USER MANUAL

Electrical Power System (EPS I & EPS I Plus) - I2C Protocol

ELECTRICAL POWER SYSTEM (EPS I & EPS I PLUS) - I2C PROTOCOL USER MANUAL

This user manual explains in detail the I²C communication protocol of EnduroSat's Electrical Power System (EPS I and EPS I Plus).

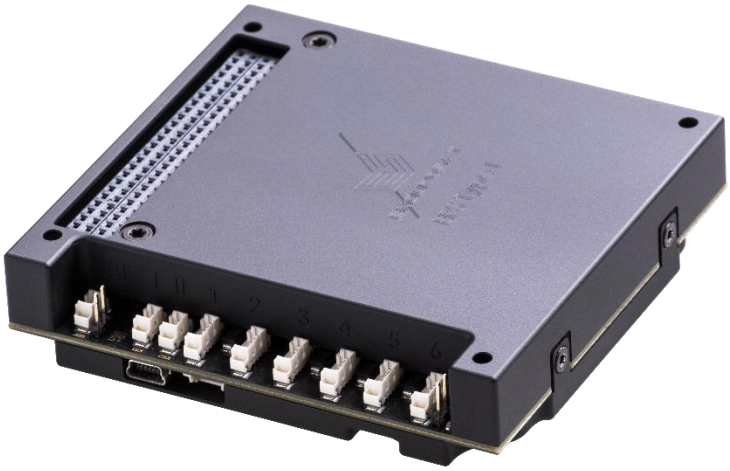

Figure 1: EnduroSat's Electrical Power System (EPS I and EPS I Plus)

1 CHANGE LOG

Date	Version	Note
20/03/2016	Rev 1	Initial
15/11/2018	Rev 2	Describes latest hardware and firmware
11/07/2019	Rev 2.1	Changed write command enumeration
27/11/2019	Rev 2.2	Changed Read and Write commands for FW v.1504

2 ACRONYM LIST

EPS	Electrical Power System
I²C	Inter-Integrated Circuit
LSB	Least Significant Bit
MSB	Most Significant Bit
OBC	Onboard Computer

3 COMMUNICATION

The I²C interface allows a master device (typically the On-Board Computer - OBC) to monitor and control the EPS module. The EPS is configured as a slave device with a 7-bit address. The MSB should be sent first and the I²C clock speed is 400 kHz. The address of the EPS on the I²C is 0x18, but it can be modified based on customer requirements.

4 I2C PROTOCOL DESCRIPTION

The EPS module can receive two types of command instructions: READ & WRITE. The WRITE commands can be used to turn ON or OFF specific outputs or power BUSes. These commands are described in Table 7. The READ commands are used to return "Telemetry" results. Both READ & WRITE commands start with the same 7-bit slave address. An acknowledge must be received before initiating the transmission of the command number. Typical I²C communication is shown in Figure 2a and 2b. The EPS I²C interface uses 4.7kΩ pull-up resistors .

The READ commands are described in Table 1. The first byte is the EPS address shifted left by one bit. The LSB bit is now '0'. The second byte is the number of the command (according to Table 1). It should be followed by repeat start. The third byte should be the address of the EPS shifted left by one bit. The LSB bit is now '1'. The returned result of every READ command is always 2 bytes and the MSB is received first.

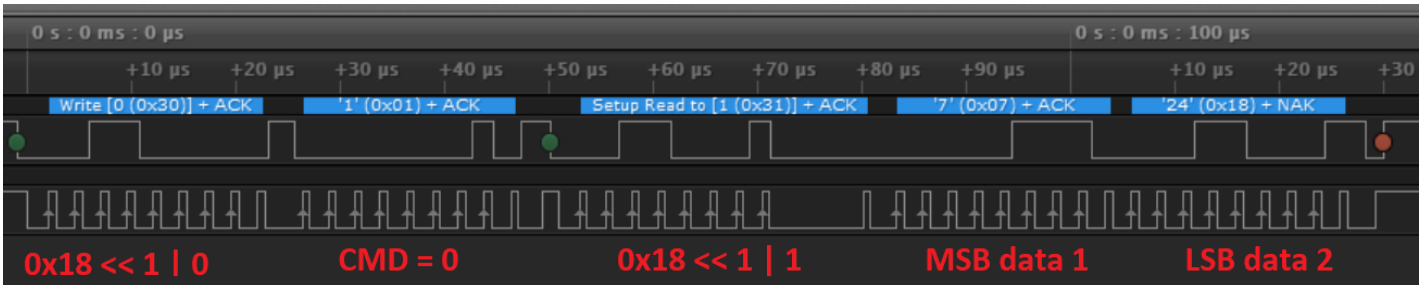

Figure 2a: Typical I2C READ Command Communication (e.g. "Battery Voltage", Command 1)

The WRITE Command is 3 bytes. The first byte is the EPS address shifted left by one bit. The LSB bit is '0'. The second byte is a command number. The third byte is the state (0 = Auto Off, 1 = Auto On, 2 = Forced OFF, 3 = Forced ON).

Figure 2b: Typical I2C WRITE Command Communication (e.g. turning ON the "Out 1")

A full list of all READ commands are shown in Table 1.

Name	Command	Comment – 2 Bytes of Raw Data	Conversion Coefficient	Dimension after conversion
Battery Voltage	1	Batt. BUS voltage - 12 bit ADC Units (from 0 to 4095)	*0.0023394775	V
Battery Current	2	Batt. BUS current - 12 bit ADC Units	*0.0030517578	A
BCR Voltage	3	Ext. Battery Pack - 12 bit ADC Units	*0.0023394775	V
BCR Current	4	Ext. Battery Pack - 12 bit ADC Units	*0.0015258789	A
X Voltage	5	Solar Panel X axis voltage - 12 bit ADC Units	*0.0024414063	V
X- Current	6	Solar Panel X- current - 12 bit ADC Units	*0.0006103516	A
X+ Current	7	Solar Panel X+ current - 12 bit ADC Units	*0.0006103516	A
Y Voltage	8	Solar Panel Y axis voltage - 12 bit ADC Units	*0.0024414063	V
Y- Current	9	Solar Panel Y- current - 12 bit ADC Units	*0.0006103516	A
Y+ Current	10	Solar Panel Y+ current - 12 bit ADC Units	*0.0006103516	A

Z Voltage	11	Solar Panel Z axis voltage - 12 bit ADC Units	*0.0024414063	V
Z- Current	12	Solar Panel Z- current - 12 bit ADC Units	*0.0006103516	A
Z+ Current	13	Solar Panel Z+ current - 12 bit ADC Units	*0.0006103516	A
3.3V Current	14	3.3V BUS current - 12 bit ADC Units.	*0.0020345052	A
5V Current	15	5V BUS current - 12 bit ADC Units.	*0.0020345052	A
LUP 3.3V	16	3.3V Latch-up protected Output Status (ON\OFF)	n/a	
LUP 5V	17	5V Latch-up protected Output Status (ON\OFF)	n/a	
MCU Temp	18	MCU Temperature	((raw_value * 0.0006103516) – 0.986)/0.00355	°C
Batt. Temp. Sens. 1	19	Batt. Cell 1 Temp.	*0.00390625	°C
Batt. Temp. Sens. 2	20	Batt. Cell 2 Temp.	*0.00390625	°C
Batt. Temp. Sens. 3	21	Batt. Cell 3 Temp.	*0.00390625	°C
Batt. Temp. Sens. 4	22	Batt. Cell 4 Temp.	*0.00390625	°C
Input Condition	23	Bits description in Table 2	n/a	
Outputs Conditions	24	Bits description in Table 3	n/a	
Outputs Conditions 2	25	Bit description in Table 4	n/a	
Power_ON_Cycles	26	Counter for number of times the condition occurred	n/a	
V_Under_Voltage	27	Counter for number of times the condition occurred	n/a	
V_Short_Circuit	28	Counter for number of times the condition occurred	n/a	
V_Over Temperature	29	Counter for number of times the condition occurred	n/a	
MAX_Temp 1	30	Batt. Pack 1 Temp.Sens.1	*0.00390625	°C
MAX_Temp 2	31	Batt. Pack 1 Temp.Sens.2	*0.00390625	°C
MAX_Temp 3	32	Batt. Pack 2 Temp.Sens.1	*0.00390625	°C
MAX_Temp 4	33	Batt. Pack 2 Temp.Sens.2	*0.00390625	°C

MIN_Temp 1	34	Batt. Pack 1 Temp.Sens.1	*0.00390625	°C
MIN_Temp 2	35	Batt. Pack 1 Temp.Sens.2	*0.00390625	°C
MIN_Temp 3	36	Batt. Pack 2 Temp.Sens.1	*0.00390625	°C
MIN_Temp 4	37	Batt. Pack 2 Temp.Sens.2	*0.00390625	°C
Temp Sensor 5	38	External Temp. Sensor 5	*0.00390625	°C
Temp Sensor 6	39	External Temp. Sensor 6	*0.00390625	°C
Temp Sensor 7	40	External Temp. Sensor 7	*0.00390625	°C
Reserved (Temp Sensor 8)	41	(for future use of External Temp. Sensor 8)	n/a (*0.00390625)	n/a °C
Software version	42	EPS Software Version	n/a	
Defaults 1	43	Default values of LUPs and Fast charge modes See Table 5	n/a	
Defaults 2	44	Default Values of Output 1 to 6 See Table 6	n/a	
Charge_Cycles	48	Counter for number of charging cycles	n/a	

Table 1: READ Commands

Description of the 16 bits of the READ command 23 (i.e. Input Condition) is shown in Table 2.

READ Command 23 (Input Condition)		
Bit	**EPS Parameter**	**Description**
0	LUP 5	Latch-up Protected output 5V– Least Significant Bit
1	LUP 3V3	Latch-up Protected output 3.3V
2	PGood3.3V	3.3V Power Good
3	PGood5V	5V Power Good
4	KS_Lock_Reset	Reset SW Self Lock
5	CmplSTS	Battery Status – Complete
6	ChrgSTS	Battery Status – Charge in progress
7	-	
8	-	
9	-	
10	-	
11	-	
12	-	
13	-	
14	-	
15	-	Most Significant Bit

Table 2: Description of the Bits of Command 23 (Input Condition)

Bit description of result of READ command 24 “Output Condition” is shown in Table 3.

READ Command 24 (Output Condition)		
Bit	**EPS Parameter**	**Description**
1	SWSelfLock	SW Self Lock – Least Significant Bit
2	VBATTEN	Enable Battery BUS
3	BCROutEN	Enable BCR BUS
4	SHD_3.3V	Enable 3.3V BUS
5	SHD_5V	Enable 5V BUS
6	RESERVED	N/A
7	RESERVED	N/A
8	OUT1	Output 1 / Payload
9	OUT2	Output 2
10	OUT3	Output 3 / OBC
11	OUT4	Output 4 / UHF
12	OUT5	Output 5
13	OUT6	Output 6
14	Heater 1	Battery heater 1
15	Heater 2	Battery heater 2
16	Heater 3	Battery heater 3 – Most Significant Bit

Table 3: Description of the Bits of Command 24 (Output Condition)

Bit description of result of READ command 43 “Output Condition2” is shown in table 4.

READ Command 25 (Output Condition)		
Bit	**EPS Parameter**	**Description**
1	LUP 3.3V	Latch-up Protected output 3.3V (High Level - OFF)
2	LUP 5V	Latch-up Protected output 5V (High Level - OFF)
3	SHDChrg	Shutdown Battery Charger (High Level - OFF) Maximum Current 230 mA.
4	Fast Charge +230mA	Fast battery charge. Maximum current limit is increased with 230mA
5	Fast Charge +350mA	Fast battery charge. Maximum current limit is increased with 350mA
6	-	
7	-	
8	-	
9	-	
10	-	
11	-	
12	-	
13	-	
14	-	
15	-	
16	-	Most Significant Bit

Table 4: Description of the Bits of Command 24 (Output Condition)

Bit description of result of READ command 43 “Defaults 1” is shown in Table 4.

READ Command 43 (Defaults 1)		
Bit	**EPS Parameter**	**Description**
1	LUP 3.3V Defefault	State on power up of output “LUP 3.3V”
2	LUP 5V Default	State on power up of output “LUP 5V”
3	Fast Charge +230mA Default	State on power up of output “Fast Charge +230mA”
4	Fast Charge +350mA Defefault	State on power up of output “Fast Charge +350mA”
5	-	
6	-	
7	-	
8	-	
9	-	
10	-	
11	-	
12	-	
13	-	
14	-	
15	-	
16	-	Most Significant Bit

Table 5: Description of the Bits of Command 43 (Defaults 1)

Bit description of result of READ command 44 “Defaults 2” is shown in Table 4.

READ Command 44 (Defaults 2)		
Bit	**EPS Parameter**	**Description**
1	Output 1 Default	State on power up of output OUT 1
2	Output 2 Default	State on power up of output OUT 2
3	Output 3 Default	State on power up of output OUT 3
4	Output 4 Default	State on power up of output OUT 4
5	Output 5 Default	State on power up of output OUT 5
6	Output 6 Default	State on power up of output OUT 6
7	-	
8	-	
9	-	
10	-	
11	-	
12	-	
13	-	
14	-	
15	-	
16	-	Most Significant Bit

Table 6: Description of the Bits of Command 44 (Defaults)

WRITE Commands		
WRITE Command Number	**EPS Parameter**	**Comment**
0x00	SWSelfLock	SWSelfLock
0x01	VBATTEN	Enable Battery BUS
0x02	BCROutEN	Enable BCR BUS
0x03	SHD_3.3V	Enable 3.3V BUS
0x04	SHD_5V	Enable 5V BUS
0x05	LUP3.3V	LUP3.3V (High Level ON, Low level OFF)
0x06	LUP5V	LUP5V (High Level ON, Low level OFF)
0x07	SHDChrg	Shutdown Battery Charger (High Level ON, Low level OFF)
0x08	Chrg_I1	Fast/Slow Battery Charge 1
0x09	Chrg_I2	Fast/Slow Battery Charge 2
0x0A	OUT1	Output 1 / Payload
0x0B	OUT2	Output 2
0x0C	OUT3	Output 3
0x0D	OUT4	Output 4 / OBC
0x0E	OUT5	Output 5
0x0F	OUT6	Output 6
0x10	Heater 1	Battery heater 1
0x11	Heater 2	Battery heater 2
0x12	Heater 3	Battery heater 3

Table 7: WRITE Commands

5 CONNECTORS

5.1 Connector Location

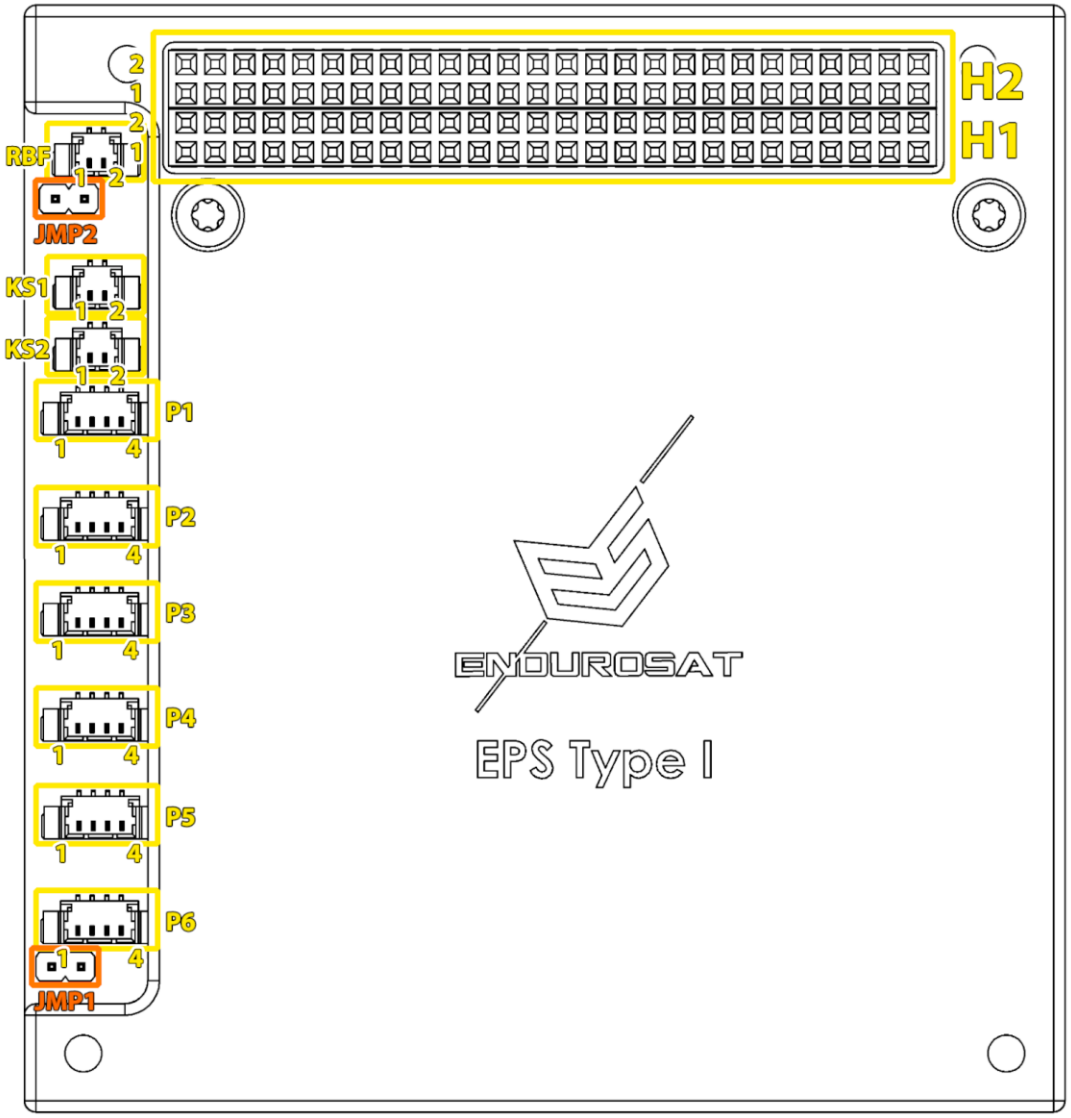

Figure 3: Location of Connectors and their Pinouts

5.2 H1 & H2 – PC/104 Stack Connector

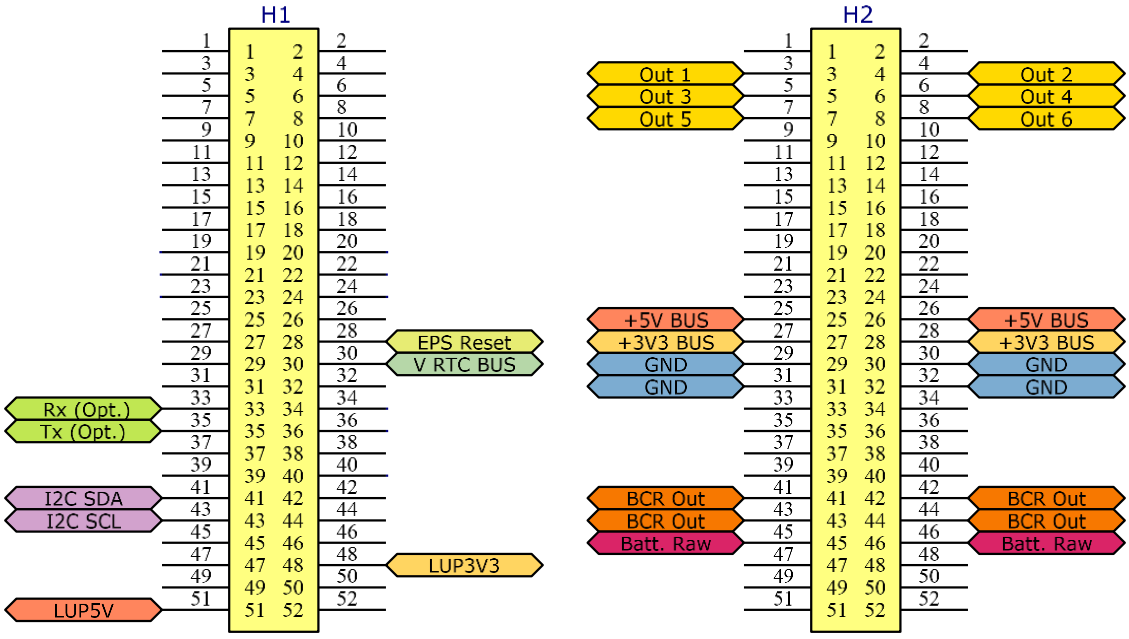

Figure 4: Pinouts of PC/104 Stack Connector

5.3 H1 - Stack Connector

Pin	Mnemonic
H1-28	EPS Reset
H1-30	V_{RTC} BUS
H1-39	UART RX[1]
H1-40	UART TX[1]
H1-41	I2C SDA
H1-43	I2C CLK
H1-48	LUP1 3.3V
H1-51	LUP2 5V

[1] Optional – Hardware Customizable

Table 5: Pinouts of H1

5.4 H2 - Stack Connector

Pin	Mnemonic
H2-3	OUT1
H2-4	OUT2
H2-5	OUT3
H2-6	OUT4
H2-7	OUT5
H2-8	OUT6
H2-25	5V BUS
H2-26	5V BUS
H2-27	3.3V BUS
H2-28	3.3V BUS
H2-29	GND
H2-30	GND
H2-31	GND
H2-32	GND
H2-41	BCR Out
H2-42	BCR Out
H2-43	BCR Out
H2-44	BCR Out
H2-45	VBATT BUS
H2-46	VBATT BUS

Table 6: Pinouts of H2