SERaero C2-16B

Command & Control Uplink Protocol ICD

Version 1.0

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Revision: 1

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SERaero C2-16B Protocol Description

SPECIFICATION DETAIL

Document Author	JP	
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Document Approved by & Date	TBD	TBD

RELATED DOCUMENTS

- LikeAbird SERaero Telemetry ICD Specifications
- LikeAbird SERaero C2-8B ICD Specifications

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CHANGE LOG

Date of Change	Version	Paragraph Changed	Summary of Changes	Editor
20/05/22	Rev 01 draft 1		Original document created.	JP
19/07/22	Rev 01 draft 1		Frame rate from 33 Hz to 50 Hz	JP
19/08/22	Rev 01 draft 1		Button Groups redefinition	JP

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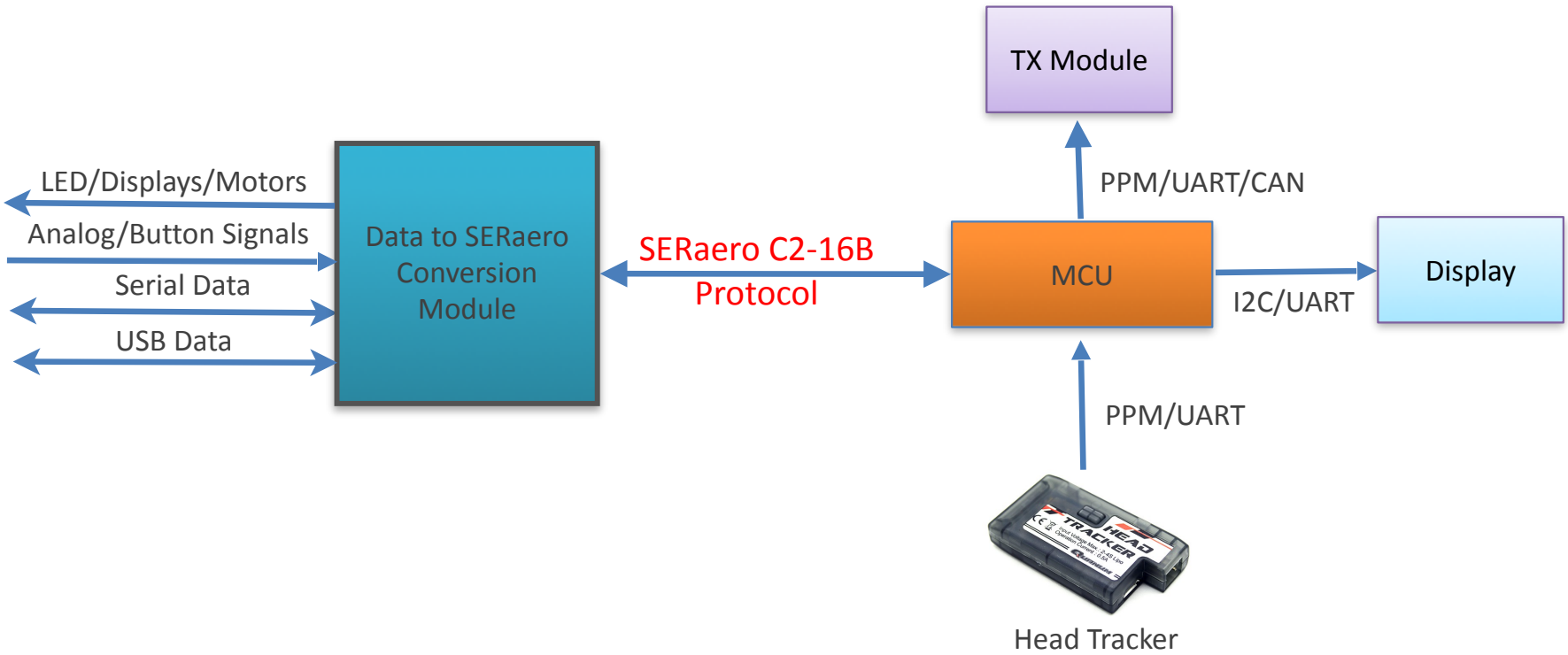
Protocol Usage Description

The SERaero C2-16B has been specifically developed to act as a Command & Control protocol for unmanned systems (air/land/sea). It is the ICD software interface between Human Machine Interfaces (HMI) and the RF or wired transmitting device. The protocol support „Multi-Source“, e.g. for multiport USB to SERaero conversion modules. This allow to use multiple USB HID class devices to be grouped in a multi-stream SERaero protocol in order to support e.g. flight stick, throttle quadrants, HOTAS, button boxes steering wheels and pedals simulation devices. The protocol is bidirectional in order to send data to sources for force feedback, LEDs or display drivers.

The protocol has been optimized to work with USB HID data, as this offers ready made HMI devices.



SERaero C2-16B Protocol Description

SPECIFICATION DETAIL

This part of the document describes the SERaero command & control (C2) uplink protocol pulse train structure to support the unmanned systems applications. The data protocol is referred to as SERaero C2-16B. The designation “C2-16B” refers to “Command & Control (C2)” and the “16 Bit” analog value range.

ELECTRICAL, TIMING AND PROTOCOL PARAMETERS

SERaero C2-16B is implemented by a 115.200 bit/s serial data stream and the data stream is generated by the USB2RC module. The module generates a data frame at a rate of 50 Hz (20 ms). Each data frame consists of a header followed by a data section representing the channel data, and is concluded by a CRC checksum. LF (Line Feed) command (\n, 0x0A) can act as a frame delimiter after the CRC bytes.

The main protocol parameters are:

- UART connection (TxD, RxD, GND) in TTL (3.3V) logic
- Serial COM Port parameters: 115.2 kbit/s, 8 data bits, 1 Stop bit, no parity
- 35-Byte data string transmitted each 20 ms (50 Hz)

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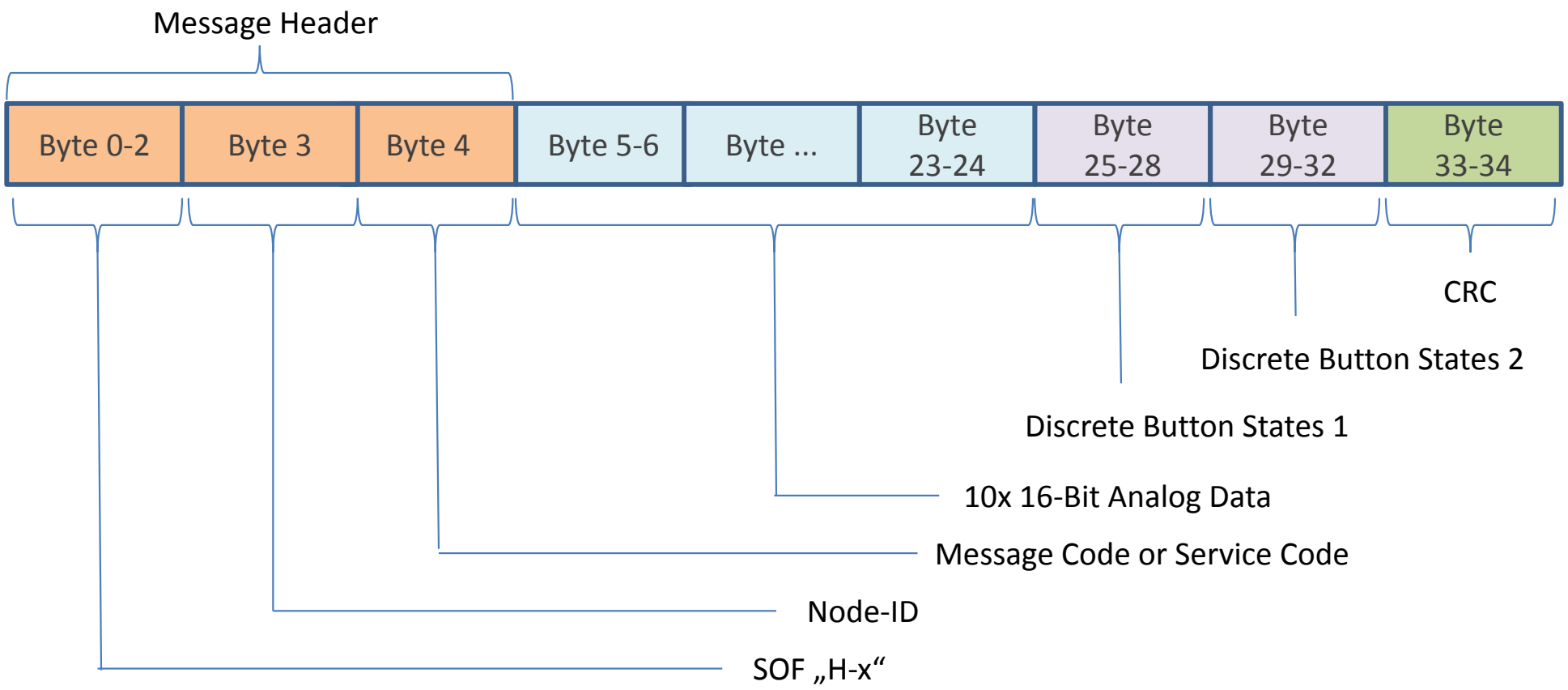
SERaero C2-16B Data String Layout

The SERaero C2-16B messages consist of 3 SOF bytes, 1 Node-ID bytes, 1 Message or Service Code byte, 10 analog channel bytes with 16-bit resolution and 2 x 4 byte for discrete state functions. The data layout is a fixed 35 byte long string with final CRC checksum. LF (Line Feed) command (\n, 0x0A) can act as a frame delimiter after the CRC bytes.



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SERaero C2-16B Default Data String Definition

Byte Number	Parameter	Data Type	Range
0-2	SOF (ASCII “H-x”)	ASCII characters	See Header definition for “x”
3	Node-ID (Source)	8-Bit Unsigned Integer	0x00 – 0xFF
4	Message Code or Service Code	8-Bit Unsigned Integer	0x00 – 0xFF
5-6	X Axis	16-Bit Integer	signed or unsigned**
7-8	Y Axis	16-Bit Integer	signed or unsigned**
9-10	Z Axis	16-Bit Integer	signed or unsigned**
11-12	Slider	16-Bit Integer	signed or unsigned**
13-14	Rx Axis	16-Bit Integer	signed or unsigned**
15-16	Ry Axis	16-Bit Integer	signed or unsigned**
17-18	Rz Axis	16-Bit Integer	signed or unsigned**
19-20	Dial	16-Bit Integer	signed or unsigned**
21-22	Aux Analog Input - 1	16-Bit Integer	signed or unsigned**
23-24	Aux Analog Input - 2	16-Bit Integer	signed or unsigned**
25-28	Buttons Group 1 (see*)	32-Bit Unsigned Integer	0x00000000 - 0xFFFFFFFF
29-32	Buttons Group 2 (see*)	32-Bit Unsigned Integer	0x00000000 - 0xFFFFFFFF
33-34	CRC (see***)	CRC16	n.a.

- LSB first; e.g. switch 1 on encoded as 0x1
- **HID Descriptor dependent. Must be described in the application IDC
- *** CRC-16 polynomial 10000000 00000101

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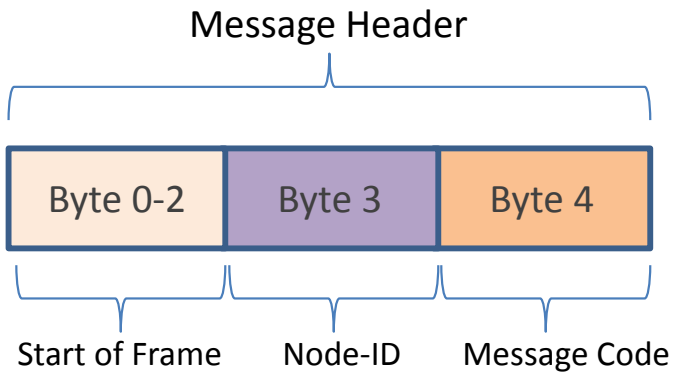
SERaero C2-16B Header Description

- **SOF** (Byte 0-2): The Start of Frame indicates a new start of a SERaero C2-16B data string.
- **Node-ID** (Byte 3): The Node-ID identifies the data source. The Node-ID allows to send command & control data to a remote MCU device or to a remote vehicle. Up to 255 source can be identified and allows to register more than one data source units to a single receiving unit. Special enumeration format is used for USB2RC data source devices.
- **Message Code** (Byte 4): For normal operation data (NOD) messages, the Message Code (byte 4) is incremented by one for each message and may be used to monitor the sequence of incoming messages. The message code then rolls over to zero after passing 255. This feature allows any node in the network to determine the age of a signal and the proper sequence for monitoring purposes. It can be used for statistical purposes of signal quality and failsafe condition or contains Service Codes. The Message Code is also used as the Destination-ID in case of Handover requests.



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SERaero C2-16B Protocol Description

HEADER DATA STRUCTURE

The Header consits of 3 bytes:

- byte 1 signaling the Start of Header (SOH)
- byte 2 acting as a constant separator
- byte 3 signaling the data source status or service code trigger.

In version 1.0 of the SERaero C2-16B following transmitter status values are defined:

“>”: valid and live data frame

“!”: valid data frame with data source in fail safe condition

“<”: Send request for data source configuration data

“&”: valid data frame with data source handover request

“%”: data source low battery warning

“1”: Message type „USB Device Connected“ - NODE-ID contains Device Number and Port Number

“2”: Message type „USB Device Disconnected“ - NODE-ID contains Device Number and Port Number

“3”: Message type „USB Device Error“ - NODE-ID contains Device Number and Port Number

“4”: Message type „USB Request Device Poll“ - NODE-ID contains Device Number and Port Number to be polled

“5”: Message type „USB Device String“ - NODE-ID contains Device Number and Port Number - Payload contains Device Name (max 12 Bytes)

“6”: Message type „USB Device vID-pID“ - NODE-ID contains Device Number and Port Number - Payload contains Vendor and Product ID

“7”: Message type „USB Device Type“ - NODE-ID contains Device Number and Port Number - Payload contains Type Info (max 12 Bytes)

“8”: Message type „USB Controller Startup“

More transmitter status values can be defined and added in further protocol evolvement.

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SERaero C2-16B Header Definition

Byte Number	Byte Name	Data Type	Byte Value	Remark
0	Start of Header	ASCII character	0x48	“H”
1	Header Separator	ASCII character	0x2D	“-”
2	Data Source Status	ASCII character	0x3E	“>” valid and live data frame
2	Data Source Status	ASCII character	0x21	“!” valid data frame with data source in fail safe condition
2	Data Source Status	ASCII character	0x3C	“<“ valid and live data frame with telemetry or config data request
2	Data Source Status	ASCII character	0x26	“&” valid data frame with handover request
2	Data Source Status	ASCII character	0x25	“%” low battery warning
2	Data Source Status	HEX value	0x01 to 0x08	HID Device messages
2	Data Source Status		other values	Values different to what defined above indicate an invalid data frame and should not be processed

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SERaero C2-16B Protocol Description

NODE-ID DATA INTERPRETATION

The SERaero C2-16B Node-ID default ranges from 0-255. If the data source is sent from a USB-to-SERaero data source device, predefined NODE-ID are defined to easily identify USB device number and USB Root Hub Port number.

USB device #	Root Hub Port #	NODE-ID
0	0	0x00
1	1	0x01
2	2	0x02
3	3	0x03

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SERaero C2-16B Header Definition

Byte Number	Byte Name	Data Type	Byte Value	Remark
3	Service Code	TBD		

SERVICE CODES TBD

SERaero C2-16B Protocol Description

ANALOG CHANNEL DATA INTERPRETATION

The SERaero C2-16B is a simple serial data stream for sending values of up to 10 x 16 Bit analog channels and two discrete messages. The analog values can range from 8 Bit up to 16 Bit. Scaling to predefined value must be processed in the MCU

For reference only:

Using PPM/PWM receivers, the data range is derived from the pulse length for standard servos. The servo position may be calculated by pulse_length = (signed channel_data (0-65.535) * 0,015259) + 1.000 with 1500µs for neutral position and 1000µs/2000µs indicating the maximum end positions. Normalized stick position mapping table:

Stick Position	Channel Value	Remark
Low position	-32.768 (0)	Equivalent to 1000us pulse length
Neutral	0 (32.767)	Equivalent to 1500us pulse length
High position	+32.767 (65.535)	Equivalent to 2000 pulse length

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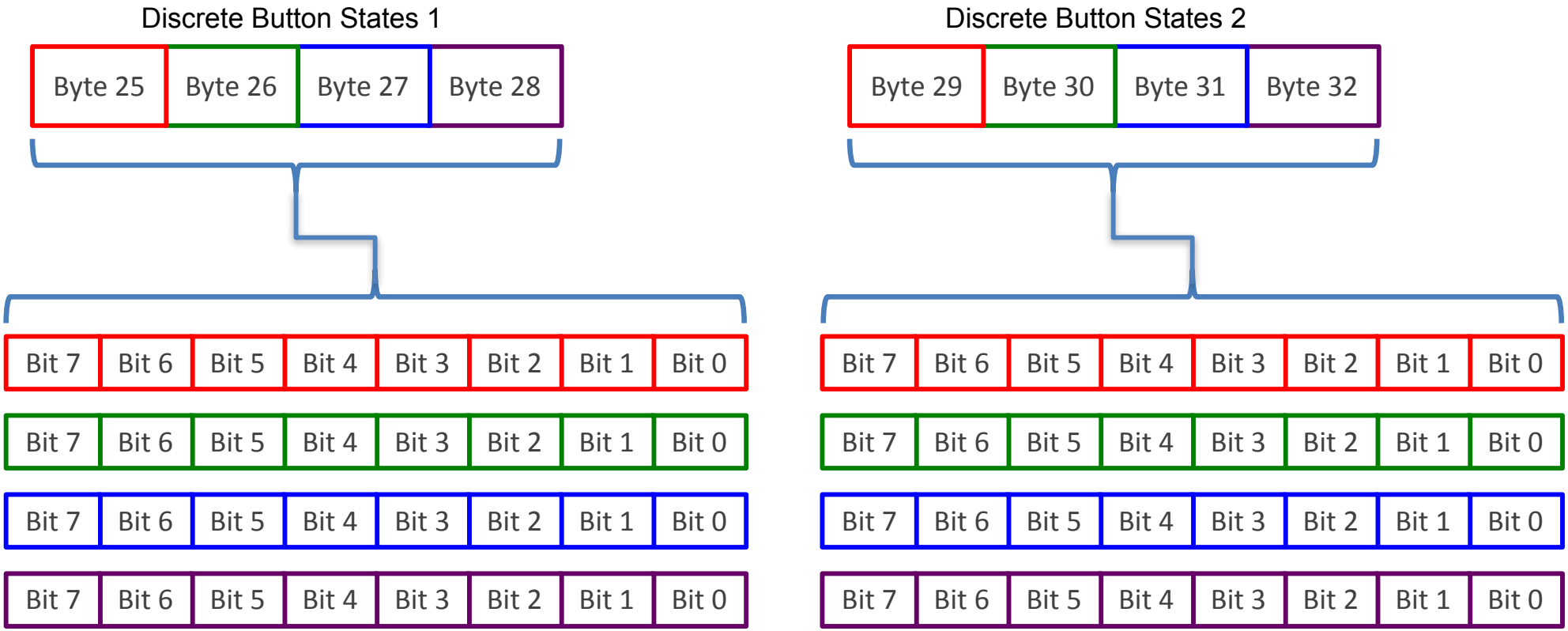
BUTTON GROUP DISCRETE MESSAGE ENCODING

The SERaero C2-16B discrete messages consist of a data type „BLONG“. Each bit defines a discrete state. 32 bits are coded into four SERaero data bytes.



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BUTTON GROUP DEFINITIONS

Button Group 1

"Switch-Group 1" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 25**	**Byte 26**	**Byte 27**	**Byte 28**
SG1_SA	Button 01	*Button Type?*	*Write here your switch function*	0x01	0x00	0x00	0x00
SG1_SB	Button 02			0x02	0x00	0x00	0x00
SG1_SC	Button 03			0x04	0x00	0x00	0x00
SG1_SD	Button 04			0x08	0x00	0x00	0x00
SG1_SE	Button 05			0x10	0x00	0x00	0x00
SG1_SF	Button 06			0x20	0x00	0x00	0x00
SG1_SG	Button 07			0x40	0x00	0x00	0x00
SG1_SH	Button 08			0x80	0x00	0x00	0x00

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
Bit 10000000 = Hex 0x80

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Button Group 1

"Switch-Group 1" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 25**	**Byte 26**	**Byte 27**	**Byte 28**
SG1_SI	Button 09	*Button Type?*	*Write here your switch function*	0x00	0x01	0x00	0x00
SG1_SJ	Button 10			0x00	0x02	0x00	0x00
SG1_SK	Button 11			0x00	0x04	0x00	0x00
SG1_SL	Button 12			0x00	0x08	0x00	0x00
SG1_SM	Button 13			0x00	0x10	0x00	0x00
SG1_SN	Button 14			0x00	0x20	0x00	0x00
SG1_SO	Button 15			0x00	0x40	0x00	0x00
SG1_SP	Button 16			0x00	0x80	0x00	0x00

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
Bit 10000000 = Hex 0x80

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Button Group 1

"Switch-Group 1" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 25**	**Byte 26**	**Byte 27**	**Byte 28**
SG1_SQ	Button 17	*Button Type?*	*Write here your switch function*	0x00	0x00	0x01	0x00
SG1_SR	Button 18			0x00	0x00	0x02	0x00
SG1_SS	Button 19			0x00	0x00	0x04	0x00
SG1_ST	Button 20			0x00	0x00	0x08	0x00
SG1_SU	Button 21			0x00	0x00	0x10	0x00
SG1_SV	Button 22			0x00	0x00	0x20	0x00
SG1_SW	Button 23			0x00	0x00	0x40	0x00
SG1_SX	Button 24			0x00	0x00	0x80	0x00

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
Bit 10000000 = Hex 0x80

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Button Group 1

"Switch-Group 1" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 25**	**Byte 26**	**Byte 27**	**Byte 28**
SG1_SY1	HAT Switch	POV-HAT	UP	0x00	0x00	0x00	0x01
SG1_SY2	HAT Switch	POV-HAT	UP-RIGHT	0x00	0x00	0x00	0x02
SG1_SY3	HAT Switch	POV-HAT	RIGHT	0x00	0x00	0x00	0x04
SG1_SY4	HAT Switch	POV-HAT	RIGHT-DOWN	0x00	0x00	0x00	0x08
SG1_SY5	HAT Switch	POV-HAT	DOWN	0x00	0x00	0x00	0x10
SG1_SY6	HAT Switch	POV-HAT	DOWN-LEFT	0x00	0x00	0x00	0x20
SG1_SY7	HAT Switch	POV-HAT	LEFT	0x00	0x00	0x00	0x40
SG1_SY8	HAT Switch	POV-HAT	LEFT-UP	0x00	0x00	0x00	0x80

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
Bit 10000000 = Hex 0x80

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Button Group 2

"Switch-Group 2" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 29**	**Byte 30**	**Byte 31**	**Byte 32**
SG2_SA	Button 25	*Button Type?*	*Write here your switch function*	0x01	0x00	0x00	0x00
SG2_SB	Button 26			0x02	0x00	0x00	0x00
SG2_SC	Button 27			0x04	0x00	0x00	0x00
SG2_SD	Button 28			0x08	0x00	0x00	0x00
SG2_SE	Button 29			0x10	0x00	0x00	0x00
SG2_SF	Button 30			0x20	0x00	0x00	0x00
SG2_SG	Button 31			0x40	0x00	0x00	0x00
SG2_SH	Button 32			0x80	0x00	0x00	0x00

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
Bit 10000000 = Hex 0x80

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Button Group 2

"Switch-Group 2" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 29**	**Byte 30**	**Byte 31**	**Byte 32**
SG2_SI	Button 33	*Button Type?*	*Write here your switch function*	0x00	0x01	0x00	0x00
SG2_SJ	Button 34			0x00	0x02	0x00	0x00
SG2_SK	Button 35			0x00	0x04	0x00	0x00
SG2_SL	Button 36			0x00	0x08	0x00	0x00
SG2_SM	Button 37			0x00	0x10	0x00	0x00
SG2_SN	Button 38			0x00	0x20	0x00	0x00
SG2_SO	Button 39			0x00	0x40	0x00	0x00
SG2_SP	Button 40			0x00	0x80	0x00	0x00

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
Bit 10000000 = Hex 0x80

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Button Group 2

"Switch-Group 2" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 29**	**Byte 30**	**Byte 31**	**Byte 32**
SG1_SQ	Button 41	*Button Type?*	*Write here your switch function*	0x00	0x00	0x01	0x00
SG1_SR	Button 42			0x00	0x00	0x02	0x00
SG1_SS	Button 43			0x00	0x00	0x04	0x00
SG1_ST	Button 44			0x00	0x00	0x08	0x00
SG1_SU	Button 45			0x00	0x00	0x10	0x00
SG1_SV	Button 46			0x00	0x00	0x20	0x00
SG1_SW	Button 47			0x00	0x00	0x40	0x00
SG1_SX	Button 48			0x00	0x00	0x80	0x00

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
Bit 10000000 = Hex 0x80

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Button Group 2

"Switch-Group 2" – Default Layout Assignements							
RC Switch	**HID Mapping**	**Knob Style**	**Function - Label**	**Byte 29**	**Byte 30**	**Byte 31**	**Byte 32**
SG1_SY	Button 49	*Button Type?*	*Write here your switch function*	0x00	0x00	0x00	0x01
SG1_SZ	Button 50			0x00	0x00	0x00	0x02
SG1_SAB	Button 51			0x00	0x00	0x00	0x04
SG1_SAC	Button 52			0x00	0x00	0x00	0x08
SG1_SAD	Button 53			0x00	0x00	0x00	0x10
SG1_SAE	Button 54			0x00	0x00	0x00	0x20
SG1_SAF	Button 55			0x00	0x00	0x00	0x40
SG1_SAG	Button 56			0x00	0x00	0x00	0x80

NOTE: GPIO signal will follow respective input bit setting in message.

Bit 00000001 = Hex 0x01
Bit 00000010 = Hex 0x02
Bit 00000100 = Hex 0x04
Bit 00001000 = Hex 0x08
Bit 00010000 = Hex 0x10
Bit 00100000 = Hex 0x20
Bit 01000000 = Hex 0x40
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SERaero C2-16B CRC Description

CRC CALCULATION

CRC is a common method for detecting errors in transmitted messages or stored data. The CRC is a very powerful, but easily implemented technique to obtain data reliability.

This note describes the CRC-16 polynomial Cyclic Redundancy Check (CRC) calculation and implementation. The theory of a CRC calculation is straight forward. The data is treated by the CRC algorithm as a binary number. This number is divided by another binary number called the polynomial. The rest of the division is the CRC checksum, which is appended to the transmitted message.

The receiver divides the message (including the calculated CRC), by the same polynomial the transmitter used. If the result of this division is zero, then the transmission was successful. However, if the result is not equal to zero, an error occurred during the transmission and the frame will be discarded. The latest valid frame will be still valid.

The SERaero CRC is calculated taking Header and Data into account as is derived by the following algorithm:

SERaero CRC16 Algorithm

```
#define CRC16 0x8005
/*****************************************************************************
*Function Name: gen_crc16
*Description: CRC16 calculation with Polynomial 0x8005
*****************************************************************************/
uint16_t gen_crc16(const uint8_t *data, uint16_t size)
{
    uint16_t out = 0, crc;
    int bits_read = 0, bit_flag, i;
    int j = 0x0001;

    if(data == NULL)
        return 0;

    while(size > 0)
    {
        bit_flag = out >> 15;
        out <<= 1;
        out |= (*data >> bits_read) & 1;

        bits_read++;
        if(bits_read > 7)
        {
            bits_read = 0;
            data++;
            size--;
        }

        if(bit_flag)
            out ^= CRC16;
    }

    for (i = 0; i < 16; ++i) {
        bit_flag = out >> 15;
        out <<= 1;
        if(bit_flag)
            out ^= CRC16;
    }

    i = 0x8000;
    for (; i != 0; i >>=1, j <<= 1) {
        if (i & out) crc |= j;
    }

    return crc;
}
```

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