	CPLD34
CPLD35	39	40	CPLD36
CPLD37	41	42	CPLD38
OBC-COM_3	43	44	OBC-COM_4
OBC-COM_5	45	46	OBC-COM_6
OBC-COM_7	47	48	OBC-COM_8
SUP_3V3_1	49	50	SUP_3V3_1

C104 (MSN-1)			
Signal Name	Pin Number		Signal Name
COM_to_RAB_GIO_1	1	2	COM_to_RAB_GIO_2
COM_to_RAB_GIO_3	3	4	COM_to_RAB_GIO_4
COM_to_RAB_GIO_5	5	6	COM_to_RAB_GIO_6
FAB_to_RAB_GIO_1	7	8	FAB_to_RAB_GIO_2
FAB_to_RAB_GIO_3	9	10	FAB_to_RAB_GIO_4
FAB_to_RAB_GIO_5	11	12	FAB_to_RAB_GIO_6
GND-SYS	13	14	GND-SYS
SUP_5V0	15	16	SUP_5V0
CPLD39	17	18	CPLD40
CPLD41	19	20	CPLD42
CPLD43	21	22	CPLD44
SUP_UNREG_1	23	24	SUP_UNREG_1
SUP_3V3_2	25	26	SUP_3V3_2
CPLD45	27	28	CPLD46
CPLD47	29	30	CPLD48
CPLD49	31	32	CPLD50
CPLD51	33	34	CPLD52
SUP_UNREG_2	35	36	SUP_UNREG_2
CPLD53	37	38	CPLD54
CPLD55	39	40	CPLD56
CPLD57	41	42	CPLD58
CPLD59	43	44	CPLD60
CPLD61	45	46	CPLD62
CPLD63	47	48	CPLD64
SUP_3V3_1	49	50	SUP_3V3_1

Table 4.3-3 C105 and C106 connector pin assignment

C105 (MSN-2)			
Signal Name	Pin Number		Signal Name
COM_to_RAB_GIO_1	1	2	COM_to_RAB_GIO_2
COM_to_RAB_GIO_3	3	4	COM_to_RAB_GIO_4
COM_to_RAB_GIO_5	5	6	COM_to_RAB_GIO_6
FAB_to_RAB_GIO_1	7	8	FAB_to_RAB_GIO_2
FAB_to_RAB_GIO_3	9	10	FAB_to_RAB_GIO_4
FAB_to_RAB_GIO_5	11	12	FAB_to_RAB_GIO_6
GND-SYS	13	14	GND-SYS
SUP_5V0	15	16	SUP_5V0
CPLD39	17	18	CPLD40
CPLD41	19	20	CPLD42
CPLD43	21	22	CPLD44
SUP_UNREG_1	23	24	SUP_UNREG_1
SUP_3V3_2	25	26	SUP_3V3_2
CPLD45	27	28	CPLD46
CPLD47	29	30	CPLD48
CPLD49	31	32	CPLD50
CPLD51	33	34	CPLD52
SUP_UNREG_2	35	36	SUP_UNREG_2
CPLD53	37	38	CPLD54
CPLD55	39	40	CPLD56
CPLD57	41	42	CPLD58
CPLD59	43	44	CPLD60
CPLD61	45	46	CPLD62
CPLD63	47	48	CPLD64
SUP_3V3_1	49	50	SUP_3V3_1

C106 (RAB)			
Signal Name	Pin Number		Signal Name
COM_to_RAB_GIO_1	1	2	COM_to_RAB_GIO_2
COM_to_RAB_GIO_3	3	4	COM_to_RAB_GIO_4
COM_to_RAB_GIO_5	5	6	COM_to_RAB_GIO_6
FAB_to_RAB_GIO_1	7	8	FAB_to_RAB_GIO_2
FAB_to_RAB_GIO_3	9	10	FAB_to_RAB_GIO_4
FAB_to_RAB_GIO_5	11	12	FAB_to_RAB_GIO_6
GND-SYS	13	14	GND-SYS
SUP_5V0	15	16	SUP_5V0
CPLD65	17	18	CPLD66
CPLD67	19	20	CPLD68
CPLD69	21	22	CPLD70
SUP_UNREG_1	23	24	SUP_UNREG_1
SUP_3V3_2	25	26	SUP_3V3_2
CPLD71	27	28	CPLD72
CPLD73	29	30	CPLD74
CPLD75	31	32	CPLD76
CPLD77	33	34	CPLD78
SUP_UNREG_2	35	36	SUP_UNREG_2
CPLD79	37	38	CPLD80
CPLD81	39	40	CPLD82
CPLD83	41	42	CPLD84
CPLD85	43	44	CPLD86
CPLD87	45	46	CPLD88
CPLD89	47	48	CPLD90
SUP_3V3_1	49	50	SUP_3V3_1

Table 4.3-4 SW1, SW2 and SW3 and SW4 connector pin assignment

Pin Number	SW1	SW2	SW3	SW4
1	Dep_SW_1	Dep_SW_2	Dep_SW_3	Dep_SW_4
2	GND_SYS	BAT_GND	GND_SYS	GND_SYS

Table 4.3-5 SP1, SP2, SP3, SP4 and SP5 connector pin assignment

SP1	
Pin Number	Signal Name
1	GND_SYS
2	SUP_3V3_1
3	Unassigned
4	SP_BUS_1
5	SP_BUS_2
6	Unassigned
7	Unassigned
8	POWERSC_+X
9	POWERSC_+X
10	TEMP_1 +X
11	Unassigned
12	GND_SYS

SP2	
Pin Number	Signal Name
1	GND_SYS
2	SUP_3V3_1
3	SUP_UNREG_2
4	Unassigned
5	Unassigned
6	Unassigned
7	Unassigned
8	POWERSC_-X
9	POWERSC_-X
10	TEMP_5 -X
11	Unassigned
12	GND_SYS

SP3	
Pin Number	Signal Name
1	GND_SYS
2	SUP_3V3_1
3	Unassigned
4	SP_BUS_1
5	SP_BUS_2
6	Unassigned
7	Unassigned
8	POWERSC_+Y
9	POWERSC_+Y
10	TEMP_4 +Y
11	Unassigned
12	GND_SYS

SP4	
Pin Number	Signal Name
1	GND_SYS
2	SUP_3V3_1
3	Unassigned
4	SP_BUS_1
5	SP_BUS_2
6	Unassigned
7	Unassigned
8	POWERSC_-Y
9	POWERSC_-Y
10	TEMP_2 -Y
11	Unassigned
12	GND_SYS

SP5	
Pin Number	Signal Name
1	GND_SYS
2	SUP_3V3_1
3	Unassigned
4	SP_BUS_1
5	SP_BUS_2
6	Unassigned
7	Unassigned
8	POWERSC_-Z
9	POWERSC_-Z
10	TEMP_3 -Z
11	Unassigned
12	GND_SYS

Table 4.3-6 JTAG connector pin assignment

JTAG	
Pin Number	Signal Name
1	SUP_3V3_2
2	TDO
3	TDI
4	TMS
5	TCK
6	GND_SYS

Table 4.3-7 CN303 and CN304 connector pin assignment

CN303 (Battery Power)	
Pin Number	Signal Name
1	GND_BAT
2	GND_BAT
3	GND_BAT
4	GND_BAT
5	Unassigned
6	Unassigned
7	PWR_BAT
8	PWR_BAT
9	PWR_BAT
10	PWR_BAT

CN303 (Battery heater and sensor)	
Pin Number	Signal Name
1	PWR_BAT
2	BAT_HEATER
3	BAT_TEMP
4	GND_SYS

Table 4.3-8 CN401 connector pin assignment

CN401	
Pin Number	Signal Name
1	GND_SYS
2	SUP_3V3_1
3	Unassigned
4	Unassigned
5	Unassigned
6	Unassigned
7	Unassigned
8	POWERSC_+Z
9	POWERSC_+Z
10	TEMP_7 +Z
11	TEMP_8 +Z
12	GND_SYS

The backplane board is equipped with Complex Programmable Logic Device (CPLD from Lattice Semiconductor (ispMACH4000ZE) to add flexibility in connection between components. The CPLD can adapt the change of pin-assignment in the mission boards so there is no need to remake the backplane when routing changes is needed. The detail of CPLD device can be found in Ref. (7). The backplane with CPLD has been flying onboard BIRDS-3 since 2019 for more than 1 year in ISS orbit. The CPLD can handle digital data only.

4.4 Data transfer rate from mission payload to platform

Figure 4.4 shows the data transfer between BIRDS platform and mission payload. Digital I/O lines and UART communications are used between Main PIC and mission payload. The data transfer rate of UART is 9,600 bps. In addition, SPI communication is used for data transfer to the shared flash memory. The data transfer rate for SPI communication is 1 Mbps.

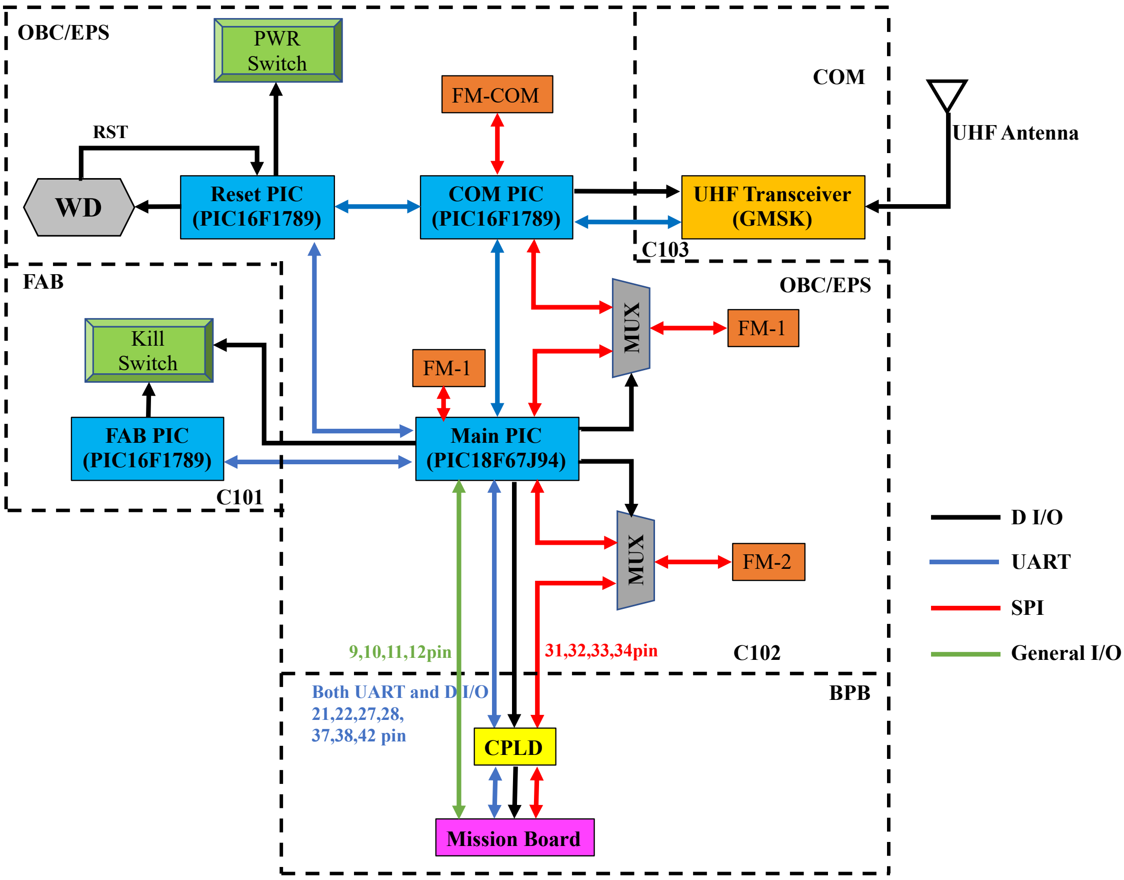


Figure 4.4 Data transfer between platform and payload

5 Software information

5.1 Software development environment

The software development environment of BIRDS platform is based on C programming language using CCS compiler ver.5.076 (http://www.ccsinfo.com/content.php?page=compilers). Microchip's PICkit programmer is required to write and load the program to PIC micro-controllers. Each PIC micro-controller on OBC board and FAB board has its own connectors for programming placed next to it, The connector pins have 1.27 mm pitch. When the satellite is fully assembled, the micro-controllers can be programmed through J1 socket connector in FAB that is accessible externally in the access window at +X side (see Section 4.1). J2 socket connector in FAB is for RS232 interface with Main PIC, user can make monitoring and debugging function with it. Figure 5.1-1 shows PICkit-3 programmer and its pin out and Table 5.1-1 shows PICkit to J1 connection.

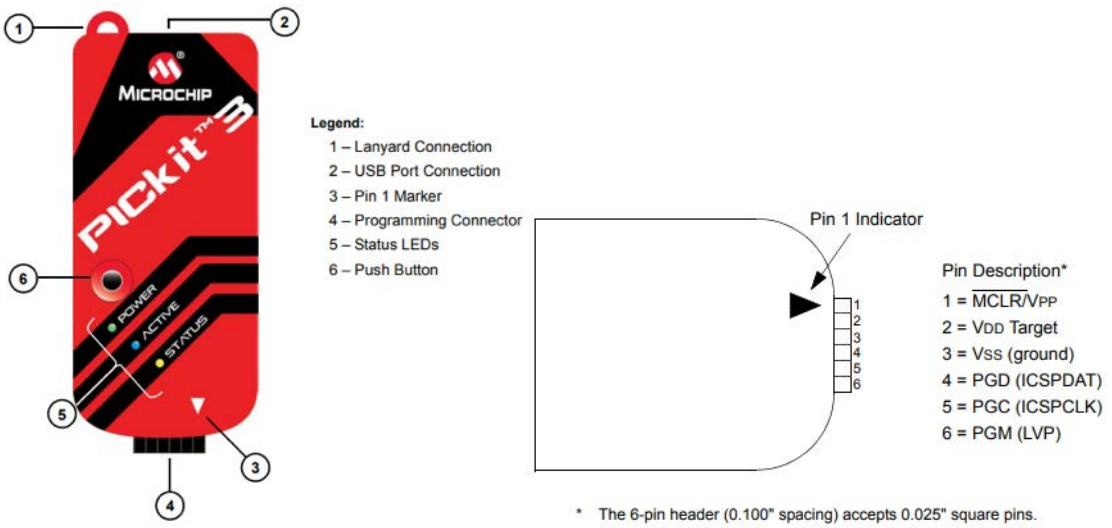


Figure 5.1-1 Microchip PICkit 3 programmer

(https://ww1.microchip.com/downloads/en/DeviceDoc/51795B.pdf)

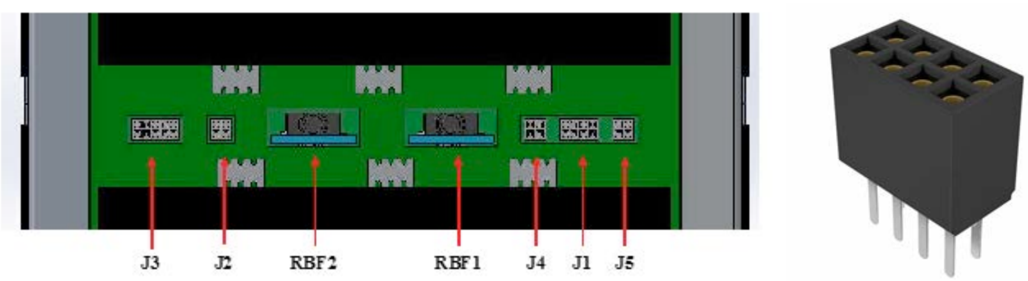


Figure 5.1-2 Connectors on FAB (Left), CAD of 1.27mm pitch socket connector (Right)

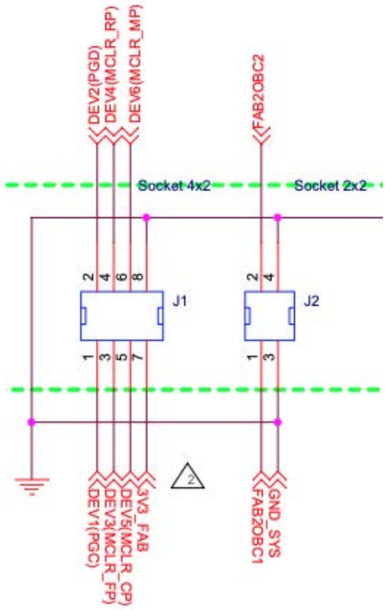


Figure 5.1-3 Pin assignment of J1 and J2 connector

PICkit needs to be connected with J1 connector for the programming of each PIC processor as like below table. Pin 1 of PICkit should be connected only one pin of J1 from pin 3 to pin 6 following the PIC processor which needs to be programmed.

Table 5.1-1 Connection between PICkit and J1 for programming

PICkit Pin No.	J1 Pin No.	Pin description
1	3	MCLR for FAB PIC
	4	MCLR for Reset PIC
	5	MCLR for COM PIC
	6	MCLR for Main PIC
2	7	3.3V power of satellite
3	8	Power ground
4	2	PGD, Data line of programming
5	1	PGC, Clock line of programming

PC (Personal Computer) of user needs to be connected with J2 of FAB using RS232 interface as like below table for monitoring or debugging.

Table 5.1-2 Pin connection for RS232 interface of J2

RS232 Pin No.	J2 Pin No.	Pin description
2	1	RxD, From Satellite to PC
3	2	TxD, Form PC to Satellite
5	3	Power ground

CPLD acts as a digital follower connecting the OBC and mission payload. VHDL is used in implementing the input-output routes based on OBC-mission payload pin map. Lattice Semiconductor's ispLever Classic IDE is used to generate JEDEC file which is then loaded to the CPLD using Lattice Semiconductor's Diamond Programmer software. CPLD is programmed through JTAG found in the backplane board. Figure 5.1-4 shows the programming cable for CPLD.

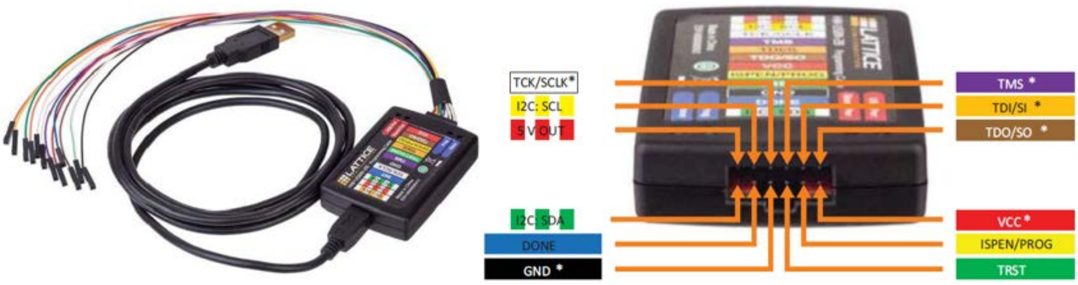


Figure 5.1-4 CPLD programming cable

(https://www.latticesemi.com/en/Products/DevelopmentBoardsAndKits/ProgrammingCablesforPCs)

5.2 Source code availability. Source code programming language details.

Sample code of four PIC processors is available for reference of software development. The first sample code is for FAB PIC of solar cell power monitoring. The second sample code is for Reset PIC of satellite power management. The third sample code is for COM PIC of satellite communication functionality between satellite and ground station. The fourth sample code is for Main PIC of satellite data management. Sample codes are written in C-language based on BIRDS-3 project heritage. Software library of CCS compiler is used extensively including serial interfaces between processors.

5.3 Ground station operation source code availability. Source code programming language details.

Ground station is constructed using amateur radio devices from antenna to operating personal computer. Operation software has been developed by Kyutech using C# language, and its code is available to uses as sample code. It uses SatPC32 of amateur radio software for satellite tracking and antenna control. SatPC32 is written and supported by Erich Eichmann(DK1TB), member of amateur radio community. He donated all the proceeds from the software to AMSAT to support amateur satellite. User can download SafPC32 software from the webpage of AMSAT, https://www.amsat.org/product/satpc32-by-electronic-download/, with some charge of 50USD. The webpage of AMSAT has also basic information about SatPC32.

6 Operation-related information

6.1 Maximum, nominal, and minimum power to payload

BIRDS platform can supply nominal, minimum, and maximum power of 1500 mW, 1350 mW, and 1880 mW, respectively, from the bus system to the payload.

6.2 Platform power consumption

The power generated in one orbit is about 1.23 Wh for maximum and 0.88Wh minimum in ISS orbit based on BIRDS-3 in-orbit results. The nominal power consumption in one orbit is 0.424 Wh.

6.3 Nominal supply voltage, maximum supply current, overcurrent protection threshold to payload

There are five power lines in BIRDS platform: Unreg1, Unreg2, 5V0, 3V3#1, and 3V3#2. Unreg1 and Unreg2 are raw voltages from the battery at 4.2 V maximum. A boost DC/DC converter is used to convert the RAW voltage to 5V in the 5V0 line, while buck-boost converters are used to convert the raw voltage to 3.3 V for 3V3#1 and 3V3#2 lines. The rated current of each DC/DC converter for 5V and 3.V lines is 2A. Each power line is equipped with overcurrent protection circuit, and the threshold for overcurrent protection is set to 4.0 A for Unreg1, 3.0 A for Unreg2, and 2.0 A for 5V0, 3V3#1, and 3V3#2. Figure 6.3 shows the EPS block diagram.

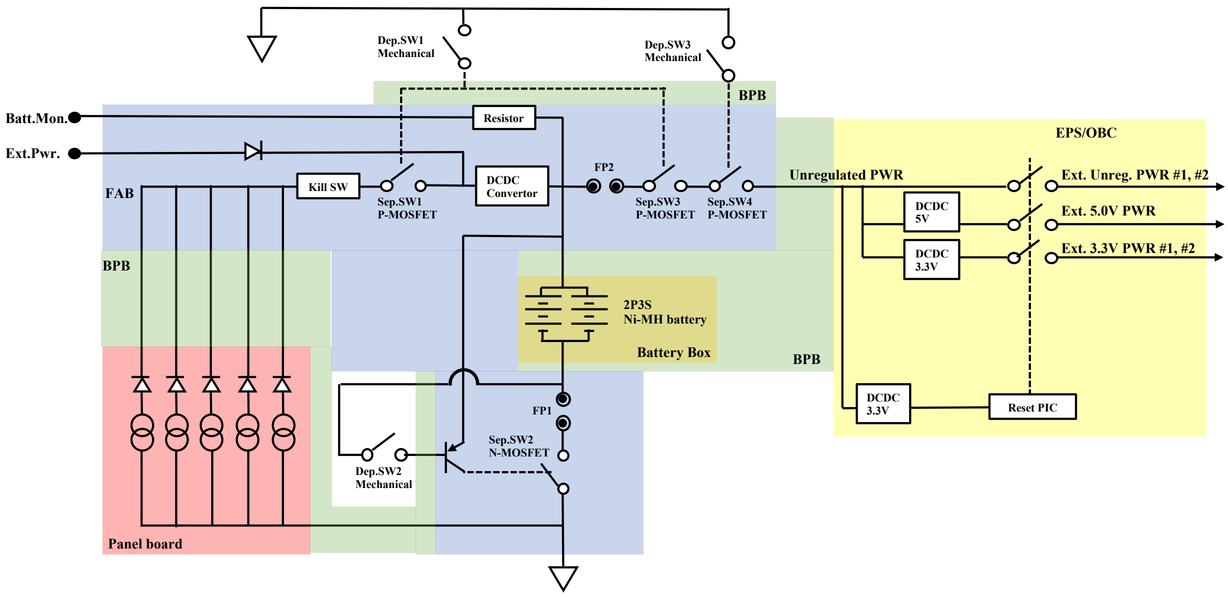


Figure 6.3 EPS Block Diagram

The Unreg1 corresponds to the pins #23 and #24 in the backplane 50pin connectors is reserved for the UHF Tx/Rx. Therefore, it is not recommended to take the power from those two pins. The Unreg2 corresponds to the pins #35 and #36 in the backplane 50 pin connectors is used for burner circuit of antenna deployment. If the payload requires a large amount of power, it is suggested to use this line, but the payload side shall have a proper protection such as over-current-protection as the line is directly connected to the battery. 5V0 (#15 and #16 in 50 pin connectors) can be used for any payload that requires 5V. 3V3#1 (#49 and #50 in 50 pin connectors) is used for powering FAB PIC, whose nominal power consumption is 66mW. 3V3#2 (#25 and #26 in 50 pin connectors) is used for payloads. If the payload boards use 3.3V, it is recommended to use 3V3#2.

6.4 Battery

There are six cells in the battery used in BIRDS platform. The cells are connected in 3-series and 2-parallel configuration. All cells are NiMH (NiOOH / Metal Alloy / KOH). Table 6.4-1 shows the specification of each cell, and Table 6.4-2 shows the specification of the battery. See Ref. (8) for the charging procedure.

Table 6.4-1 Cell specification

Chemistry	NiMH (NiOOH/Metal Alloy/KOH)
Size [mm]	Diameter 14.35 × Length 50.4
Nominal OCV [V]	1.2
Maximum Voltage [V]	1.6
Minimum Voltage [V]	0.9
Rated Capacity [mAh]	2,000
Maximum Discharge Current [mA]	6,000
Discharge Temperature [°C]	0 to +50
Charge Temperature [°C]	0 to +40
Storage Temperature [°C]	-20 to +40

Table 6.4-2 Battery specification

Quantity of cell	6
Cell connectivity	3S2P
Operation Battery Environment Temperature [°C]	0 to +40
Nominal OCV [V]	3.6
Maximum Voltage [V]	4.8
Minimum Voltage [V]	2.7
Rated Capacity [mAh]	4,000

6.5 Data storage capacity allocation for mission data

Main PIC shares one NOR type flash memory (MT25QL01GBBB8ESF-0SIT) of SPI interface with the mission payloads, and its capacity is 1 Gbit =128,000 kBytes. The flash memory is fully allocated to mission data. Table 6.5 shows the sample of BIRDS-3 project for storage capacity allocation for the mission data in BIRDS platform.

Table 6.5 Mission data storage allocation sample, 1 sector has 64 kBytes

CAM	90 sectors	5,760 kBytes
LDM	1 sector	64 kBytes
ADCS	500 sectors	32,000 kBytes

High Sampling	409 sectors	26,176 kBytes
Normal Sampling	1000 sectors	64,000 kBytes
Total	**2000 sectors**	**128,000 kBytes**

6.6 ADCS detection and pointing accuracy and control mode

BIRDS platform has no function of ADCS (Attitude Determination and Control System). User can install permanent magnet and hysteresis damper in structure for passive attitude stabilization control. Or, if active attitude control functionality is required, it needs to be developed as mission system by users.

The attitude control sensor, such as magnetometers, gyro-sensors, etc, can be mounted on RAB or mission board, it depends on user's ADCS design.

6.7 ADCS Stability

N/A

6.8 In-orbit software configuration

Software cannot be reconfigured in orbit.

6.9 Satellite position and time stamp

In BIRDS platforms, the satellite knows its own position by communicating with the GS based on the result of orbit calculation. If GPS is installed as an option, the satellite can know its own position by GPS. The time is counted by Reset PIC. The time and position information can be handed over to the mission payload through OBC. The time information is not discontinued at the satellite resets (either routine or non-routine reset). If something goes wrong with Reset PIC and Reset PIC is reset, the time information is reset.

6.10 Housekeeping data

In nominal operation mode given by the sample OBC program, the following set of data is collected at every 90 seconds (Table 6.10). In high sampling mode, the data is collected at every 5 seconds. Table 6.10 shows housekeeping contents and data size, while Figure 6.10 shows the housekeeping data format.

Table 6.10 Housekeeping contents and data size

Field	Byte Number	Data size [byte]	Field	Byte Number	Data size [byte]
Header (0x33)	0	2	SRC Voltage	40	1
seconds	2	1	RAW Voltage	41	1
minutes	3	1	SRC Current HIGH,LOW	42	2
hours	4	1	Battery Voltage	44	1
days	5	2	Battery Current HIGH,LOW	45	2
(0xAA)	7	3	Battery Temperature	47	1
+X Temperature HIGH,LOW	10	2	Heater Status Flag	48	1
-Y Temperature HIGH,LOW	12	2	Kill switch Status Flag	49	1
-Z Temperature HIGH,LOW	14	2	(0xBB)	50	3
+Y Temperature HIGH,LOW	16	2	*Magnetometer data X axis	53	2
-X Temperature HIGH,LOW	18	2	*Magnetometer data Y axis	55	2
Backplane Temp HIGH,LOW	20	2	*Magnetometer data Z axis	57	2
+Z Temperature HIGH,LOW	22	2	*Gyroscope data X axis	59	2
+X Voltage HIGH,LOW	24	2	*Gyroscope data Y axis	61	2
-Y Voltage HIGH,LOW	26	2	*Gyroscope data Z axis	63	2
-Z Voltage HIGH,LOW	28	2	*GPS data	65	48
+Y Voltage HIGH,LOW	30	2	(0xCC)	113	3
+Z Voltage HIGH,LOW	32	2	Voltage RAW	116	1
+X Current	34	1	Current 3V3#1 line	117	1
-Y Current	35	1	Current 3V3#2 line	118	1
-Z Current	36	1	Current UNREG#1 line	119	1
+Y Current	37	1	Current UNREG#2 line	120	1
+Z Current	38	1	Reset Time	121	1
Raw Current	39	1	Footer (0x44)	122	2

Note: The data marked with (*) are not read from BIRDS platform, in the given sample OBC program. Those are read from an ADCS mission

Header (0x33)		sec	min	hour	day		0xAA			+X Temp HIGH,LOW		-Y Temp HIGH,LOW		-Z Temp HIGH,LOW		+Y Temp_HIGH,		-X Temp HIGH,LOW		BPB TEMP HIGH_LOW	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte

+Z Temp HIGH,LOW		+X Voltage HIGH,LOW		-Y Voltage HIGH,LOW		-Z Voltage HIGH,LOW		+Y Voltage HIGH,LOW		+Z Voltage HIGH,LOW		+X Current	-Y Current	-Z Current	+Y Current	+Z Current	Raw Current	SRC Voltage	RAW Voltage	SRC Current HIGH,LOW	
23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte

Battery Voltage	Battery Current H&L		Battery Temp	Heater FLAG	Kill Status	0xBB			Magnetometer X		Magnetometer Y		Magnetometer Z		GYRO X		GYRO Y		GYRO Z	
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte

GPS																							
66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte

GPS																							
90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte

0xCC			Voltage RAW	Current 3V3#1	Current 3V3#2	Current UNREG#1	Current UNREG#2	Reset Time	Footer (0x44)	
114	115	116	117	118	119	120	121	122	123	124
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte

Figure 6.10 Housekeeping data format

6.11 Uplink, downlink, and CW specifications including frequency, bandwidth, modulation, rate and data format

Table 6.11-1 to Table 6.11-3 show the uplink, downlink, and CW specifications of BIRDS Platform with the ground station.

Table 6.11-1 Uplink specification

Transmit power [W]	50 W
Frequency [MHz]	435.***
Bandwidth [kHz]	26
Modulation	GMSK
Data rate [bps]	4800
Packet format	AX.25

Table 6.11-2 Downlink specification

Transmit power [W]	0.8 W
Frequency [MHz]	437.375
Bandwidth [kHz]	26
Modulation	GMSK
Data rate [bps]	4800

Packet format	AX.25

Table 6.11-3 CW specification

Transmit power [W]	0.1
Frequency [MHz]	437.375
Bandwidth [Hz]	500
Modulation	CW morse code
Data rate [wpm]	20

If the sample software is used for the CW transmission, the following is the specification of the CW beacon.

BIRDS platform sends two CW beacons, CW Type-1 (CW-1) and CW Type-2 (CW-2). CW is transmitted every two minutes and switches between CW-1 and CW-2. Both have the same beacon format: satellite call sign followed by satellite project name, CW Short Messaging Service (CW-SMS), and finally housekeeping information. CW-1 housekeeping information is on battery health, operation modes, kill switch status, solar panels and reset. CW-2 housekeeping information is on gyro data, Automated Mission (ATDM) status, reservation command information, uplink success status and backplane board temperature. CW-SMS can be used as an outreach service where ground station sends alphanumeric message to the satellite and the satellite transmits the message in the beacon. Figure 6.11 shows the beacon format, and Table 6.11-4 shows bit-wise information on the CW-1 and CW-2 beacons.

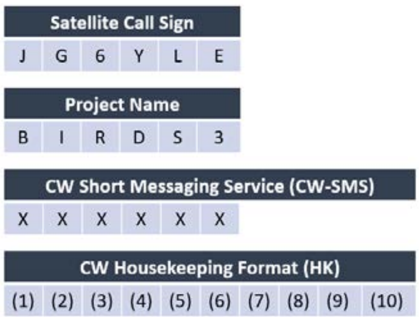


Figure 6.11 CW beacon format

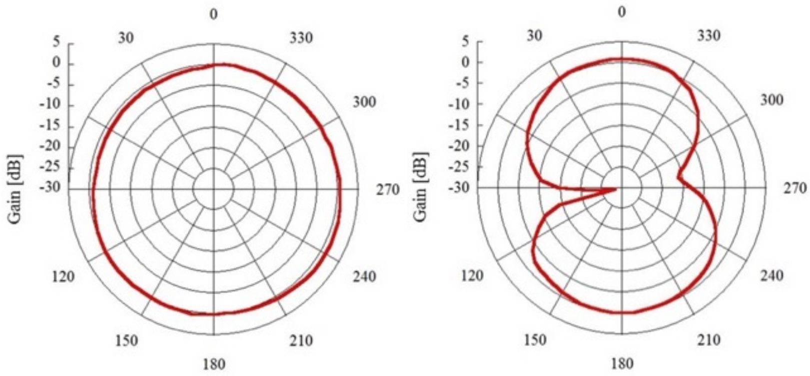
Table 6.11-4 CW-1 and CW-2 housekeeping format

HK	CW-1		CW-2	
Cell	Data	Bit	Data	Bit

(1)-(2)	Battery Voltage [mV]	8bit	Gyro X [deg/s]	8bit
(3)-(4)	Battery Current [mA]	8bit	Gyro Y [deg/s]	8bit
(5)-(6)	Battery Temp [℃]	8bit	Gyro Z [deg/s]	8bit
(7)	CW Format Identifier	1bit	CW Format Identifier	1bit
	Operation Mode	2bit	ATDM 1	1bit
			ATDM 2	1bit
	Kill Switch Main	1bit	ATDM 3	1bit
(8)	Kill Switch FAB	1bit	ATDM 4	1bit
	Antenna Deploy Status	1bit	Battery Heater	1bit
	Solar Cell +X	1bit	Reserve Command	1bit
	Solar Cell -Y	1bit	Uplink Success	1bit
(9)	Solar Cell -Z	1bit	BPB Temperature	8bit
	Solar Cell +Y	1bit		
	Solar Cell +Z	1bit		
(9)-(10)	Time after Reset in HRS	5bit		

6.12 Antenna specification including antenna pattern and maximum gain

Figure 6.12 shows the antenna pattern of the dipole antenna used in BIRDS platform.



(a) (b)

Figure 6.12 Antenna radiation pattern. (a) H-Plane (b) E-Plane

6.13 Ground Station (GS) specifications including antennas and wireless devices

Figure 6.13 shows the specifications of the GS system used for BIRDS platform. It is a typical amateur ground station. The GS consists of an encoding / decoding part consisting of a PC, TNC

(KPC-9612 Plus), Radio (IC-9100), and Low Noise Amplifier (LNA), and an antenna control part consisting of a UHF antenna and rotator. The characteristics of Radio are shown in Table 6.13-1, and the characteristics of Rotator are shown in Table 6.13-2. Antennas are used in two stack arrays. The characteristics of the antenna alone are shown in the Table 6.13-3, and the combined characteristics are shown in the Table 6.13-4.

The operating software we use for GS is developed in C++ along with the tracking software SatPC32.

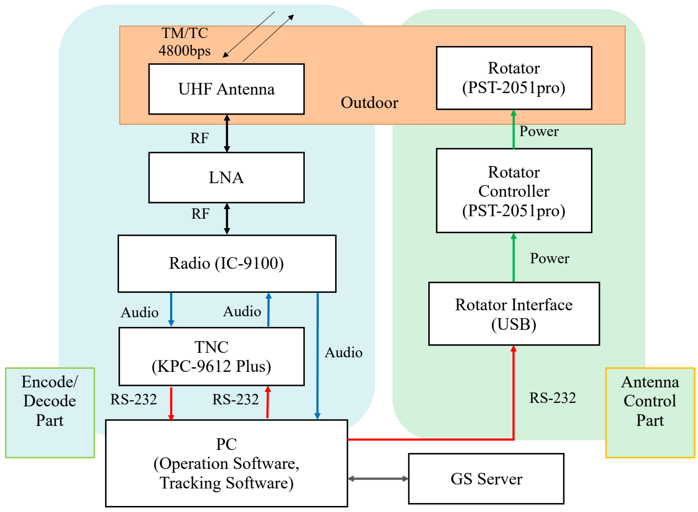


Figure 6.13 GS system on BIRDS platform

Table 6.13-1 GS Radio Specifications (ICOM 9100M)

Frequency ranges	RX	<Operating range> 30kHz to 60.000MHz 144.000MHz to 146.000MHz 430.000MHz to 440.000MHz <Guaranteed range> 500kHz to 29.9999MHz 50.000MHz to 54.000MHz 144.000MHz to 146.000MHz 430.000MHz to 440.000MHz
	TX	1.800MHz to 1.875MHz 1.9075MHz to 1.9125MHz 3.500MHz to 3.580MHz 3.599MHz to 3.612MHz 3.662MHz to 3.387MHz 3.702MHz to 3.716MHz 3.745MHz to 3.770MHz 3.791MHz to 3.805MHz 7.000MHz to 7.200MHz 10.100MHz to 10.150MHz ~ 14.350MHz 14.000MHz 18.068MHz ~ 18.168MHz 21.000MHz ~ 21.450MHz 24.890MHz ~ 24.990MHz 28.000MHz ~ 29.700MHz 50.000MHz ~ 54.000MHz 144.000MHz ~ 146.000MHz

		430.000MHz ～ 440.000MHz 4630KHz
Modulation schemes and data rates		LSB / USB, CW, RTTY, AM, FM, DV (1200bps to 9600bps)
Tuning step		1 / 10 / 100 Hz / 1 / 5 / 6.25 / 9 / 10 / 12.5 / 20 / 25 / 50 / 100 KHz / 1 MHz
Output power	SSB/CW/RTTY /FM/D-STAR	2~100 W (1.8~54 MHz bands) 2~50 W (144 MHz band) 2~50 W (430 MHz band)
	AM	2~30 W (1.8~54 MHz bands)
Frequency stability		± 0.5 ppm max with temperature from 0°C to +50°C after 5' power ON.
Frequency resolution		Minimum 1Hz
Data link layer protocol		AX.25
Data Interfaces		Jack 8-pin (microphone) Jack 3.5 mm (CI-V remote control) Jack 6.35 mm (ALC) Jack 6.35 mm (CW keyer) Jack 6.35 mm (SEND) Jack 2.5 mm (DATA1, GPS) Socket 6-pin (DATA2, TNC) Socket 13-pin (accessories) Socket 4-pin (antenna tuner) USB (PC, cloning, input modulation)

Table 6.13-2 Rotor Characteristics (ProSisTel - PST2051pro+E)

Rotational Range	Azimuth	360 degrees
	Elevation	180 degrees
Rotational Speed		90 seconds for 360 degrees
Rotor Pointing Accuracy		1 degree

Table 6.13-3 Antenna Characteristics

Model	436CP42UG
Frequency Range [MHz]	430 to 438
Gain [dBic]	18.9
Beam Width	21° circular
Boom Length / Dia.	18’10” / 1-1/2” to 1” (about 5.7m)
Wind Area / Survival	2 Sq.Ft. / 100MPH (about 160 km/h)
Weight / Ship Wt.	7.5 Lbs. / 10 Lbs. (about 3.4kg)

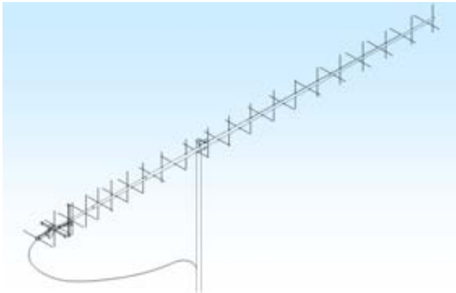
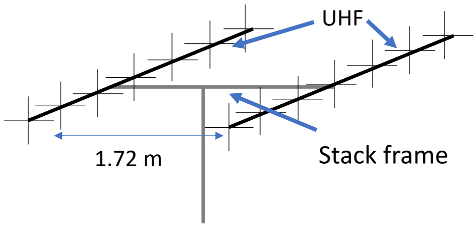
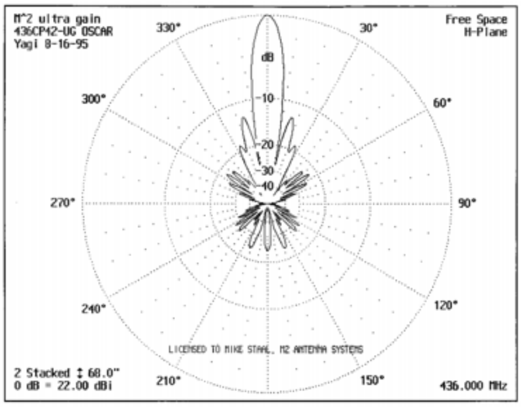
Image	

Table 6.13-4 Antenna Array Characteristics

Image	
Gain [dBi]	22.00
Weight [kg]	12.7
Stack frame [kg]	5.9
Antenna Pattern	

Typical link budget between BIRDS-3 satellites in ISS orbit and the Kyutech ground station located at N 33.892511° and E 130.840118°. The uplink was successful at the elevation angle of as low as 0 degree. FM packet downlink was successful at the elevation of as low as 0 degree. Table 6.13-5 shows link budget based on BIRDS-3 experience in orbit.

Table 6.13-5 Link budget as experienced by BIRDS-3

Elevation angle [degree]	Free space path loss [dB]	Calculated Effective attenuation [dB]	Received power of the satellite [dBm]	Link margin [dB]
0	152.6	139.8	-92.8	0.2
5	150.6	137.8	-90.8	2.2
9	149.0	136.2	-89.2	3.8

20	145.4	132.6	-85.6	7.4
30	142.9	130.1	-83.1	9.9
40	141.1	128.3	-81.3	11.7
49	139.8	127.0	-80	13
60	138.8	126.0	-79	14
70	138.1	125.3	-78.3	14.7
80	137.7	124.9	-77.9	15.1
90	137.6	124.8	-77.8	15.2

<u>Link Budget Calculation</u>

Received power of the satellite = 47 dBm - Calculated Effective attenuation using received CW power to the ground station from satellite

Link margin = Received power of the satellite – Satellite receiver sensitivity (-93 dBm)

The satellite receiver sensitivity (-93dBm) was measured by the pre-flight test. In the test, the satellite flight model fully assembled was used with its antenna deployed. The satellite was operated with battery to isolate the satellite from any ground equipment. The command uplink was sent via air (i.e. radio wave). The command success was verified by checking the acknowledgment signal sent back from the satellite via air. The attenuator was attached between the antenna and the radio on the ground side. The attenuator value was adjusted while looking at the success rate of command uplink. The receiver sensitivity was determined when the success rate became 50%.

7 Safety information

7.1 Initial sequence after deployment from POD

1） The four deployment switches (Dep.SW) are turned ON. Current flows from the solar cell to the charging line of the battery, and to the power lines of Unreg1 and Unreg2.
2） Power is supplied to the Reset PIC and the 30 minutes timer starts.
3） Reset PIC activates Main PIC, COM PIC and FAB PIC.
4） The Main PIC starts collecting satellite data from the FAB PIC every 5 seconds.
5） Reset PIC (power line) and Main PIC (signal) activate the heat cutter of the antenna deployment mechanism.
6） After antenna deployment, heat cutter is deactivated.
7） Reset PIC turns on the power to the UHF transmitter and enables RF transmission (CW beacon).

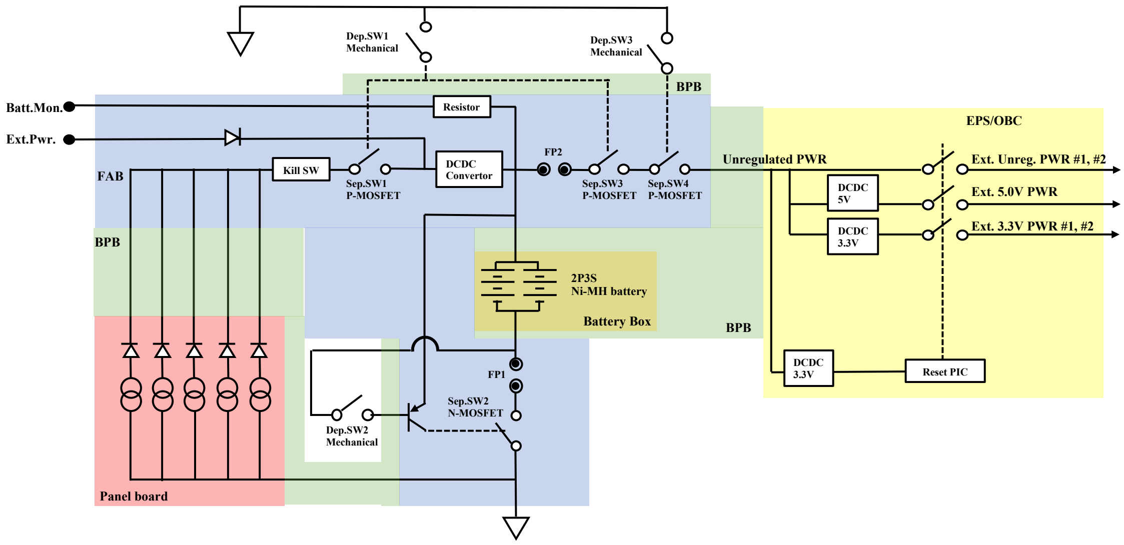
7.2 Inhibit logic that guarantees cold launch

BIRDS platform has switches designed for cold launch. Dep.SW (mechanical) and Sep.SW (electronic) switches are used. The BIRDS platform has two power sources, the battery and the solar panel. As shown in Figure 7.2-1, the power supplied from the battery to the load side is controlled by Sep.SW2, Sep.SW3, and Sep.SW4. The power supply from the solar cell panel to the load side is controlled by Sep.SW1 and Sep.SW4. And the minimum power required to activate the Reset PIC to transmit power to the load side of the satellite is 380 mW. The light inside the ISS cannot generate enough power to activate the satellite.

In this way, it responds to the cold launch requirement. The mechanism of each switch is shown below. Figure 7.2-2 shows the circuit diagram around Sep.SW. A pull-up resistor is connected to the gate of the MOSFET (Sep.SW) to avoid malfunction of the MOSFET due to charging of wires connected to Dep.SW by external radio wave.

Dep.SW is a mechanical switch that is turned once satellite is ejected from POD. The BIRDS platform uses two types of Dep.SW. Details of the switches are shown in Table 7.2. Dep.SW1 and Dep.SW3 are attached to the rail end (-Z side) of the BIRDS platform. The switch tips of Dep.SW1 and Dep.SW3 protrude up to 1.2 mm from the rail end, and the switch is turned off by pushing it up to about 0.85 mm from the rail end. See Figure 7.2-3 for details. Dep.SW2 is a side switch mounted on the rail side of the platform. The main body of Dep.SW2 is housed in the platform, and the tip of the actuator protrudes from the hole on the side of the rail. See Figure 7.2-4 for details. When the actuator is pushed to a position about 1.6 mm from the rail surface, the switch turns off. If it is pushed further, it will be pushed to the height of the rail surface.

Sep.SW is an electronic switch which uses MOSFETs. For Sep.SW1, Sep.SW3, and Sep.SW4, the gate of the P-MOSFET (SQA403EJ) is directly connected to the Dep.SW. When Dep.SW is turned ON (goes to system GND), it triggers the gate of the P-MOSFET gate and Sep.SW is turned ON. For Sep.SW2, a PNP transistor is connected between the Dep.SW and N-MOSFET (Si7998DP). When Dep.SW is turned ON (goes to battery GND), the PNP transistor is turned ON which triggers the gate of N-MOSFET. Sep.SW2 is turned ON.



	Inhibit1	Inhibit2	Inhibit3
From Battery	Sep.SW2	Sep.SW3	Sep.SW4
From Solar cell	Sep.SW1	Sep.SW4	-

Figure 7.2-1 Power system block diagram

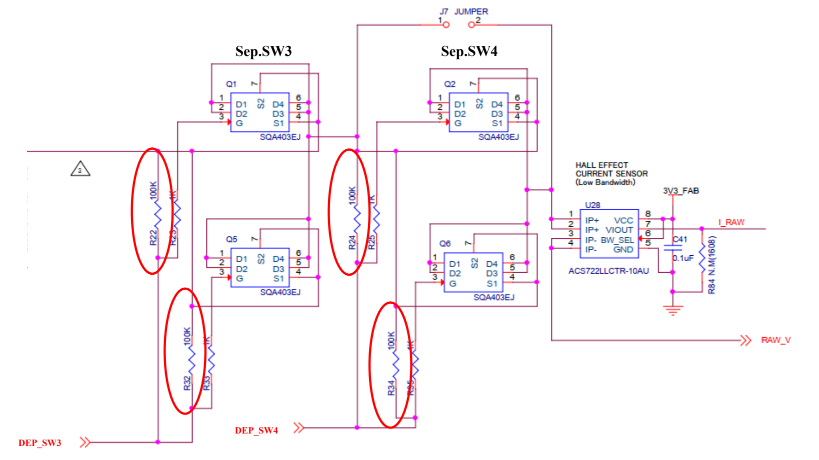
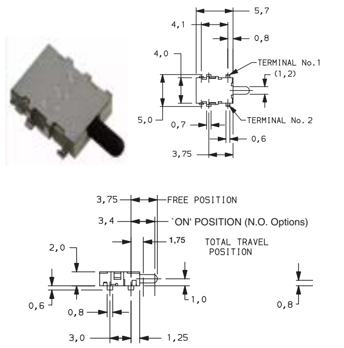
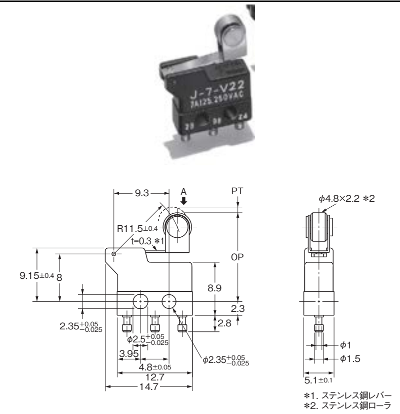


Figure 7.2-2 Circuit diagram around Sep.SW

Table 7.2 Deployment Switch specifications

	Dep.SW 1 and 3	Dep.SW 2
Manufacturer	C&K Components	OMRON Corporation Electronic
Part No.	SDS002	J-7-V22
Current rating [A]	0.100 (DC)	7
Voltage rating [V]	12 (DC)	125-250 (AC)
Releasing Force [N]	0.29	0.05
Overtravel [mm]	2	1.6
Tip shape	-	R2.4 roller type
Durability (electrical)	50,000 cycles	50,000 cycles

Operating temperature[°C]	-40 ~ +85	-10 ~ +80
Shape.		
Reference	http://www.farnell.com/datasheets/2706252.pdf?_ga=2.193125738.659546044.1563761570-297784464.1563761570	https://www.fa.omron.co.jp/product/item/8564/

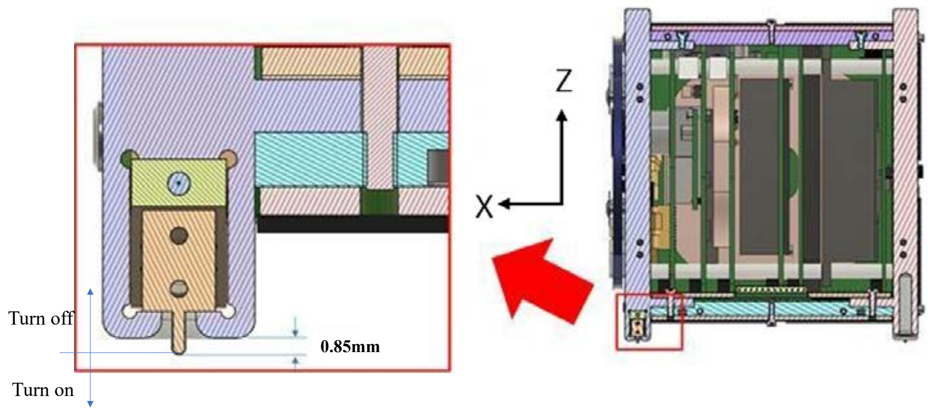


Figure 7.2-3 Dep.SW1, Dep.SW3

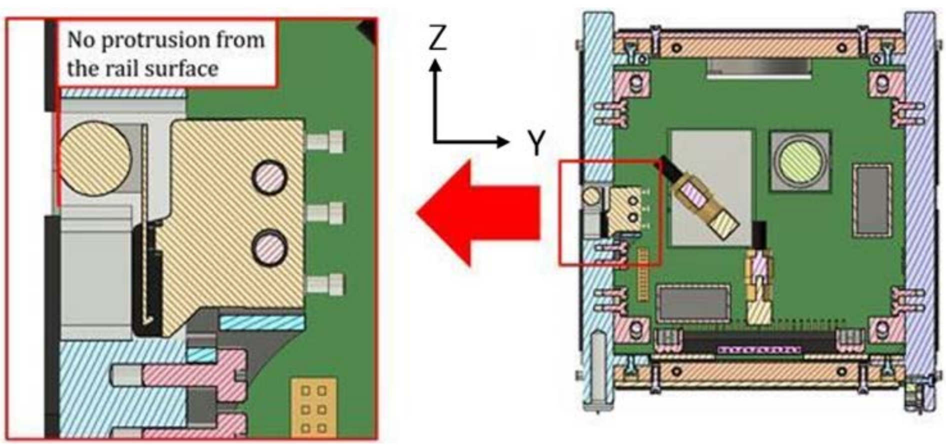
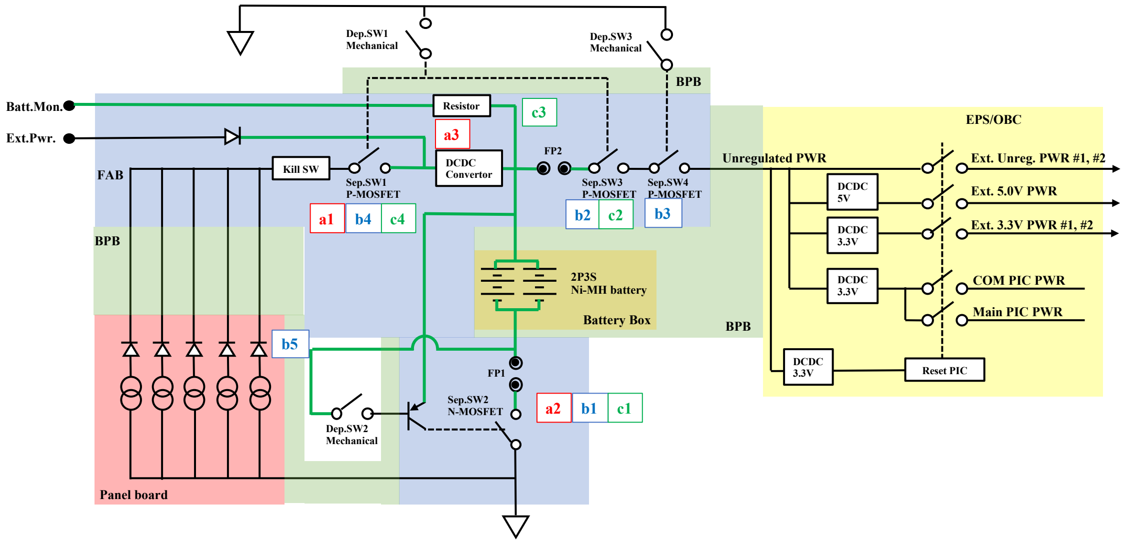


Figure 7.2-4 Dep.SW2

7.3 Battery specifications, including capacity and protection mechanism

See section 6.4 for battery specifications used on BIRDS platform. The battery has the risk of over-charge, over-discharge, short-circuit failure, rupture, etc. BIRDS platform has protection mechanism to the battery until it is released into satellite orbit. Figure 7.3 shows the protection function corresponding to each failure.



		Inhibit1	Inhibit2	Inhibit3
a. Overcharge		Sep.SW1 [a1]	Sep.SW2 [a2]	DCDC Convertor [a3]
b. Overdischarge	Load side	Sep.SW2 [b1]	Sep.SW3 [b2]	Sep.SW4 [b3]
	Solar cell side		Sep.SW1 [b4]	Diode [b5]
c. External short	Load side	Sep.SW2 [c1]	Sep.SW3 [c2]	Proper Insulation [c3]
	Solar cell side		Sep.SW1 [c4]	

Note: Proper insulation (double isolation is shown by green line in figure avobe, single isolation is black line)

Figure 7.3 Inhibits for Battery Hazard

As battery protection mechanism, BIRDS platform has Sep.SW that disconnects the charging circuit, a DCDC converter that controls the output voltage, and a diode that prevents reverse flow of current.

For protection against over-charging, the battery is separated from the solar panel and GND by two switches, Sep.SW1 and Sep.SW2. Furthermore, a DCDC converter is placed between the solar panel and the battery. The output voltage of the DCDC converter is designed to be 4.2V nominal. Therefore, even if an excessive voltage is generated from the solar panel side with respect to the battery, the voltage is stepped down by the DCDC converter to 4.2 V.

For protection against over-discharging, three inhibits are placed on the circuit from the battery to the load side, and on the circuit from the battery to the solar panel side. For the circuit from the battery to the load side, the battery is separated from the load and GND by three switches: Sep.SW2, Sep.SW3, and Sep.SW4. For the circuit from the battery to the solar panel side, the battery is separated from the solar panel and GND by two switches Sep.SW1 and Sep.SW2, and a diode placed between the solar panel and the battery. The diode prevents the reverse current flow to the solar panel side and does not cause over-discharge.

For protection against short-circuit, three inhibits are placed on the circuit from the battery to the load side. The battery is separated from the load and GND by two switches, Sep.SW2 and Sep.SW3. Also, the wiring between the battery, and the two switches is double-insulated (covered wire). The wiring is covered with an insulating film, or an insulating layer is sandwiched between the board wirings, and space insulation is placed with a distance of 1 mm or more.

Three inhibits from the battery to the solar panel side are also placed for short-circuit protection. The battery is separated from the solar panel and GND by two switches, Sep.SW1 and Sep.SW2. Also, the wiring between the battery, and Sep.SW2 and Sep.SW3 is double insulated.

Further, as shown in Figure 7.3, all the lines corresponding to the first inhibit from the battery such as the battery charging line, and the monitor line are double-insulated. Other lines are also insulated.

8 Reliability information

8.1 Subsystem TRL information (see ISO-16290)

Table 8.1 TRL information

Subsystem	TRL	Remark
OBC	9 (Flight proven)	Operational in three BIRDS-3 satellites Total cumulated time in orbit > 3years
EPS	9 (Flight proven)	
COM	9 (Flight proven)	
Backplane board with CPLD	9 (Flight proven)	Operational on one BIRDS-3 satellite Total cumulated time in orbit > 1years
Structure	9 (Flight proven)	Launched to ISS via Antares

8.2 Flight heritage including orbit, duration, and launcher

BIRDS platform was used for three BIRDS3 satellites that were delivered to ISS on board the Cygnus re-supply spacecraft launched by Antares rocket in April 2019. The three BIRDS3 satellites were released from International Space Station (ISS) into ISS orbit (altitude 400 km, inclination:

51.6º, duration: 92.6 min) in June 2019, and have been in operation for 18 months until November 2020. The backplane with CPLD was used for one BIRDS-3 satellite only.

The temperature range experienced by BIRDS-3 since June 2019 is listed in Table 8.2-1 and shown in Figure 8.2-1.

Table 8.2-1 Temperature range experienced by BIRDS-3

Components	**Temperature range** [°C]
Solar Panel	-38 to +64
Battery	-0.9 to +26.9

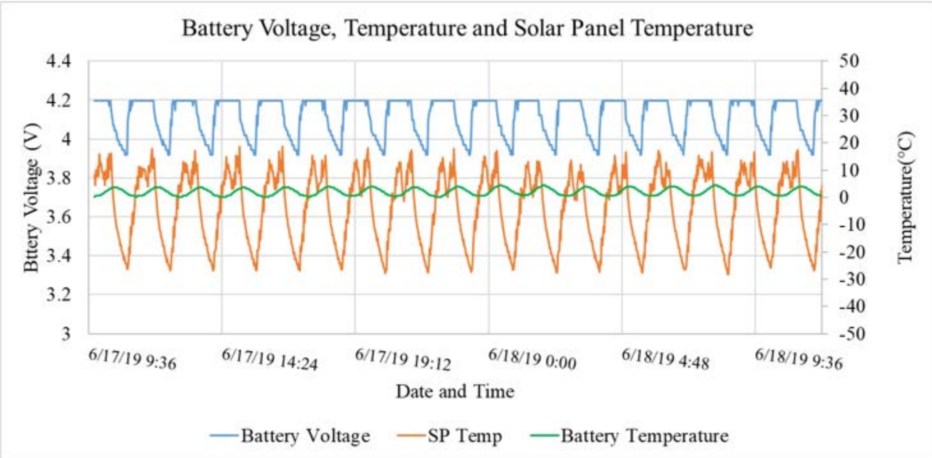


Figure 8.2-1 Temperature range experienced by BIRDS-3

The total dose from June 2019 to October 2020 in ISS orbit is shown in Table 8.2-2

Table 8.2-2 Total dose in ISS orbit

Al shield [mm]	**Total dose (16 months since June 2019) [rad]**
1	2.462×10^3
2	9.756×10^2
3	4.407×10^2
4	2.221×10^2
5	1.208×10^2

8.3 Uplink command validation

The command uplinked form the ground station is first interpreted at COM PIC. The command is made of the following format. The command is judged as valid when the following condition meets,

Table 8.3 GS Command

0x42	Sat ID	0x00	Variable command									CRC_H	CRC_L
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte

The command is judged as valid when the following condition meets

- Cyclic Redundancy Code (CRC) is correct
- Satellite Id is correct

8.4 Single-event effect protection mechanism

BIRDS platform uses over-current protection (OCP) circuit and satellite reset as the protection method from single event effects. As a default, the satellite resets at every 24 hours, where all the power is cut-off except Reset PIC. Once anomaly (hang-up) of Main PIC, COM PIC and Reset PIC is detected, they are power-cycled. The OCP is connected to each component to shut-off the power once an over-current is detected. The power is automatically turned on again after over current event is cleared.

8.5 Satellite resets

Satellite has two kinds of reset. One is regular reset of 24 hours period, another is irregular reset by trouble of freezing PIC processors, COM PIC and Main PIC.

- **Regular reset**

  Reset PIC manages all power of satellite, and it has clock timer for satellite time management. When 24 hours pass from the previous reset, Reset PIC turn off all power of satellite, and turn on the power of bus system to initialize the satellite. Satellite operation schedule needs to be determined based on this periodic initialization of regular reset.

- **Irregular reset**

  Electronic devices, especially microcontrollers, have risk of freezing always because of single event of radiation, bug of software, and so on. Reset PIC takes periodic messages from COM PIC and Main PIC. The period between messages can be determined by user based on satellite design. If Reset PIC cannot take any message from COM PIC or Main PIC more than the threshold time which determined by user, Reset PIC turn off all power of satellite, and turn on the power of bus system to initialize the satellite. For the risk of freezing Reset PIC, external watchdog timer is attached to Reset PIC. If Reset PIC does not send periodic pulse to the external watchdog timer, the watchdog timer resets Reset PIC, and satellite is forced to take hard reset for the initialization.

8.6 Test results (see ISO-19683)

BIRDS platform is compatible with the satellite launch environment of ISS (see Ref. [2]).

Some key parts were tested for Total Ionization Dose (TID) and Single Event Latch-up (SEL). These are listed in Table 8.6.

Table 8.6 Parts tested for TID and SEL

Parts	Usage	Test conducted
PIC 16F1789	COM PIC, Reset PIC, FAB PIC	Single Event Latch-up using Cf-252 source Total ionization dose using Cs-134 up to 23kRad
PIC 18F67J94	Main PIC	Single Event Latch-up using Cf-252source
IRL620(N-channel MOSFET)	Mission	Total ionization dose using Co-60 up to 50 kRad and Cs-134 up to 23kRad.
IRLML6402 (P-channel MOSFET)	Mission	Total ionization dose using Co-60 up to 50 kRad and Cs-134 up to 23kRad.

8.6.1 Vibration environment

BIRDS platform has a structure that can withstand the vibration environment of the level shown in Table 8.6.1-1 (AT) and Table 8.6.1-2 (QT). It has been tested (see: Ref.(3)) and has not experienced any damage on fastener parts, glass parts, communication equipment malfunctions, or other BIRDS platform malfunctions. The BIRDS platform also withstands qualification test (QT) level testing. In addition, satellites using the BIRDS platform are currently operating in the ISS orbit and are sufficiently resistant to the launch vibration environment.

Table 8.6.1-1 Vibration Environment (AT)

Freq. [Hz]	PSD [G2/Hz]
20	0.02
50	0.02
120	0.031
230	0.031
1000	0.0045
2000	0.0013
Overall [Grms]	4.08
Duration [sec]	60

Table 8.6.1-2 Vibration Environment (QT)

Freq. [Hz]	PSD [G2/Hz]
20	0.04
50	0.04
120	0.062
230	0.062
1000	0.009
2000	0.0026
Overall [Grms]	5.77
Duration [sec]	120

8.6.2 Vacuum environment

BIRDS platform is designed to withstand vacuum environment of $5x10^{-3}$ Pa or less. It has been tested (see: Thermal Vacuum Test Report) for about 14 hours at vacuum environment and operated normally. Moreover, satellites using the current BIRDS platform are operating for 18 months ISS orbit, and has sufficient resistance to the vacuum environment.

8.6.3 Thermal environment

The parts used for BIRDS platform is those that can withstand thermal environment of -15 °C to +60 °C (Ref.(4)). Table 8.6.3-1 shows the corresponding temperatures of the substrates used in BIRDS platform. Regarding battery, the battery cell used is guaranteed -20 °C to + 50 °C tolerance. It was also confirmed that it can accommodate up to +60 °C in the thermal vacuum test.

Table 8.6.3-1 Temperature tolerance of each component

Subsystem	Lowest Temperature [°C]	Highest Temperature [°C]
FAB	-40	+80
OBC/EPS Board	-40	+85
Battery	-20	+50 (+60)*
COM-UHF TRX Board	-20	+60
RAB	-40	+80
External Panel	-40	+85
CPLD Backplane	-40	+105

*Thermal vacuum testing has confirmed that the batteries used in the BIRDS platform can be used at -20 °C to +60 °C.

Table 8.6.3-2 Temperature level in thermal vacuum test

Subsystem	Lowest Temperature [°C]	Highest Temperature [°C]
FAB	-40	+62
OBC/EPS Board	-32	+64
Battery	-11	+48
COM-UHF TRX Board	-36	+67
RAB	-42	+69
External Panel	-50	+80
CPLD Backplane	-42	+67

9 Assembly, integration, and testing information

9.1 Satellite assembly procedure

See Assembly Procedure for BIRDS platform assembly instructions (Ref.(5)).

9.2 Functional test procedure

9.2.1 Check deployment switches and RBF pins (FP, Flight Pin) functionality

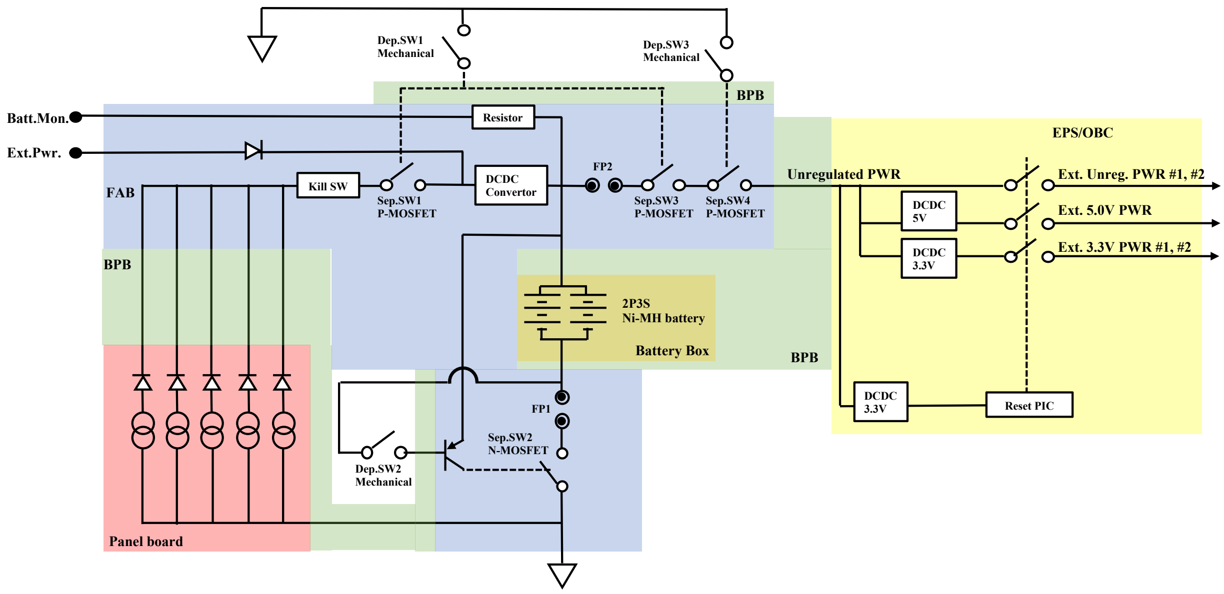


Figure 9.2.1 EPS Block Diagram of BIRDS Platform

i. Remove both of RBF pins, RBF1 (FP2 in Fig.9.2.1) and RBF2 (FP1 in Fig.9.2.1).

ii. Release all deployment switches, this means deployment switches have deployed condition

iii. RBF1 functionality check.

Insert RBF1 and check the electrical load of satellite has no power

iv. Remove RBF1

v. RBF 2 functionality check.

Insert RBF2 and check the battery is disconnected from the electrical system of satellite.

This means there is no current flow for the battery.

vi. Remove RBF2, Insert RBF1

vii. Dep.SW1 functionality check.

Push Dep.SW1, this means the deployment switch has stowed condition.

Check the battery is disconnected from solar cell. This means there is no current between solar cell and battery

Release Dep.SW1, and remover RBF1

viii. Dep.SW2 functionality check.

Push Dep.SW2, this means the deployment switch has stowed condition.

Check the electrical load of satellite has no power

Release Dep.SW2.

ix. Dep.SW3 functionality check.

Push Dep.SW3, this means the deployment switch has stowed condition.

Check the electrical load of satellite has no power

x. Release Dep.SW3. Insert both of RBF pins

9.2.2 Check PIC microcontrollers programming functionality

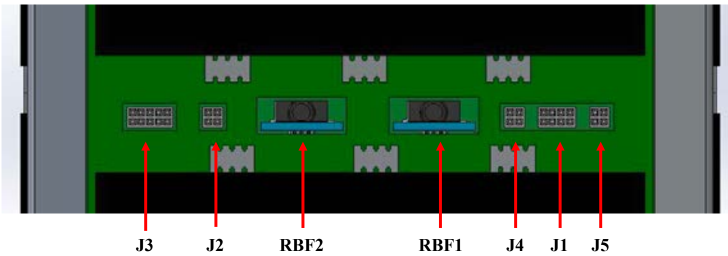


Figure 9.2.2 Connectors on FAB side

i. Insert both of RBF pins.

ii. Release all deployment switches for deployed condition.

iii. Connect J5 with external power supply.

External power supply needs to be setup, output voltage needs to be 5.0 V, current limitation is 2.0 A.

iv. Connect PICkit programmer to the socket connector of J1 for Reset PIC.

v. Remove both of RBF pins.

vi. Turn on the external power supply, and enable the output power.

Check the output current of external power supply does not hit the current limitation.

vii. Reset PIC programming functionality check.

Program Reset PIC with test software.

viii. Move PICkit programmer to FAB PIC in J1 socket connector.

ix. FAB PIC programming functionality check

Program FAB PIC with test software.

x. Move PICkit programmer to COM PIC in J1 socket connector.

xi. COM PIC programming functionality check.

Program COM PIC with test software.

xii. Move PICkit programmer to Main PIC in J1 socket connector.

xiii. Main PIC programming functionality check.

Program Main PIC with test software.

xiv. Insert both of RBF pins.

9.2.3 Check satellite condition using UART interface

i. Connect RS232 cable between PC of user and J2 connector.

ii. Open serial terminal on PC of user.

iii. Basic satellite functionality check.

Check the messages from Main PIC and check the satellite condition.

Satellite condition includes following items.

- Activation of each PIC microcontroller
- Battery voltage
- Battery current
- Battery temperature
- Solar cell voltage
- Solar cell current
- Panel board temperature
- Unregulated #1 output voltage
- Unregulated #1 output current
- Unregulated #2 output voltage
- Unregulated #2 output current
- 3.3V #1 output voltage
- 3.3V #1 output current
- 3.3V #2 output voltage
- 3.3V #2 output current
- 5V output voltage

- 5V output current
- Reset PIC timer clock

9.2.4 Check CW functionality

Make sure the radio wave does not go out the test room if you do not have a proper frequency license.

Figure 9.2.4 Communication test configuration

i. Put ground station devices, PC and radio devices on the table.
ii. Set up ground station devices for CW (Continuous Wave) receiving work.
iii. Put attenuator between iCOM radio device and antenna more than 40 dB.
iv. Put BIRDS CubeSat and monitoring PC on different table.
v. Activate the CW transmission through UART interface of J2 connector using serial terminal of monitoring PC.
vi. CW functionality check.

Record the CW sound on ground station PC and analyze its data.

9.2.5 Uplink command functionality check

Make sure the radio wave does not go out the test room if you do not have a proper frequency license.

i. Set up ground station devices for uplink work.
ii. Check the attenuator between iCOM radio device and antenna has more than 40 dB.
iii. Send uplink command to satellite using operating S/W of ground station PC.
iv. Uplink command functionality check.

Check the sound of acknowledgement from ground station devices.

Check the command data using UART interface of J2 connector on monitoring PC.

9.2.6 Deployment test procedures deployable antennas, solar panels, etc.

- Assemble satellite completely
- Start the video recording
- Remove RBF pins
- Start the external timer clock
- Activate deployment switches
- Wait for deployment of antennas/solar panels
- When antennas/solar panels are deployed, stop the timer clock
- Record the time of timer clock
- Stop the video recording

9.3 Vibration test procedure

See Vibration Test Report for BIRDS platform vibration test procedure (Ref.(3)).

9.4 Thermal test procedure

See Thermal Vacuum Test Report for BIRDS platform test procedure (Ref.(4)).

9.5 End-to-end mission simulation test procedures (see ISO-19683 8.30)

Make sure that you have a proper frequency license.

1	Remove the RBF PIN1 on the left side first and then RBF PIN2
2	Activate all deployment switches, Start the timer
3	Wait for antenna deployment. At the moment of deployment, stop the timer
4	Check the deployment delay time from timer, usually more than 30 minutes
5	Check CW in the Ground station
6	Wait for several hours
7	Check CW in the Ground station
8	Wait for several hours
9	Send command for HK (House Keeping) data from the ground station, check the telemetry data
10	Wait for several hours
11	Send command for mission payloads from the ground station

12	Wait for several hours
13	Downlink the mission data, and analyze the mission data
14	Repeat from step 6 to step 13 for several days

9.6 Battery charging procedure

See Battery charging procedure for BIRDS platform (Ref(8)).