

GHST Tx Public Protocol

Description

Document Cleared for Public Release

Anthony Cake, ImmersionRC Limited



Overview

This document describes the protocol used to interface a R/C Transmitter to a Ghost Transmitter. It is similar to, but not identical to, the GHST protocol used to interface a flight controller to a Ghost Receiver.

The driver in the OpenTx open-source software should be considered a good reference driver, and may be more up to date than this document.

History

10-Dec-2020	Initial release, matching BF driver at this point in time
19-Jan-2021	Clarify packet IDs
09-Mar-2021	Add GPS Packets
11-Nov-2021	Add menu support for touch control
06-Dec-2021	Add pure 12-bit path from R/C Tx to FC
02-Jan-2022	Add MSP packets for betafight interface
14-May-2022	Add vTx Temperature to GHST_DL_VTX_STAT (firmware v1.0.6.5)

Serial Protocol

R/C Transmitter to Ghost Tx

Parameter	Value	Description
GHST_TX_BAUDRATE_FAST	400000 (baud)	Baud rate used for control data (R/C Tx -> Ghost Tx)
GHST_TX_BAUDRATE_SLOW	115200 (baud)	Baud rate used for telemetry data (Ghost Tx -> R/C Tx)
GHST_TX_UART_WORDLENGTH	8 (bits)	8 bit UART word length
GHST_TX_UART_STOPBITS	1 (bit)	1 stop bit
GHST_TX_UART_PARITY	None	No Parity

Note: In order to work around a flawed hardware design in certain FrSky radios, the serial link between the R/C Tx, and the Ghost Tx, may use a high speed rate for the control link, and a slower-speed link for the telemetry link.

The decision for which telemetry link rate to use depends upon the module address sent by the R/C Tx (GHST_ADDR_MODULE_ASYM, vs. GHST_ADDR_MODULE_SYM)

Endianness

For various reasons (some of which we can't recall) the GHST driver has a mix of little, and big-endian. Check the tables carefully for each value.



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Device Destination Addresses

Parameter	Value	Description
GHST_ADDR_RADIO	0x80	R/C Transmitter
GHST_ADDR_TX_MODULE_SYM	0x81	Ghost Tx, Symmetrical link, 400k control, 400k telemetry ¹
GHST_ADDR_TX_MODULE_ASYM	0x88	Ghost Tx, Asymmetrical link, 400k control, 115k telemetry ¹

¹ Choice to use 0x81 or 0x82 is made by the R/C Transmitter, depending upon which radio model it is running on.

Uplink Packet IDs

Sent from R/C Tx to the Ghost Tx

Parameter	Value	Description
GHST_UL_RC_CHANS_HS4_5TO8	0x10	Control packet with 4 primary channels + CH5-8
GHST_UL_RC_CHANS_HS4_9TO12	0x11	Control packet with 4 primary channels + CH9-12
GHST_UL_RC_CHANS_HS4_13TO16	0x12	Control packet with 4 primary channels + CH13-16
GHST_UL_MENU_CTRL	0x13	Remote menu control
GHST_UL_MSP_REQ	0x21	MSP Request ²
GHST_UL_MSP_WRITE	0x22	MSP Write ²
GHST_UL_RC_CHANS_HS4_12_5TO8	0x30	Control packet with 4 primary channels + CH5-8, 12-bit raw data
GHST_UL_RC_CHANS_HS4_12_9TO12	0x31	Control packet with 4 primary channels + CH9-12, 12-bit raw data
GHST_UL_RC_CHANS_HS4_12_13TO16	0x32	Control packet with 4 primary channels + CH13-16, 12-bit raw data

² MSP packets added for v1.0.6.0.

Downlink Packet IDs

Sent from the Ghost Tx to the R/C Tx

Parameter	Value	Description
GHST_DL_OPENTX_SYNC	0x20	OpenTx Mixer Scheduler Sync packet
GHST_DL_LINK_STAT	0x21	Link Statistics
GHST_DL_VTX_STAT	0x22	Video Transmitter Status (Channel, Band, Power, etc.)
GHST_DL_PACK_STAT	0x23	Battery Status
GHST_DL_MENU_DESC	0x24	Menu description (Menu -> OpenTx)
GHST_DL_GPS_PRIMARY	0x25	Primary GPS Info
GHST_DL_GPS_SECONDARY	0x26	Secondary GPS Info
GHST_DL_MAGBARO	0x27	MagBaro
GHST_DL_MSP_RESP	0x28	MSP Response ³

³ MSP packets added for v1.0.6.0.



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Control Packet

Control packets are as short as possible, for minimum latency. The first 4 primary flight channels are sent in every packet, at full frame rate, with data for channels 4..12/16 being sent at a slower rate.

GHST_UL_RC_CHANS_HS4_5TO8, GHST_UL_RC_CHANS_HS4_9TO12, or GHST_UL_RC_CHANS_HS4_13TO16

Index	Len	Name	Description	Value
0	u8	addr	GHST_ADDR_MODULE	0x80
1	u8	len	Length including type, and crc	0x0c
2	u8	id	GHST_UL_RC_CHANS_HS4_5TO8	0x10 (or 0x30 for 12-bit raw)
3	u12	ch1	Control data, CH1 (high resolution, high rate)	
	u12	ch2	Control data, CH2 (high resolution, high rate)	
6	u12	ch3	Control data, CH3 (high resolution, high rate)	
	u12	ch4	Control data, CH4 (high resolution, high rate)	
9	u8	chaa	Control data, CH5, CH9, or CH13, depending upon ID	
10	u8	chbb	Control data, CH6, CH10, or CH14, depending upon ID	
11	u8	chcc	Control data, CH7, CH11, or CH15, depending upon ID	
12	u8	chdd	Control data, CH8, CH12, or CH16, depending upon ID	
13	u8	crc		
total	112		Total: 14 bytes	

From v1.0.5.2, a set of 12-bit packets were added, with IDs from 0x30 to 0x32.

CRC Algorithm:

The CRC algorithm used for all ghost packets is CRC-DVB S2.

Control Values (Servo Positions)

Center value, 12 bit data 0x7C0

Center value, 8 bit data 0x7C



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Frametype GHST_DL_OPENTX_SYNC

Packet used to synchronize OpenTx control processing with the Ghost Uplink, resulting in lower, and more predictable stick-to-FC latency.

Note that this packet type is optional, and not required for basic control

Index	Len	Name	Description	Value
0	u8	addr	GHST_ADDR_RADIO	0x80
1	u8	len		0x0e
2	u8	type	GHST_DL_OPENTX_SYNC	0x20
3	u32	packetRate[4]	Packet Rate, units of 100ns	MSB First
7	s32	offset[4]	Time Offset, units of 100ns	MSB First (signed)
11	u8	flags	Misc flags	V1.0.5.2 and later
12	u8	tbd2		
13	u8	crc		
	112		Total: 14	

flags							
7	6	5	4	3	2	1	0
Future Use	Future Use	Future Use	Future Use	Future Use	Future Use	Future Use	AltScale

If AltScale is set, it indicates that the Ghost Tx firmware supports 12-bit mode. It is however up to the OpenTx side to actually request it by switching packet IDs.

Frametype GHST_DL_LINK_STAT

Sent from Ghost Tx to R/C Tx to display link statistics.

Index	Len	Name	Description	Value
0	u8	addr	GHST_ADDR_RADIO	0x80
1	u8	len		0x0e
2	u8	type	GHST_DL_LINK_STAT	0x50
3	u8	rssI	RSSI, in dBm, with flipped sign	
4	u8	lq	Link quality, 0-100%	
5	u8	snr	SNR value, in dB	
6	u16	txPwr	Tx Power, in mW, 0 for μ W values	MSB first
8	u16	frameRate	Current frame rate in μ s	MSB first
10	u16	totalLatency	Total estimated latency in μ s	MSB first
12	u8	rfMode	See GHST_RFMODE	
13	u8	crc		
	112		Total: 14	



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RF Mode Options

RF Mode	Define	Value
Auto	GHST_RFMODE_AUTO	0
Normal	GHST_RFMODE_NORMAL	1
Race	GHST_RFMODE_RACE	2
Pure Race	GHST_RFMODE_PURERACE	3
Long Range	GHST_RFMODE_LONGRANGE	4
Internal	GHST_RFMODE_INTERNAL	5
Race250	GHST_RFMODE_RACE250	6
Race500	GHST_RFMODE_RACE500	7

Frametype GHST_DL_VTX_STAT

Sent from Ghost Tx to R/C Tx to display vTx Parameters.

Index	Len	Name	Description	Value
0	u8	addr	GHST_ADDR_RADIO	0x80
1	u8	len		0x0e
2	u8	type	GHST_DL_VTX_STAT	0x22
3	u8	vTxFlags	Not yet used	
4	u16	vTxFreq	vTx Frequency, in MHz	MSB first
6	u16	vTxPower	vTx Power, in mW	MSB first
8	u8	vTxBand	vTx Band, see GHST_VTXBAND	
9	u8	vTxChan	vTx Channel (1..8)	
10	u8	selRxId	Selected Rx ID	
11	u8	vTxTempC	vTx Temperature	Deg C, uint8_t, 0-255C
12	u8	spare2		
13	u8	crc		
	112		Total: 14	

vTx Band Options

Band	Define	Value
Unknown	GHST_VTXBAND_Unknown	0
IRC	GHST_VTXBAND_IRC	1
RaceBand	GHST_VTXBAND_RaceBand	2
BandE	GHST_VTXBAND_BandE	3
BandB	GHST_VTXBAND_BandB	4
BandA	GHST_VTXBAND_BandA	5



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Frametype GHST_DL_PACK_STAT

Passed from FC to Ghost Rx to Ghost Tx to R/C Tx.

Includes the most common telemetry data passed from the Flight Controller up through the chain to the R/C Tx.

Idx	Len	Name	Description	Step	Range	Value
0	u8	addr	GHST_ADDR_RADIO			0x80
1	u8	len				0x0c
2	u8	type	GHST_DL_PACK_STAT			0x23
3	u16	packVolts	Pack Voltage	10mV	0-655.35V	LSB First
5	u16	packAmps	Instantaneous Current	10mA	0-655.35A	LSB First
7	u16	packmAh	Consumed mAh	10mAh	0-655.35Ah	LSB First
9	u8	rxVolts	Rx Voltage	100mV	0-25.5V	
10	u8					
11	u8					
12	u8					
13	u8	crc				
	112		Total: 14			

Flight Pack Data : GHST_DL_GPS_PRIMARY

GPS Primary data includes the 3D position, Latitude, Longitude, Altitude.

Index	Len	Name	Description	Step	Range	Value
0	u8	addr	GHST_ADDR_RADIO			0x80
1	u8	len	Length including type, and crc			0x0c
2	u8	type	GHST_DL_GPS_PRIMARY			0x25
3	u32	gpsLat	GPS Latitude	1e-7 degrees	-90 -> +90 degrees	LSB First
7	u32	gpsLong	GPS Longitude	1e-7 degrees	-180 -> +180 degrees	LSB First
11	u16	gpsAlt	GPS Altitude	1 meter	-32000 to 32000	LSB First
13	u8	crc	CRC-DVB S2 CRC algorithm			
total	112		Total: 14 bytes			



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Flight Pack Data : GHST_DL_GPS_SECONDARY

GPS Secondary data includes auxiliary GPS position data.

Index	Len	Name	Description	Step	Range	Value
0	u8	addr	GHST_ADDR_RADIO			0x80
1	u8	len	Length including type, and crc			0x0c
2	u8	type	GHST_DL_GPS_SECONDARY			0x26
3	u16	gpsGroundSpeed	Ground Speed	1 km/h		LSB First
5	u16	gpsGroundCourse	Ground Course (heading)	0.1 degree		LSB First
7	u8	gpsNumSats	Number of satellites	0..n		
8	u16	gpsHomeDist	Distance to home, units of 10m	10m	0-655,350m	LSB First
10	u16	gpsHomeDir	Direction to home, units of degrees	1 degree		LSB First
12	u8	gpsFlags			GPS_FLAGS_FIX 0x01 GPS_FLAGS_FIX_HOME 0x02	
13	u8	crc	CRC-DVB S2 CRC algorithm			
total	112		Total: 14 bytes			



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Menu Control Packet

Menu Control packets do not include the primary flight channels. It is assumed that during menu operations, the pilot is not 'on the sticks', and that this is performed primarily when the model is on the ground.

Index	Len	Name	Description	Value
0	u8	addr	GHST_ADDR_MODULE	0x80
1	u8	len	Length including type, and crc	0x0c
2	u8	id	GHST_UL_MENU_CTRL	0x13
3	u8	buttons	Joystick States: Up, Down, Left, Right, Press	
4	u8	menuCtrl	Menu Control: Open, Close, Redraw, Back, Incr, Decr	
5	u8	lineSelect	Line selected via touch screen (1 = line 1)	(> v1.0.5.2)
6	u8	valueSelect	Value selected via touch screen (1 = 1st value)	Not Yet Implemented
7	u8	tbd	Not Yet Used	
8	u8	tbd	Not Yet Used	
9	u8	tbd	Not Yet Used	
10	u8	tbd	Not Yet Used	
11	u8	tbd	Not Yet Used	
12	u8	tbd	Not Yet Used	
13	u8	crc		
total	112		Total: 14 bytes	

Additions for Touch Screen use (builds > v1.0.5.2)

- Select Line (0..n)
Special values: 0xff = scroll down, 0xfe = scroll up
- Select Value (0..n) - Not Yet Implemented
 - Pop up dialog with all value options, for example an enum
 - App needs to request all states
 - For future use, not yet implemented



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GHST_BTN	Value
GHST_BTN_None	0x0
GHST_BTN_JoyPress	0x01
GHST_BTN_JoyUp	0x02
GHST_BTN_JoyDown	0x04
GHST_BTN_JoyLeft	0x08
GHST_BTN_JoyRight	0x10
GHST_BTN_Bind	0x20

GHST_MENU_CTRL	Value	Notes
GHST_MENU_CTRL_None	0x0	
GHST_MENU_CTRL_Open	0x01	
GHST_MENU_CTRL_Close	0x02	
GHST_MENU_CTRL_Redraw	0x04	
GHST_MENU_CTRL_Back	0x08	Back out of the current menu one level
GHST_MENU_CTRL_Increment	0x10	Increment the selected menu item (> v1.0.5.0)
GHST_MENU_CTRL_Decrement	0x20	Decrement the selected menu item (> v1.0.5.0)

Menu Telemetry Packet

Index	Len	Name	Description	Step	Range	Value
0	u8	addr	GHST_ADDR_RADIO			0x80
1	u8	len	Length including type, and crc			0x0c
2	u8	type	GHST_DL_MENU_DESC			0x24
3	u8	menuStatus	Unopened, opened, closing			
4	u8	lineFlags	Label Sel, Value Sel, Value Edit			
5	u8	lineIndex	0..n			
6	20 bytes	menuText	Pipe-delimited menu value		Rx Proto GHST	
26	u8	crc	CRC-DVB S2 CRC algorithm			
total	27		Total: 27 bytes			



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GHST_LINE_FLAGS	Value	Notes
GHST_LINE_FLAGS_None	0x0	
GHST_LINE_FLAGS_LabelSelect	0x01	Indicates that the label is currently selected, could be a menu if no split label value, or just label. Normally rendered as inverse-video.
GHST_LINE_FLAGS_ValueSelect	0x02	For split label value pairs, indicates value is selected, for example, numeric value that can then be edited with the scroll wheel on the TX16s Normally rendered as inverse video
GHST_LINE_FLAGS_ValueEdit	0x04	Used to indicate blink status, for example after firmware update, the 'Success' text blinks.
GHST_LINE_FLAGS_CanIncrement	0x08	Set if the menu item can be incremented (> v1.0.5.0)
GHST_LINE_FLAGS_CanDecrement	0x10	Set if the menu item can be decremented (> v1.0.5.0)

GHST_MENU_FLAGS	Value	Notes
GHST_MENU_FLAGS_None	0x0	
GHST_MENU_FLAGS_MenuTitle	0x01	Not yet used
GHST_MENU_FLAGS_UpdateLine	0x02	Not yet used
GHST_MENU_FLAGS_ClearMenu	0x04	Not yet used

GHST_MENU_STATUS	Value	Notes
GHST_MENU_STATUS_Unopened	0x0	
GHST_MENU_STATUS_Opened	0x01	
GHST_MENU_STATUS_Closing	0x02	



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Example of use

Open Top-level Menu

Radio		Module	
GHST_UL_MENU_CTRL	GHST_MENU_CTRL_Open		
		GHST_DL_MENU_DESC	GHST_MENU_FLAGS_MenuTitle
		GHST_DL_MENU_DESC	GHST_MENU_FLAGS_UpdateLine
		GHST_DL_MENU_DESC	GHST_MENU_FLAGS_UpdateLine
		...	...
		GHST_DL_MENU_DESC	GHST_MENU_FLAGS_UpdateLine
GHST_UL_MENU_CTRL	GHST_LINE_FLAGS_ValueSelect		

Joystick Up

Radio		Module	
GHST_UL_MENU_CTRL	GHST_BTN_JoyUp		

Close Menu

Radio		Module	
GHST_UL_MENU_CTRL	GHST_MENU_CTRL_Close		



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MSP Packets

GHST_UL_MSP_REQ/GHST_UL_MSP_WRITE

Index	Len	Name	Description	Value
0	u8	addr	GHST_ADDR_MODULE	0x80
1	u8	len	Length including type, and crc	0x0c
2	u8	type	GHST_UL_RC_CHANS_HS4_RSSI	0x13 (or 0x33 for 12-bit mode)
3	u8	data0		
4	u8	data1		
5	u8	data2		
6	u8	data3		
7	u8	data4		
8	u8	data5		
9	u8	data6		
10	u8	data7		
11	u8	data8		
12	s8	data9		
13	u8	crc	CRC-DVB S2 CRC algorithm	
total	112		Total: 14 bytes	

10 bytes of payload, note that length is the length of the entire packet, and not the payload length. Payload length not sent, and needs to be handled by the next layer up the protocol stack

Flight Pack Data : GHST_DL_MSP_RESP

Index	Len	Name	Description	Step	Range	Value
0	u8	addr	GHST_ADDR_RADIO			0x80
1	u8	len	Length including type, and crc			0x0c
2	u8	type	GHST_DL_MSP_RESP			0x28
3	u8	msp0	MSP Payload, 6 bytes			
4	u8	msp1				
5	u8	msp2				
6	u8	msp3				
7	u8	msp4				
8	u8	msp5				
9	u8	tbd0	Not yet used (not sent OTA)			
10	u8	tbd1				
11	u8	tbd2				
12	u8	tbd3				
13	u8	crc	CRC-DVB S2 CRC algorithm			
total	112		Total: 14 bytes			



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Timing

R/C Tx -> Ghost Tx

Parameter	Bits	Baud Rate	Frame Time
Control Packets (pulses)	112 (14 bytes)	400k	350us
Telemetry Packets (Sym)	112 (14 bytes)	400k	350us
Telemetry packets (Asym)	112 (14 bytes)	115k	1.21ms

Ghost Rx -> FC, assuming GHST protocol

Parameter	Bits	Baud Rate	Frame Time
Control Packets (pulses)	112 (14 bytes)	420k	333us
Telemetry Packets	112 (14 bytes)	420k	333us

