



SimpleBGC 2.5 serial protocol specification

Applicable for 32-bit boards with firmware 2.5x

Revision history

- rev. 0.1 - 24.03.2015: this is first revision
- rev. 0.2 – 27.03.2015: add missed data
- rev. 0.3 – 30.04.2015: add missed data in CMD_READ_PARAMS_EXT
- rev. 0.4 – 01.07.2015: CMD_CONTROL extended format; add MENU_CMD_LEVEL_ROLL_PITCH; FRAME_ANGLE_XX replaced by ROTOR_ANGLE_XX in the CMD_REALTIME_DATA_4; CMD_AHRS_HELPER updated;
- rev. 0.5 – 30.07.2015: PROFILE_FLAGS1, GENERAL_FLAGS1 set is extended; CMD_EXECUTE_MENU set is extended; FRAME_CAM_ANGLE_XX is deprecated;
- rev. 0.6 – 12.08.2015: new mode in the CMD_CONTROL: MODE_ANGLE_REL_FRAME; new commands CMD_GET_ANGLES_EXT, CMD_SET_ADJ_VARS_VAL;
- rev. 0.7 – 22.10.2015: new config parameters ORDER_OF_AXES, EULER_ORDER; set of PROFILE_FLAGS1, GENERAL_FLAGS1 extended; SKIP_GYRO_CALIB options extended;
- rev. 0.8 – 09.11.2015: CMD_AHRS_HELPER is extended;
- rev. 0.9 – 22.12.2015: new command CMD_GYRO_CORRECTION; list of adjustable variables was extended by the FRAME_HEADING_ANGLE, GYRO_HEADING_CORRECTION; GENERAL_FLAGS1, PROFILE_FLAGS1 set was extended;
- rev. 0.10 – 13.02.2016: CMD_AUTO_PID updated; NOTCH_GAIN range extended;
- rev. 0.11 – 07.03.2016: new command CMD_READ_PARAMS_EXT2; new parameter MOTOR_MAG_LINK_FINE; new command CMD_CALIB_MOTOR_MAG_LINK; ACC_LIMITER split to axes; extended form of CMD_HELPER_DATA;
- rev. 0.12 – 02.04.2016: new commands CMD_DATA_STREAM_INTERVAL, CMD_REALTIME_DATA_CUSTOM;
- rev. 0.13 – 05.06.2016: new command CMD_BEEP_SOUND; new adjustment variables;
- rev. 0.14 – 21.06.2016: CMD_ADJ_VARS_STATE described;
- rev. 0.15 – 09.07.2016: CMD_READ_PARAMS_EXT2 was extended; CMD_AUTO_PID - CFG_FLAGS was extended; CMD_CALIB_INFO was documented; CMD_DATA_STREAM_INTERVAL was corrected;

Overview

Serial API allows external application or device to communicate with the SimpleBGC controller via UART port. Each controller has one or more UART ports that can be used to send and receive Serial API commands. Commands may be used to retrieve actual system state and realtime data, change settings, control gimbal, trigger pin state, execute various actions, get access to internal EEPROM and I2C bus, and so on. Moreover, SimpleBGC GUI software uses the same Serial API to communicate with the board, so all of its functions may be implemented in third-party applications.

Message format

Communications is initiated from the GUI side (host) by sending *outgoing* commands. The controller board may do some action and send response (further named as *incoming* commands). Each command consists of the *header* and the *body*, both with checksum. Commands with the wrong header or body checksum, or with the body size that differs from expected, should be ignored.

Board can work on different serial baud rate, so the GUI should find proper baud rate by sending CMD_BOARD_INFO command on every speed and wait for response, until valid response is received.

32bit boards with firmware version 2.40, works only with parity=EVEN COM-port setting. Starting from 2.41, both EVEN and NONE parity are supported (NONE is default, and EVEN is detected automatically). So beside baud rates, host should vary parity setting when connecting to boards ver.>3.0

Make a small delay after sending each command to prevent overflow of the input buffer. Delay should be about 10-20 ms, and depends on the size of the request and response. If new serial data comes when the input buffer is full, whole message will be lost. There is also a control of overflow of the output buffer on the board's side: if it have to write an answer to the output buffer, it hangs until buffer will have enough space to accept new data. If requests comes with too big rate, it may negatively affect normal operation of the board and impact stabilization.

Input and output commands have the same format, described below:

Header:

character '>'
command ID - 1u
data_size – 1u, may be zero
header checksum = (command ID + data_size) modulo 256 - 1u

Body:

[array of bytes *data_size* length]
body checksum - 1u

Checksum is calculated as a sum of all bytes modulo 256.

Example: outgoing command to read Profile2:

0x3E (>)	0x52 (R)	0x01	0x53	0x01	0x01
	command id	data size	header checksum	data	body checksum
header				body	

Data type notation

- 1u – 1 byte unsigned

- 1s – 1 byte signed
- 2u – 2 byte unsigned (little-endian order)
- 2s – 2 byte signed (little-endian order)
- 4f – float (IEEE-754 standard)
- 4s – 4 bytes signed (little-endian order)
- string – ASCII character array, first byte is array size
- Nb – byte array size N

Command ID definitions

```
#define CMD_READ_PARAMS 82
#define CMD_WRITE_PARAMS 87
#define CMD_REALTIME_DATA 68
#define CMD_BOARD_INFO 86
#define CMD_CALIB_ACC 65
#define CMD_CALIB_GYRO 103
#define CMD_CALIB_EXT_GAIN 71
#define CMD_USE_DEFAULTS 70
#define CMD_CALIB_POLES 80
#define CMD_RESET 114
#define CMD_HELPER_DATA 72
#define CMD_CALIB_OFFSET 79
#define CMD_CALIB_BAT 66
#define CMD_MOTORS_ON 77
#define CMD_MOTORS_OFF 109
#define CMD_CONTROL 67
#define CMD_TRIGGER_PIN 84
#define CMD_EXECUTE_MENU 69
#define CMD_GET_ANGLES 73
#define CMD_CONFIRM 67

// Board v3.x only
#define CMD_BOARD_INFO_3 20
#define CMD_READ_PARAMS_3 21
#define CMD_WRITE_PARAMS_3 22
#define CMD_REALTIME_DATA_3 23
#define CMD_REALTIME_DATA_4 25
#define CMD_SELECT_IMU_3 24
#define CMD_READ_PROFILE_NAMES 28
#define CMD_WRITE_PROFILE_NAMES 29
#define CMD_QUEUE_PARAMS_INFO_3 30
#define CMD_SET_ADJ_VARS_VAL 31
#define CMD_SAVE_PARAMS_3 32
#define CMD_READ_PARAMS_EXT 33
#define CMD_WRITE_PARAMS_EXT 34
#define CMD_AUTO_PID 35
#define CMD_SERVO_OUT 36
#define CMD_I2C_WRITE_REG_BUF 39
#define CMD_I2C_READ_REG_BUF 40
#define CMD_WRITE_EXTERNAL_DATA 41
#define CMD_READ_EXTERNAL_DATA 42
#define CMD_READ_ADJ_VARS_CFG 43
#define CMD_WRITE_ADJ_VARS_CFG 44
#define CMD_API_VIRT_CH_CONTROL 45
#define CMD_ADJ_VARS_STATE 46
#define CMD_EEPROM_WRITE 47
#define CMD_EEPROM_READ 48
#define CMD_CALIB_INFO 49
#define CMD_BOOT_MODE_3 51
```

```
#define CMD_SYSTEM_STATE 52
#define CMD_READ_FILE 53
#define CMD_WRITE_FILE 54
#define CMD_FS_CLEAR_ALL 55
#define CMD_AHRS_HELPER 56
#define CMD_RUN_SCRIPT 57
#define CMD_SCRIPT_DEBUG 58
#define CMD_CALIB_MAG 59
#define CMD_GET_ANGLES_EXT 61
#define CMD_READ_PARAMS_EXT2 62
#define CMD_WRITE_PARAMS_EXT2 63
#define CMD_GET_ADJ_VARS_VAL 64
#define CMD_CALIB_MOTOR_MAG_LINK 74
#define CMD_GYRO_CORRECTION 75
#define CMD_DATA_STREAM_INTERVAL 85
#define CMD_REALTIME_DATA_CUSTOM 88
#define CMD_BEEP_SOUND 89
#define CMD_ENCODERS_CALIB_OFFSET_4 26
#define CMD_ENCODERS_CALIB_FLD_OFFSET_4 27
#define CMD_MAVLINK_INFO 250
#define CMD_MAVLINK_DEBUG 251
#define CMD_DEBUG_VARS_INFO_3 253
#define CMD_DEBUG_VARS_3 254
#define CMD_ERROR 255
```

Incoming commands

CMD_BOARD_INFO – version and board info information

- BOARD_VER - 1u (split into decimal digits X . X, for example 10 means 1.0)
- FIRMWARE_VER - 2u (split into decimal digits X . XX . X, for example 2305 means 2.30b5)
- DEBUG_MODE - 1u (should hide DEBUG output if DEBUG_MODE = 0)
- BOARD_FEATURES – 2u
- CONNECTION_FLAGS – 1u
- FRW_EXTRA_ID - 4u
- reserved – 7b

CMD_BOARD_INFO_3 – additional board information

- deviceID 9b – device ID
- mcuID 12b - MCU ID
- EEPROM_SIZE – 4u
- SCRIPT_SLOT1_SIZE – 2u – size of user-written scripts stored in each slot, 0 if slot is empty.
SCRIPT_SLOT2_SIZE – 2u
SCRIPT_SLOT3_SIZE – 2u
SCRIPT_SLOT4_SIZE – 2u
SCRIPT_SLOT5_SIZE - 2u
- reserved - 34b

CMD_READ_PARAMS_3 – Receive parameters

Receive parameters for single profile together with general parameters .

Profile parameters:

- PROFILE_ID – 1u (ID of profile to read, starting from 0)
- for(axis in [ROLL, PITCH, YAW]) {
 - P - 1u
 - I - 1u (multiplied by 100)
 - D - 1u
 - POWER - 1u
 - INVERT – 1u (checked=1, not checked=0)
 - POLES - 1u
- }
- ACC_LIMITER_ALL - 1u
- EXT_FC_GAIN_ROLL - 1s

- EXT_FC_GAIN_PITCH – 1s
-
- for(axis in [ROLL, PITCH, YAW]) {
 - RC_MIN_ANGLE - 2s
 - RC_MAX_ANGLE - 2s
 - RC_MODE - 1u
 - RC_LPF – 1u
 - RC_SPEED – 1u
 - RC_FOLLOW - 1u
- }
- GYRO_TRUST – 1u
- USE_MODEL – 1u
- PWM_FREQ – 1u
- SERIAL_SPEED – 1u
- RC_TRIM_ROLL - 1s
- RC_TRIM_PITCH - 1s
- RC_TRIM_YAW - 1s
- RC_DEADBAND - 1u
- RC_EXPO_RATE - 1u
- RC_VIRT_MODE – 1u
-
- RC_MAP_ROLL – 1u
- RC_MAP_PITCH – 1u
- RC_MAP_YAW – 1u
- RC_MAP_CMD – 1u
- RC_MAP_FC_ROLL – 1u
- RC_MAP_FC_PITCH – 1u
-
- RC_MIX_FC_ROLL - 1u
- RC_MIX_FC_PITCH - 1u
-
- FOLLOW_MODE – 1u
- FOLLOW_DEADBAND – 1u
- FOLLOW_EXPO_RATE – 1u
- FOLLOW_OFFSET_ROLL – 1s

- FOLLOW_OFFSET_PITCH – 1s
- FOLLOW_OFFSET_YAW - 1s
-
- AXIS_TOP – 1s
- AXIS_RIGHT – 1s
- FRAME_AXIS_TOP – 1s
- FRAME_AXIS_RIGHT – 1s
- FRAME_IMU_POS - 1u
- GYRO_DEADBAND– 1u
- GYRO_SENS - 1u
- I2C_INTERNAL_PULLUPS – 1u
- SKIP_GYRO_CALIB – 1u
-
- RC_CMD_LOW – 1u
- RC_CMD_MID – 1u
- RC_CMD_HIGH – 1u
-
- MENU_CMD_1 - 1u
- MENU_CMD_2 - 1u
- MENU_CMD_3 - 1u
- MENU_CMD_4 - 1u
- MENU_CMD_5 - 1u
- MENU_CMD_LONG - 1u
-
- OUTPUT_ROLL - 1u
- OUTPUT_PITCH – 1u
- OUTPUT_YAW – 1u
-
- BAT_THRESHOLD_ALARM – 2s
- BAT_THRESHOLD_MOTORS – 2s
- BAT_COMP_REF – 2s
-
- BEEPER_MODES – 1u
-
- FOLLOW_ROLL_MIX_START - 1u

- FOLLOW_ROLL_MIX_RANGE - 1u
-
- BOOSTER_POWER_ROLL - 1u
- BOOSTER_POWER_PITCH - 1u
- BOOSTER_POWER_YAW - 1u
-
- FOLLOW_SPEED_ROLL - 1u
- FOLLOW_SPEED_PITCH - 1u
- FOLLOW_SPEED_YAW - 1u
-
- FRAME_ANGLE_FROM_MOTORS - 1u
-
- RC_MEMORY_ROLL – 2s
- RC_MEMORY_PITCH – 2s
- RC_MEMORY_YAW – 2s
-
- SERVO1_OUT – 1u
- SERVO2_OUT – 1u
- SERVO3_OUT – 1u
- SERVO4_OUT – 1u
- SERVO_RATE – 1u
-
- ADAPTIVE_PID_ENABLED – 1u
- ADAPTIVE_PID_THRESHOLD – 1u
- ADAPTIVE_PID_RATE – 1u
- ADAPTIVE_PID_RECOVERY_FACTOR – 1u
-
- FOLLOW_LPF_ROLL – 1u
- FOLLOW_LPF_PITCH – 1u
- FOLLOW_LPF_YAW – 1u
-
- GENERAL_FLAGS1 – 2u
- PROFILE_FLAGS1 - 2u
- SPEKTRUM_MODE - 1u
-

- ORDER_OF_AXES – 1b
- EULER_ORDER - 1b
-
- CUR_IMU - 1u (currently selected IMU)
- CUR_PROFILE_ID – 1u (profile ID which is currently active in the controller)

CMD_READ_PARAMS_EXT – read extended set of params for

- PROFILE_ID – 1u (ID of profile to read, starting from 0)
- for(1..3) {
 - NOTCH_FREQ[3] – 1u * 3
 - NOTCH_WIDTH[3] – 1u * 3
- }
- LPF_FREQ[3] – 2u * 3
- FILTERS_EN[3] – 1u * 3
- ENCODER_OFFSET[3] – 2s * 3
- ENCODER_FLD_OFFSET[3] – 2s * 3
- ENCODER_MANUAL_SET_TIME[3] – 1u * 3
- MOTOR_HEATING_FACTOR[3] - 1u * 3
- MOTOR_COOLING_FACTOR[3] – 1u * 3
- RESERVED – 2b
- FOLLOW_INSIDE_DEADBAND - 1u
- MOTOR_MAG_LINK[3] – 1u * 3 (deprecated, replaced by MOTOR_MAG_LINK_FINE)
- MOTOR_GEARING[3] – 2u * 3
- ENCODER_LIMIT_MIN[3] – 1s * 3
- ENCODER_LIMIT_MAX[3] – 1s * 3
- NOTCH1_GAIN[3] – 1s * 3
- NOTCH2_GAIN[3] – 1s * 3
- NOTCH3_GAIN[3] – 1s * 3
-
- BEEPER_VOLUME – 1u
- ENCODER_GEAR_RATIO[3] – 2u * 3
- ENCODER_TYPE[3] – 1u * 3
- ENCODER_CFG[3] – 1u * 3
- OUTER_P[3] – 1u * 3
- OUTER_I[3] – 1u * 3

- MAG_AXIS_TOP – 1s
- MAG_AXIS_RIGHT – 1s
- MAG_TRUST – 1u
- MAG_DECLINATION – 1s
- ACC_LPF_FREQ – 2u
- D_TERM_LPF_FREQ[3] – 1u * 3

CMD_READ_PARAMS_EXT2 – read extended set of parameters

- RESERVED – 16b
- MOTOR_MAG_LINK_FINE[3] – 2u * 3
- ACC_LIMITER3[3] – 1u * 3
- PID_GAIN[3] – 1u*3
- FRAME_IMU_LPF_FREQ – 1u
- AUTO_PID_CFG – 1u
- AUTO_PID_GAIN - 1u
- RESERVED - 119b

CMD_REALTIME_DATA_3 - receive real-time data for

- for(axis in [ROLL, PITCH, YAW]) {
 - ACC_DATA – 2s
 - GYRO_DATA – 2s
- }
- SERIAL_ERROR_CNT – 2u
- SYSTEM_ERROR – 2u
- SYSETEM_SUB_ERROR – 1u
- RESERVED - 3b
- RC_ROLL - 2s
- RC_PITCH - 2s
- RC_YAW - 2s
- RC_CMD – 2s
- EXT_FC_ROLL – 2s
- EXT_FC_PITCH – 2s
- ANGLE_ROLL – 2s
- ANGLE_PITCH – 2s

- ANGLE_YAW – 2s
- FRAME_IMU_ANGLE_ROLL – 2s
- FRMAE_IMU_ANGLE_PITCH – 2s
- FRAME_IMU_ANGLE_YAW – 2s
- RC_ANGLE_ROLL - 2s
- RC_ANGLE_PITCH - 2s
- RC_ANGLE_YAW - 2s
- CYCLE_TIME - 2u
- I2C_ERROR_COUNT - 2u
- ERROR_CODE – 1u (deprecated, use 16bit SYSTEM_ERROR above)
- BAT_LEVEL - 2u
- OTHER_FLAGS - 1u
- CUR_IMU - 1u
- CUR_PROFILE – 1u
- MOTOR_POWER_ROLL – 1u
- MOTOR_POWER_PITCH – 1u
- MOTOR_POWER_YAW- 1u

CMD_REALTIME_DATA_4 - receive extended real-time data

- **..all data from CMD_REALTIME_DATA_3..**
- STATOR_ROTOR_ANGLE[3] – 2s*3
- RESERVED – 1b
- BALANCE_ERROR[3] – 2s*3
- CURRENT – 2u (units: mA)
- MAG_DATA[3] – 2s*3
- IMU_TEMPERATURE – 1s (units: Celsius)
- FRAME_IMU_TEMPERATURE – 1s (units: Celsius)
- IMU_G_ERR – 1u
- IMU_H_ERR - 1u
- RESERVED - 36b

CMD_CONFIRM – confirmation of previous command

- CMD – 1u
- DATA – depends on CMD

Board sends confirmation on commands: A, G, P, W, etc. DATA is empty unless mentioned in command

description.

CMD_ERROR – error on executing previous command

- ERROR_CODE – 1u
- ERROR_DATA – 4b

Data depends on error type.

CMD_GET_ANGLES - Information about actual RC control state

- for(axis in [ROLL, PITCH, YAW]) {
 - IMU_ANGLE - 2s
 - RC_TARGET_ANGLE - 2s
 - RC_SPEED - 2s
- }

CMD_GET_ANGLES_EXT - Information about angles in different format

- for(axis in [ROLL, PITCH, YAW]) {
 - IMU_ANGLE - 2s
 - RC_TARGET_ANGLE - 2s
 - STATOR_ROTOR_ANGLE – 4s
 - RESERVED - 10b
- }

CMD_READ_PROFILE_NAMES_3 – receive profile names from EEPROM

Each name is encoded in UTF-8 format and padded with '\0' character to 48 byte size

- PROFILE1_NAME – 48b
- PROFILE2_NAME – 48b
- PROFILE3_NAME – 48b
- PROFILE4_NAME – 48b
- PROFILE5_NAME – 48b

CMD_GET_PARAMS_3 – receive information about configurable parameters: type, range, etc.
--not yet implemented--

CMD_I2C_READ_REG_BUF – result of reading from I2C device

- DATA – 1..255 byte, depends on the DATA_LEN parameter in the request.

CMD_AUTO_PID – progress of PID auto tuning

- P[3] – 1u * 3
- I[3] – 1u * 3
- D[3] – 1u * 3
- LPF_FREQ[3] – 2u * 3
- ITER_NUM - 2u
- for(1..3) {
 - TRACKING_ERROR – float

- RESERVED – 6b
- }
- RESERVED – 10b

CMD_DEBUG_VARS_INFO_3 – receive specification of the debug variables

- DEBUG_VARS_NUM – 1u - number of debug vars
- ```
for(i=0; i<DEBUG_VARS_NUM; i++) {
 • VAR_NAME – string
 • VAR_TYPE – 1u (see definitions below)
 • RESERVED – 2b
}
```

### **CMD\_DEBUG\_VARS\_3 – values of some variables reflecting a state of the system.**

A set and an order of variables is not strictly defined, and may vary depending on the firmware version. Use *CMD\_DEBUG\_VARS\_INFO\_3* to get a specification of the variables.

- ```
for(i=0; i<DEBUG_VARS_NUM; i++) {
    • VAR_VALUE – <size and type from CMD_DEBUG_VARS_INFO_3 structure>
}
```

CMD_READ_EXTERNAL_DATA – receive user data, stored in the EEPROM

- data – 128b

CMD_SET_ADJ_VARS_VAL – receive the values of adjustable variables.

See corresponding outgoing command for format description.

CMD_READ_ADJ_VARS_CFG – receive the configuration of mapping of control inputs to adjustable variables

There are 10 “trigger” slots and 15 “analog” slots. “Trigger” type is used to execute action depending on the RC signal level, where full range is split into 5 levels (see [Available actions](#)). “Analog” type is used to adjust parameter by RC signal. MIN_VAL and MAX_VAL specify a working range, that is combined with the native range of particular parameter (see [List of available parameters](#))

- ```
for(i=0; i<10; i++) {
 • SRC_CH – 1u
 • ACTION1 – 1u
 • ACTION2 – 1u
 • ACTION3 – 1u
 • ACTION4 – 1u
 • ACTION5 – 1u
}
for(i=0; i<15; i++) {
 • SRC_CH – 1u
 • PARAM_ID – 1u
 • MIN_VAL – 1u
 • MAX_VAL – 1u
}
• RESERVED – 8b
```

### **CMD\_RESET – notification on device reset**

Device sent this command when goes to reset. There is a delay 1000ms after this command is sent and reset is actually done. External application can free up resources and properly close the serial connection.

**CMD\_EEPROM\_READ** – receive block of data from EEPROM at the specified address.

- ADDR – 4u, 64-byte aligned
- DATA – any size, as specified in the CMD\_EEPROM\_READ outgoing command.

**CMD\_CALIB\_INFO** – receive information required for the "Calibration helper" dialog window.

- PROGRESS – 1u
- IMU\_TYPE – 1u
- ACC\_DATA[3] – 2s\*3
- GYRO\_ABS\_VAL – 2u
- ACC\_CUR\_AXIS – 1u
- ACC\_LIMITS\_INFO – 1u
- IMU\_TEMP\_CELS – 1s
- TEMP\_CALIB\_GYRO\_ENABLED – 1u
- TEMP\_CALIB\_GYRO\_T\_MIN\_CELS – 1s
- TEMP\_CALIB\_GYRO\_T\_MAX\_CELS – 1s
- TEMP\_CALIB\_ACC\_ENABLED – 1u
- TEMP\_CALIB\_ACC\_SLOT\_NUM[6] – 1u\*6
- TEMP\_CALIB\_ACC\_T\_MIN\_CELS – 1s
- TEMP\_CALIB\_ACC\_T\_MAX\_CELS – 1s
- H1\_ERR\_LENGTH – 1u
- RESERVED – 7b

**CMD\_READ\_FILE** – result of reading file from internal filesystem

In case of success:

- FILE\_SIZE – 2u – total size of file, bytes
- PAGE\_OFFSET – 2u – offset that was requested, in pages. 1 page = 64 bytes
- DATA – size that was requested, or less if end of file is reached

In case of errors:

- ERR\_CODE – 1u (see error definitions in the CMD\_WRITE\_FILE command)

**CMD\_SCRIPT\_DEBUG** – state of execution of user-written script

- CMD\_COUNT – 2u – current command counter
- ERR\_CODE – 1u (see error definitions in the CMD\_WRITE\_FILE command)

**CMD\_AHRS\_HELPER** – current attitude in vector form.

- Z1\_VECTOR[3] – 4f \* 3
- H1\_VECTOR[3] – 4f \* 3

**CMD\_REALTIME\_DATA\_CUSTOM** – configurable realtime data (ver. 2.59+)

- TIMESTAMP\_MS – 2u
- DATA – variable length, depends on request. See specification below.

**CMD\_ADJ\_VARS\_STATE** – receive the state of adjustable variable in the requested slot

- TRIGGER\_RC\_DATA – 2s
- TRIGGER\_ACTION – 1u
- ANALOG\_RC\_DATA – 2s
- ANALOG\_VALUE – 4s
- RESERVED - 6b

## Outgoing command

### **CMD\_BOARD\_INFO – request board and firmware information**

Simple format: no parameters

Extended format:

- CFG – 2b - configuration for this serial driver:
  - for UARTs – period (in ms) between 20-bytes packets for BLE mode
  - for USB – not used
- RESERVED – size undefined

### **CMD\_BOARD\_INFO\_3 – request additional board information**

### **CMD\_REALTIME\_DATA,**

**CMD\_REALTIME\_DATA\_3 – request real-time data, response is CMD\_REALTIME\_DATA\_3**

**CMD\_REALTIME\_DATA\_4 – request extended real-time data, response is CMD\_REALTIME\_DATA\_4**

### **CMD\_CALIB\_ACC – calibrate accelerometer**

### **CMD\_CALIB\_GYRO – calibrate gyroscope**

Simple format: no parameters. Starts regular calibration of currently active IMU (set by CMD\_SELECT\_IMU\_3 command)

Extended format (for both commands):

- IMU\_IDX – 1u (0 – currently active IMU, 1 – main IMU, 2 – frame IMU)
- ACTION – 1u
  - 1 – do regular calibration
  - 2 – reset all calibrations and restart
  - 3 – do temperature calibration
  - 4 – enable temp. calib. data, if present and restart
  - 5 – disable temp. calib. data (but keep in memory) and restart
  - 6 – copy calibration from the sensor's EEPROM to the main EEPROM ("restore factory calibration" option)
  - 7 – copy calibration from the main EEPROM to the sensor's EEPROM
- RESERVED - 10b

If all parameters are valid, confirmation is sent immediately on reception and in the end of calibration.

### **CMD\_CALIB\_EXT\_GAIN – calibrate EXT\_FC gains**

### **CMD\_USE\_DEFAULTS – reset to factory defaults**

- PROFILE\_ID – 1u – profile to reset, 0..NUM\_PROFILE-1  
Special values:  
253 – erase EEPROM

**CMD\_CALIB\_POLES – calibrate poles and direction**

**CMD\_READ\_PARAMS,**

**CMD\_READ\_PARAMS\_3 – request parameters from the board**

**CMD\_READ\_PARAMS\_EXT – request extended parameters**

**CMD\_READ\_PARAMS\_EXT2 – request extended parameters**

- PROFILE\_ID – 1u – profile to load

**CMD\_WRITE\_PARAMS,**

**CMD\_WRITE\_PARAMS\_3 - write parameters to board and saves to EEPROM**

**CMD\_WRITE\_PARAMS\_EXT – write extended parameters**

Data structure is the same as for corresponding CMD\_READ\_PARAMS\_xx incoming command.

**CMD\_RESET – reset device**

Simple format: reset device without delay and confirmation

Extended format:

- CONFIRM – 1u (0 – no confirmation, 1 - command CMD\_RESET will be sent back)
- DELAY\_MS – 2u - delay before reset, in ms. External application can free up resources and properly close the serial connection.

**CMD\_BOOT\_MODE\_3 – enter bootloader mode to upload firmware**

Simple format: enter without delay and confirmation

Extended format:

- CONFIRM – 1u (0 – no confirmation, 1 - command CMD\_RESET will be sent back)
- DELAY\_MS – 2u - delay before entering bootloader mode, in ms.

**CMD\_CALIB\_OFFSET – calibrate follow offset**

**CMD\_CALIB\_BAT - calibrate battery (voltage sensor)**

- ACTUAL\_VOLTAGE - 2u

**CMD\_CONTROL – control gimbal movement**

- CONTROL\_MODE – 1u
- SPEED\_ROLL – 2s
- ANGLE\_ROLL – 2s
- SPEED\_PITCH – 2s
- ANGLE\_PITCH – 2s
- SPEED\_YAW – 2s
- ANGLE\_YAW – 2s

Extended format (firmware ver. 2.55b5): mode is set independently for each axes, that allows to have RC control mixed with serial control, or different control modes for different axes:

- CONTROL\_MODE\_ROLL – 1u



- CONTROL\_MODE\_PITCH – 1u
- CONTROL\_MODE\_YAW – 1u
- SPEED\_ROLL – 2s
- ANGLE\_ROLL – 2s
- SPEED\_PITCH – 2s
- ANGLE\_PITCH – 2s
- SPEED\_YAW – 2s
- ANGLE\_YAW – 2s

**CMD\_TRIGGER\_PIN - trigger output pin**

- PIN\_ID - 1u
- STATE - 1u

Confirmation is sent only if pin is not used for input and is really triggered.

**CMD\_MOTORS\_ON - switch motors ON**

Confirmation send 'M'

**CMD\_MOTORS\_OFF - switch motors OFF**

Confirmation send 'm'

**CMD\_EXECUTE\_MENU - execute menu command**

- CMD\_ID - 1u

**CMD\_HELPER\_DATA – pass helper data**

- FRAME\_ACC\_X – 2s
- FRAME\_ACC\_Y – 2s
- FRAME\_ACC\_Z – 2s
- FRAME\_ANGLE\_ROLL – 2s
- FRAME\_ANGLE\_PITCH – 2s

Extended form supported in 2.59+ firmware:

- FRAME\_ACC[3] – 2s \* 3
- FRAME\_ANGLE\_ROLL – 2s
- FRAME\_ANGLE\_PITCH – 2s
- COORD\_SYS – 1u
- FRAME\_SPEED[3] – 2s \* 3
- RESERVED – 3b

**CMD\_GET\_ANGLES, CMD\_GET\_ANGLES\_EXT - Request information about angles and RC control state**

See description for incoming command.

**CMD\_SELECT\_IMU\_3 – Select which IMU to configure**

- IMU\_TYPE – 1u

**CMD\_READ\_PROFILE\_NAMES\_3 – Request profile names stored in EEPROM**

**CMD\_WRITE\_PROFILE\_NAMES\_3 – Writes profile names to EEPROM**

Each name is encoded in UTF-8 format and padded with '\0' character to 48 byte size

- PROFILE1\_NAME – 48b
- PROFILE2\_NAME – 48b

- PROFILE3\_NAME – 48b
- PROFILE4\_NAME – 48b
- PROFILE5\_NAME – 48b

**CMD\_GET\_PARAMS\_3 – Request information about configurable parameters: type, range, current value**

In response, board may send multiple CMD\_GET\_PARAMS\_3 commands if all data will not fit to single command.

--not yet implemented--

**CMD\_SET\_ADJ\_VARS\_VAL – Update the value of selected parameter(s).**

This command is intended to change parameters on-the-fly during system operation, and does not save parameters to EEPROM. You need to send CMD\_SAVE\_PARAMS\_3 to do this. [List of available parameters](#)

- NUM\_VARS - 1u
- PARAM1\_ID – 1u
- PARAM1\_VALUE – 4s
- PARAM2\_ID – 1u
- PARAM2\_VALUE – 4s
- ...repeat for remaining parameters...

On success, confirmation is sent in response.

**CMD\_GET\_ADJ\_VARS\_VAL – Query the actual value of selected parameter(s).**

This command requests actual values of adjustable parameters. [List of available parameters](#).

- NUM\_VARS - 1u
- PARAM1\_ID – 1u
- PARAM2\_ID – 1u
- ...repeat for remaining parameters...

On success, CMD\_SET\_ADJ\_VARS\_VAL is sent in response.

**CMD\_SAVE\_PARAMS\_3 – Saves current params from volatile memory to EEPROM, to the active profile slot.**

**CMD\_AUTO\_PID – Starts automatic PID calibration**

- PROFILE\_ID – 1u - switch to this profile before start of calibration
- CFG\_FLAGS – 1u
- GAIN\_VS\_STABILITY – 1u
- RESERVED - 16b

**CMD\_SERVO\_OUT – Output PWM signal on the specified pins**

Although it takes 8 values, the real number of hardware outputs depends on board version and may be less.

- SERVO1\_TIME – 2s - shared with FC\_ROLL
- SERVO2\_TIME – 2s - shared with FC\_PITCH
- SERVO3\_TIME – 2s - shared with RC\_PITCH
- SERVO4\_TIME – 2s - shared with AUX1
- SERVO5\_TIME – 2s - reserved
- SERVO6\_TIME – 2s - reserved
- SERVO7\_TIME – 2s - reserved
- SERVO8\_TIME – 2s - reserved

**CMD\_I2C\_WRITE\_REG\_BUF – writes data to any device connected to I2C line**

- DEVICE\_ADDR – 1u  
bit0: I2C port: 0 for main (sensor) port, 1 for second (EEPROM) port  
bit1..7: address

- REG\_ADDR – 1u
- DATA – remaining bytes

On successful writing, confirmation CMD\_CONFIRM is sent in response.

**CMD\_I2C\_READ\_REG\_BUF – requests reading from any device connected to I2C line**

Meaning of parameters are the same as for CMD\_I2C\_WRITE\_REG\_BUF command.

- DEVICE\_ADDR – 1u
- REG\_ADDR – 1u
- DATA\_LEN – 1u

On successful reading, CMD\_I2C\_READ\_REG\_BUF command is sent in response.

**CMD\_DEBUG\_VARS\_INFO\_3 – request information about debug variables**

**CMD\_DEBUG\_VARS\_3 – request values of debug variables**

**CMD\_WRITE\_EXTERNAL\_DATA – stores any user data to the dedicated area in the EEPROM**

- data – 128b

**CMD\_READ\_EXTERNAL\_DATA – request user data, stored in the EEPROM**

- data – 128b

**CMD\_API\_VIRT\_CH\_CONTROL – update a state of 32 virtual channels that named “API\_VIRT\_CHXX” in the GUI**

These channels can be selected as RC source to control camera or to do other tasks.

- VAL\_CH1 – 2s
- ...
- VAL\_CH32 - 2s

**CMD\_READ\_ADJ\_VARS\_CFG – request configuration of mapping of control inputs to adjustable variables**

CMD\_READ\_ADJ\_VARS\_CFG incoming command is sent in response.

**CMD\_WRITE\_ADJ\_VARS\_CFG – writes configuration of mapping of control inputs to adjustable variables**

- Data format is the same as in corresponding CMD\_READ\_ADJ\_VARS\_CFG incoming command.

On success, confirmation is sent in response.

**CMD\_EEPROM\_WRITE – writes a block of data to EEPROM to specified address**

- ADDR – 4u, 64-byte aligned
- DATA – any size, 64-byte aligned

On success, confirmation CMD\_CONFIRM is sent with parameters CMD\_EEPROM\_WRITE, ADDR.

**CMD\_EEPROM\_READ – request a reading of block of data from EEPROM at the specified address and size.**

- ADDR – 4u, 64-byte aligned
- SIZE – 2u, 64-byte aligned

On success, CMD\_EEPROM\_READ is sent. See its description.

#### **CMD\_CALIB\_INFO – request information required for the "Calibration helper" dialog window**

- IMU\_TYPE – 1u (1 – main IMU, 2 – frame IMU)
- RESERVED – 11b

On success, CMD\_CALIB\_INFO is sent in response.

#### **CMD\_READ\_FILE – read file from internal filesystem**

- FILE\_ID – 2u
- PAGE\_OFFSET – 2u
- MAX\_SIZE – 2u
- RESERVED – 14b

This command reads a portion of data from the file with identifier FILE\_ID, started at PAGE\_OFFSET pages (1page = 64byte). MAX\_SIZE bytes will be read or less, if file end is reached. Size should not exceed maximum allowed command data length. Read data or error code is sent in the incoming command CMD\_READ\_FILE.

#### **CMD\_WRITE\_FILE – write file to internal filesystem**

- FILE\_ID – 2u
- FILE\_SIZE – 2u
- PAGE\_OFFSET – 2u
- DATA – 0 or any size

This command writes a portion of data to a file with identifier FILE\_ID. If file is not exists, it is created. If FILE\_SIZE is not equal to existing file size, file is adjusted to new size. If DATA is empty, file is deleted. In response CMD\_CONFIRM is sent, with parameter ERR\_CODE. Possible codes:

```
NO_ERROR = 0
ERR_EEPROM_FAULT = 1
ERR_FILE_NOT_FOUND = 2
ERR_FAT = 3
ERR_NO_FREE_SPACE = 4
ERR_FAT_IS_FULL = 5
ERR_FILE_SIZE = 6
ERR_CRC = 7
ERR_LIMIT_REACHED = 8
```

#### **CMD\_FS\_CLEAR\_ALL – delete all files from internal filesystem**

Returns CMD\_CONFIRM with parameter ERR\_CODE (see definitions in the CMD\_WRITE\_FILE command)

#### **CMD\_RUN\_SCRIPT – start or stop user-written script**

- MODE – 1u (0 – stop, 1 – start, 2 – start with debug information is sent back in the CMD\_SCRIPT\_DEBUG)
- SLOT – 1u
- RESERVED – 32b

#### **CMD\_CALIB\_MAG – run magnetometer calibration**

Simple format: not parameters

Extended format: not implemented

#### **CMD\_AHRS\_HELPER – send or request attitude of the IMU sensor.**

Use this command to replace internal IMU calculations by high-grade external IMU, providing new data with 50-100 Hz rate.

- MODE – 1u
- Z1\_VECTOR[3] – 4f\*3

- H1\_VECTOR[3] – 4f\*3

**CMD\_GYRO\_CORRECTION** – correct gyroscope sensor manually

- IMU\_TYPE – 1u
- GYRO\_ZERO\_CORR[X] - 2s
- GYRO\_ZERO\_CORR[Y] - 2s
- GYRO\_ZERO\_CORR[Z] - 2s
- GYRO\_ZERO\_HEADING\_CORR – 2s

**CMD\_DATA\_STREAM\_INTERVAL** – register or update *data stream* – a sequence of commands sent by the controller with the fixed rate without request. (ver. 2.59+)

- CMD\_ID – 1u
- INTERVAL\_MS – 2u
- CONFIG – 8b
- RESERVED – 10b

For each serial interface, only one unique combination of CMD\_ID + CONFIG bytes may be registered. If the data stream is already registered, it will be updated. To unregister it, specify INTERVAL\_MS=0. The total number of data streams over all serial interfaces is limited (for 2.59 ver. limit is 10)

If the data stream is successfully registered or updated, the CMD\_CONFIRM is sent in answer.

Take care of the serial bandwidth: if data flow exceeds bandwidth, particular samples may be skipped. The same is true when the TX buffer is full when sending long commands like CMD\_READ\_PARAMS\_3.

The interval is maintained with the +-1ms tolerance for the individual sample, but the averaged sample rate exactly matches to specified.

Meaning of the CONFIG bytes is specific for each command and is described in the 'Parameters' section.

**CMD\_REALTIME\_DATA\_CUSTOM** – request configurable realtime data (ver. 2.59+)

- FLAGS – 4u
- RESERVED – 6b

**CMD\_BEEP\_SOUND** – play melody by motors or emit standard beep sound

- MODE - 2u
- NOTE\_LENGTH - 1u
- DECAY\_FACTOR - 1u
- RESERVED - 8b
- NOTE\_FREQ\_HZ[0..30] - array of 2u elements, size 0..30

**CMD\_ENCODERS\_CALIB\_OFFSET\_4** - calibrate offset of encoders

**CMD\_ENCODERS\_CALIB\_FLD\_OFFSET\_4** - start field offset calibration of encoders

**CMD\_ADJ\_VARS\_STATE** – request the state of adjustable variable in the given trigger and analog slots.

Slots are counted from 0.

- TRIGGER\_SLOT – 1u
- ANALOG\_SLOT – 1u

## Variables description and range

| Name                                         | Type | Min  | Max | Possible values, remarks                                                                                                                                                                                  |
|----------------------------------------------|------|------|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>CMD_BOARD_INFO - Version information</b>  |      |      |     |                                                                                                                                                                                                           |
| BOARD_VER                                    | 1u   |      |     | Multiplied by 10: 3.0 => 30                                                                                                                                                                               |
| FIRMWARE_VER                                 | 2u   |      |     | major_ver = (int)(FIRMWARE_VER/1000);<br>minor_ver = (int)((FIRMWARE_VER%1000)/10);<br>beta_ver = FIRMWARE_VER%10;                                                                                        |
| BOARD_FEATURES                               | 2u   |      |     | Bit set:<br>BOARD_FEATURE_3AXIS = 1<br>BOARD_FEATURE_BAT_MONITORING = 2<br>BOARD_FEATURE_ENCODERS = 4<br>BOARD_FEATURE_BODE_TEST = 8<br>BOARD_FEATURE_SCRIPTING = 16<br>BOARD_FEATURE_CURRENT_SENSOR = 32 |
| CONNECTION_FLAG                              | 1u   |      |     | Bit set:<br>CONNECTION_USB = 1                                                                                                                                                                            |
| <b>CMD_READ_PARAMS_3, CMD_WRITE_PARAMS_3</b> |      |      |     |                                                                                                                                                                                                           |
| PROFILE_ID                                   | 1u   |      |     | profile ID to read or write. To read or write current (active) profile, specify 255. Possible values: 0..4                                                                                                |
| P                                            | 1u   | 0    | 255 |                                                                                                                                                                                                           |
| I                                            | 1u   | 0    | 255 | divided by 100 when displayed in the GUI                                                                                                                                                                  |
| D                                            | 1u   | 0    | 255 |                                                                                                                                                                                                           |
| POWER                                        | 1u   | 0    | 255 |                                                                                                                                                                                                           |
| INVERT                                       | 1u   | 0    | 1   |                                                                                                                                                                                                           |
| POLES                                        | 1u   | 0    | 255 |                                                                                                                                                                                                           |
| ACC_LIMITER_ALL                              | 1u   | 0    | 255 | <i>Units: 5 degrees/sec<sup>2</sup> 0 – disabled.</i><br>(from ver. 2.59 is deprecated; replaced by the ACC_LIMITER3)                                                                                     |
| EXT_FC_GAIN                                  | 1s   | -127 | 127 |                                                                                                                                                                                                           |
| RC_MIN_ANGLE[axis]                           | 2s   | -720 | 720 | <i>Units: degrees</i>                                                                                                                                                                                     |
| RC_MAX_ANGLE[axis]                           | 2s   | -720 | 720 | <i>Units: degrees</i>                                                                                                                                                                                     |
| RC_MODE[axis]                                | 1u   |      |     | 0..2 bits - mode:<br>RC_MODE_ANGLE = 0<br>RC_MODE_SPEED = 1<br>3rd bit - control is inverted, if set to 1                                                                                                 |
| RC_LPF[axis]                                 | 1u   | 0    | 16  |                                                                                                                                                                                                           |
| RC_SPEED[axis]                               | 1u   | 0    | 255 |                                                                                                                                                                                                           |
| RC_FOLLOW[axis]                              | 1u   | -127 | 127 | ROLL, PITCH: this value specify follow rate for flight controller.<br>YAW: if value != 0, "follow motor" mode is                                                                                          |

|                                                                                              |    |      |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------------|----|------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                              |    |      |     | enabled.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| GYRO_TRUST                                                                                   | 1u | 0    | 255 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| USE_MODEL                                                                                    | 1u | 0    | 1   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| PWM_FREQ                                                                                     | 1u |      |     | PWM_FREQ_LOW = 0<br>PWM_FREQ_HIGH = 1<br>PWM_FREQ_ULTRA_HIGH = 2 (BOARD_VER >= 30)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| SERIAL_SPEED                                                                                 | 1u |      |     | 115200 = 0<br>57600 = 1<br>38400 = 2<br>19200 = 3<br>9600 = 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| RC_TRIM_ROLL<br>RC_TRIM_PITCH<br>RC_TRIM_YAW                                                 | 1s | -127 | 127 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| RC_DEADBAND                                                                                  | 1u | 0    | 255 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| RC_EXPO_RATE                                                                                 | 1u | 0    | 100 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| RC_VIRT_MODE                                                                                 | 1u |      |     | Mode of RC_ROLL input pin operation:<br>RC_VIRT_MODE_NORMAL = 0<br>RC_VIRT_MODE_CPPM = 1<br>RC_VIRT_MODE_SBUS = 2 (BOARD_VER >= 30)<br>RC_VIRT_MODE_SPEKTRUM = 3 (BOARD_VER >= 30)<br>RC_VIRT_MODE_API = 10 (BOARD_VER >= 30)                                                                                                                                                                                                                                                                                                                                                                                                                          |
| RC_MAP_ROLL<br>RC_MAP_PITCH<br>RC_MAP_YAW<br>RC_MAP_CMD<br>RC_MAP_FC_ROLL<br>RC_MAP_FC_PITCH | 1u |      |     | Assigns pin input or virtual channel (in serial modes), and specifies input mode.<br><br>INPUT_NO = 0<br><br><b>PWM source</b><br>RC_INPUT_ROLL = 1<br>RC_INPUT_PITCH = 2<br>EXT_FC_INPUT_ROLL = 3<br>EXT_FC_INPUT_PITCH = 4<br>RC_INPUT_YAW = 5 (BOARD_VER >= 30)<br><br><b>Analog source</b><br>Input number + 32 (5 <sup>th</sup> bit is set)<br>BOARD_VER < 30:<br>RC_INPUT_ROLL = 33<br>RC_INPUT_PITCH = 34<br>EXT_FC_INPUT_ROLL = 35<br>EXT_FC_INPUT_PITCH = 36<br><br>BOARD_VER >= 30:<br>ADC1 = 33<br>ADC2 = 34<br>ADC3 = 35<br><br><b>RC Serial source (CPPM/SBUS/SPEKTRUM):</b><br>Virtual channel (1..31) + 64 (6 <sup>th</sup> bit is set) |

|                                                                |    |      |     |                                                                                                                                                                                                                                                      |
|----------------------------------------------------------------|----|------|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                |    |      |     | <b>API Virtual control source</b><br>Virtual channel (1..31) + 128 (7 <sup>th</sup> bit is set)                                                                                                                                                      |
| RC_MIX_FC_ROLL<br>RC_MIX_FC_PITCH                              | 1u |      |     | Add FC channel to selected RC channels with given rate.<br>bits 0..5: mix rate. For example,<br>0 - no mix (100% RC)<br>32 - 50% RC, 50% FC,<br>63 - 0% RC, 100% FC<br>bits 6,7: target RC channel<br>0 - no mix<br>1 - ROLL<br>2 - PITCH<br>3 - YAW |
| FOLLOW_MODE                                                    | 1u |      |     | FOLLOW_MODE_DISABLED=0<br>FOLLOW_MODE_FC=1<br>FOLLOW_MODE_PITCH=2                                                                                                                                                                                    |
| FOLLOW_DEADBAND                                                | 1u | 0    | 255 |                                                                                                                                                                                                                                                      |
| FOLLOW_EXPO_RATE                                               | 1u | 0    | 100 |                                                                                                                                                                                                                                                      |
| FOLLOW_OFFSET_ROLL<br>FOLLOW_OFFSET_PITCH<br>FOLLOW_OFFSET_YAW | 1s | -127 | 127 |                                                                                                                                                                                                                                                      |
| FOLLOW_ROLL_MIX_ST<br>ART                                      | 1u | 0    | 90  |                                                                                                                                                                                                                                                      |
| FOLLOW_ROLL_MIX_RA<br>NGE                                      | 1u | 0    | 90  |                                                                                                                                                                                                                                                      |
| AXIS_TOP<br>AXIS_RIGHT<br>FRAME_AXIS_TOP<br>FRAME_AXIS_RIGHT   | 1s |      |     | Main IMU and frame IMU orientation:<br>X = 1<br>Y = 2<br>Z = 3<br>-X = -1<br>-Y = -2<br>-Z = -3                                                                                                                                                      |
| FRAME_IMU_POS                                                  | 1u |      |     | Location of the frame IMU:<br>FRAME_IMU_DISABLED = 0<br>FRAME_IMU_BELOW_YAW = 1<br>FRAME_IMU_ABOVE_YAW = 2<br>FRAME_IMU_BELOW_YAW_PID_SOURCE = 3                                                                                                     |
| GYRO_DEADBAND                                                  | 1u | 0    | 255 | <i>Units: 0.1 of gyro sensor's units.</i>                                                                                                                                                                                                            |
| I2C_INTERNAL_PULLUP<br>S                                       | 1u | 0    | 1   |                                                                                                                                                                                                                                                      |
| SKIP_GYRO_CALIB                                                | 1u |      |     | Skip calibration of gyroscope.<br>0 – do not skip<br>1 – skip always<br>2 – try to calibrate but skip if motion is detected                                                                                                                          |
| RC_CMD_LOW<br>RC_CMD_MID<br>RC_CMD_HIGH                        | 1u |      |     | Available actions:<br>MENU_CMD_NO = 0<br>MENU_CMD_PROFILE1 = 1<br>MENU_CMD_PROFILE2 = 2                                                                                                                                                              |



|                                                                |    |       |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------------------------------------------------|----|-------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MENU_CMD_1..5<br>MENU_CMD_LONG                                 |    |       |      | MENU_CMD_PROFILE3 = 3<br>MENU_CMD_SWAP_PITCH_ROLL = 4<br>MENU_CMD_SWAP_YAW_ROLL = 5<br>MENU_CMD_CALIB_ACC = 6<br>MENU_CMD_RESET = 7<br>MENU_CMD_SET_ANGLE = 8<br>MENU_CMD_CALIB_GYRO = 9<br>MENU_CMD_MOTOR_TOGGLE = 10<br>MENU_CMD_MOTOR_ON = 11<br>MENU_CMD_MOTOR_OFF = 12<br>MENU_CMD_FRAME_UPSIDE_DOWN = 13<br>MENU_CMD_PROFILE4 = 14<br>MENU_CMD_PROFILES5 = 15<br>MENU_CMD_AUTO_PID = 16<br>MENU_CMD_LOOK_DOWN = 17<br>MENU_CMD_HOME_POSITION = 18<br>MENU_CMD_RC_BIND = 19<br>MENU_CMD_CALIB_GYRO_TEMP = 20<br>MENU_CMD_CALIB_ACC_TEMP = 21<br>MENU_CMD_BUTTON_PRESS = 22<br>MENU_CMD_RUN_SCRIPT1 23<br>MENU_CMD_RUN_SCRIPT2 24<br>MENU_CMD_RUN_SCRIPT3 25<br>MENU_CMD_RUN_SCRIPT4 26<br>MENU_CMD_RUN_SCRIPT5 27<br>MENU_CMD_CALIB_MAG 33<br>MENU_CMD_LEVEL_ROLL_PITCH 34<br>MENU_CMD_CENTER_YAW 35<br>MENU_CMD_UNTWIST_CABLES 36<br>MENU_CMD_SET_ANGLE_NO_SAVE 37 |
| OUTPUT_ROLL<br>OUTPUT_PITCH<br>OUTPUT_YAW                      | 1u |       |      | DISABLED = 0<br>ROLL = 1<br>PITCH = 2<br>YAW = 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| BAT_THRESHOLD_ALARM                                            | 2s | -3000 | 3000 | Negative means means alarm is disabled<br><i>Units: 0.01V</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| BAT_THRESHOLD_MOTORS                                           | 2s | -3000 | 3000 | Negative value means function is disabled<br><i>Units: 0.01V</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| BAT_COMP_REF                                                   | 2s | -3000 | 3000 | Negative value means compensation is disabled.<br><i>Units: 0.01V</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| BEEPER_MODES                                                   | 1u |       |      | BEEPER_MODE_CALIBRATE=1<br>BEEPER_MODE_CONFIRM=2<br>BEEPER_MODE_ERROR=4<br>BEEPER_MODE_ALARM=8<br><br>BEEP_BY_MOTORS=128<br><i>(if this flag is set, motors emit sound instead of internal buzzer)</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| BOOSTER_POWER_ROLL<br>BOOSTER_POWER_PITCH<br>BOOSTER_POWER_YAW | 1u | 0     | 255  | Additional power to correct broken synchronization                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| FOLLOW_SPEED_ROLL<br>FOLLOW_SPEED_PITCH<br>FOLLOW_SPEED_YAW    | 1u | 0     | 255  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

|                                                       |    |        |       |                                                                                                                                                                                                                                                                                      |
|-------------------------------------------------------|----|--------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CUR_IMU                                               | 1u |        |       | IMU_TYPE_MAIN=1<br>IMU_TYPE_FRAME=2                                                                                                                                                                                                                                                  |
| FRAME_ANGLE_FROM_MOTORS                               | 1u | 0      | 1     |                                                                                                                                                                                                                                                                                      |
| RC_MEMORY_ROLL<br>RC_MEMORY_PITCH<br>RC_MEMORY_YAW    | 2s | -36767 | 32767 | Initial angle that is set at system start-up, in 14bit resolution<br><br><i>Units: 0,02197265625 degree</i>                                                                                                                                                                          |
| SERVO1_OUT<br>SERVO2_OUT<br>SERVO3_OUT<br>SERVO4_OUT  | 1u |        |       | Disabled = 0<br>1..32 - Virtual channel number as source of data to be output                                                                                                                                                                                                        |
| SERVO_RATE                                            | 1u | 5      | 40    | PWM frequency, 10 Hz per unit.                                                                                                                                                                                                                                                       |
| ADAPTIVE_PID_ENABLE<br>D                              | 1u |        |       | Set of bits (0 - disable all):<br>EN_ROLL = 1<br>EN_PITCH = 2<br>EN_YAW = 4                                                                                                                                                                                                          |
| ADAPTIVE_PID_THRES<br>HOLD                            | 1u | 0      | 255   |                                                                                                                                                                                                                                                                                      |
| ADAPTIVE_PID_RATE                                     | 1u | 1      | 255   |                                                                                                                                                                                                                                                                                      |
| ADAPTIVE_PID_RECOVERY_FACTOR                          | 1u | 0      | 10    |                                                                                                                                                                                                                                                                                      |
| FOLLOW_LPF_ROLL<br>FOLLOW_LPF_PITCH<br>FOLLOW_LPF_YAW | 1u | 0      | 16    |                                                                                                                                                                                                                                                                                      |
| CUR_PROFILE                                           | 1u | 0      |       | Active profile, 0..4                                                                                                                                                                                                                                                                 |
| GENERAL_FLAGS1                                        | 2u |        |       | REMEMBER_LAST_USED_PROFILE = (1<<0)<br>UPSIDE_DOWN_AUTO = (1<<1)<br>SWAP_FRAME_MAIN_IMU = (1<<2)<br>BLINK_PROFILE = (1<<3)<br>EMERGENCY_STOP = (1<<4)<br>MAGNETOMETER_POS_FRAME = (1<<5)<br>FRAME_IMU_FF = (1<<6)<br>OVERHEAT_STOP_MOTORS = (1<<7)<br>CENTER_YAW_AT_STARTUP = (1<<8) |
| PROFILE_FLAGS1                                        | 2u |        |       | ADC1_AUTO_DETECTION = (1<<0)<br>ADC2_AUTO_DETECTION = (1<<1)<br>ADC3_AUTO_DETECTION = (1<<2)<br>FOLLOW_USE_FRAME_IMU = (1<<4)<br>BRIEFCASE_AUTO_DETECTION = (1<<5)<br>UPSIDE_DOWN_AUTO_ROTATE = (1<<6)<br>FOLLOW_LOCK_OFFSET_CORRECTION = (1<<7)<br>START_NEUTRAL_POSITION = (1<<8)  |
| SPEKTRUM_MODE                                         | 1u |        |       | 0 Auto-detection (default)<br>1 DSM2/11ms/10bit<br>2 DSM2/11ms/11bit<br>3 DSM2/22ms/10bit<br>4 DSM2/22ms/11bit                                                                                                                                                                       |

|                                                                        |    |      |      |                                                                                                                                                                                                                                                                                      |
|------------------------------------------------------------------------|----|------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                        |    |      |      | 5 DSMX/11ms/10bit<br>6 DSMX/11ms/11bit<br>7 DSMX/22ms/10bit<br>8 DSMX/22ms/11bit                                                                                                                                                                                                     |
| ORDER_OF_AXES                                                          | 1u |      |      | Order of hardware axes, counting from a camera:<br><br>PITCH_ROLL_YAW = 0<br>YAW_ROLL_PITCH = 1<br>ROLL_YAW_PITCH* = 2<br>ROLL_PITCH_YAW = 3<br><br>* not implemented                                                                                                                |
| EULER_ORDER                                                            | 1u |      |      | Order of Euler angles to represent the current orientation of a camera and the target of stabilization:<br><br>PITCH_ROLL_YAW = 0<br>ROLL_PITCH_YAW = 1<br>LOCAL_ROLL* = 2<br>ROLL_LOCAL* = 3<br>YAW_ROLL_PITCH = 4<br>YAW_PITCH_ROLL = 5<br><br>* dedicated for 2-axis systems only |
| <b>CMD_READ_PARAMS_EXT, CMD_WRITE_PARAMS_EXT - Extended parameters</b> |    |      |      |                                                                                                                                                                                                                                                                                      |
| NOTCH_FREQ                                                             | 1u | 0    | 255  | Center frequency, x2 Hz (value 10 means 20Hz)                                                                                                                                                                                                                                        |
| NOTCH_WIDTH                                                            | 1u | 0    | 255  | Width of -3dB gain band, Hz                                                                                                                                                                                                                                                          |
| LPF_FREQ                                                               | 2u | 0    | 1000 | Low-pass filter -3dB cut-off frequency, Hz                                                                                                                                                                                                                                           |
| FILTERS_EN                                                             | 1u |      |      | Set of bits (0 - disable all):<br>EN_NOTCH1 = 1<br>EN_NOTCH2 = 2<br>EN_NOTCH3 = 4<br>EN_LPF = 8                                                                                                                                                                                      |
| NOTCH_GAIN                                                             | 1s | -100 | 100  | Notch gain, in dB (positive – notch, negative – peak filter)                                                                                                                                                                                                                         |
| ENCODER_OFFSET                                                         | 2s |      |      | <i>Units: 0,02197265625 degree</i>                                                                                                                                                                                                                                                   |
| ENCODER_FLD_OFFSET                                                     | 2s |      |      | <i>Units: 0,02197265625 degree</i>                                                                                                                                                                                                                                                   |
| ENCODER_MANUAL_SETTIME                                                 | 1u | 0    | 255  | <i>Units: 10ms</i>                                                                                                                                                                                                                                                                   |
| MOTOR_HEATING_FACTOR                                                   | 1u | 0    | 255  |                                                                                                                                                                                                                                                                                      |
| MOTOR_COOLING_FACTOR                                                   | 1u | 0    | 255  |                                                                                                                                                                                                                                                                                      |
| FOLLOW_INSIDE_DEADBAND                                                 | 1u | 0    | 255  |                                                                                                                                                                                                                                                                                      |

|                                           |    |      |      |                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------|----|------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MOTOR_MAG_LINK                            | 1u | 0    | 255  | Deprecated, replaced by MOTOR_MAG_LINK_FINE                                                                                                                                                                                                                                                                                                                                                                              |
| MOTOR_GEARING                             | 2u |      |      | Real number encoded as 8.8 fixed point (1.0f → 256)                                                                                                                                                                                                                                                                                                                                                                      |
| ENCODER_LIMIT_MIN                         | 1s | -127 | 127  | Units: 3 degree                                                                                                                                                                                                                                                                                                                                                                                                          |
| ENCODER_LIMIT_MAX                         | 1s | -127 | 127  | Units: 3 degree                                                                                                                                                                                                                                                                                                                                                                                                          |
| NOTCH1_GAIN<br>NOTCH2_GAIN<br>NOTCH3_GAIN | 1u | 0    | 100  |                                                                                                                                                                                                                                                                                                                                                                                                                          |
| BEEPER_VOLUME                             | 1u | 0    | 255  |                                                                                                                                                                                                                                                                                                                                                                                                                          |
| ENCODER_GEAR_RATIO                        | 2u |      |      | Units: 0.001                                                                                                                                                                                                                                                                                                                                                                                                             |
| ENCODER_TYPE                              | 1u |      |      | Bits 0..3:<br>ENC_TYPE_AS5048A = 1<br>ENC_TYPE_AS5048B = 2<br>ENC_TYPE_AS5048_PWM = 3<br>ENC_TYPE_AMT203 = 4<br>ENC_TYPE_MA3_10BIT = 5<br>ENC_TYPE_MA3_12BIT = 6<br>ENC_TYPE_ANALOG = 7<br>ENC_TYPE_I2C_DRV1 = 8<br>ENC_TYPE_I2C_DRV2 = 9<br>ENC_TYPE_I2C_DRV3 = 10<br>ENC_TYPE_I2C_DRV4 = 11<br>ENC_TYPE_AS5600_PWM = 12<br>ENC_TYPE_AS5600_I2C = 13<br>Bit 4:<br>SKIP_DETECTION = 1<br>Bit 7:<br>ENCODER_IS_GEARED = 1 |
| ENCODER_CFG                               | 1u |      |      | For SPI encoders:<br>SPI_SPEED_1MHz = 0<br>SPI_SPEED_2MHz = 1<br>SPI_SPEED_4MHz = 2<br>SPI_SPEED_500kHz = 3<br>For I2C_DRV:<br>internal encoder type                                                                                                                                                                                                                                                                     |
| OUTER_P                                   | 1u | 0    | 255  |                                                                                                                                                                                                                                                                                                                                                                                                                          |
| OUTER_I                                   | 1u | 0    | 255  |                                                                                                                                                                                                                                                                                                                                                                                                                          |
| MAG_AXIS_TOP<br>MAG_AXIS_RIGHT            | 1s |      |      | X = 1<br>Y = 2<br>Z = 3<br>-X = -1<br>-Y = -2<br>-Z = -3                                                                                                                                                                                                                                                                                                                                                                 |
| MAG_TRUST                                 | 1u | 0    | 255  |                                                                                                                                                                                                                                                                                                                                                                                                                          |
| MAG_DECLINATION                           | 1s | -127 | 127  | Units: 1 degree                                                                                                                                                                                                                                                                                                                                                                                                          |
| ACC_LPF_FREQ                              | 2u | 0    | 1000 | Units: 0.01Hz                                                                                                                                                                                                                                                                                                                                                                                                            |
| D_TERM_LPF_FREQ[3]                        | 1u | 0    | 60   | Units: 10Hz                                                                                                                                                                                                                                                                                                                                                                                                              |

|                                                                               |    |        |       |                                                                                                                       |
|-------------------------------------------------------------------------------|----|--------|-------|-----------------------------------------------------------------------------------------------------------------------|
|                                                                               |    |        |       |                                                                                                                       |
| <b>CMD_READ_PARAMS_EXT2, CMD_WRITE_PARAMS_EXT2 - Extended parameters set2</b> |    |        |       |                                                                                                                       |
| MOTOR_MAG_LINK_FIN<br>E                                                       | 2u | 0      | 65535 | Units: 0.01                                                                                                           |
| ACC_LIMITER[3]                                                                | 1u | 0      | 200   | Units: 5 degrees/sec <sup>2</sup>                                                                                     |
| PID_GAIN[3]                                                                   | 1u | 0      | 255   | pid_gain_float[axis] = 0.1 + PID_GAIN[axis]*0.02                                                                      |
| FRAME_IMU_LPF_FREQ                                                            | 1u | 0      | 255   | Units: Hz                                                                                                             |
| AUTO_PID_CFG                                                                  | 1u |        |       | See 'CFG_FLAGS' in the CMD_AUTO_PID                                                                                   |
| AUTO_PID_GAIN                                                                 | 1u | 0      | 255   | See 'GAIN_VS_STABILITY' in the CMD_AUTO_PID                                                                           |
|                                                                               |    |        |       |                                                                                                                       |
|                                                                               |    |        |       |                                                                                                                       |
| <b>CMD_REALTIME_DATA_3 - Real-time data</b>                                   |    |        |       |                                                                                                                       |
| ACC_DATA<br>GYRO_DATA                                                         | 2s |        |       | raw data from sensors.<br><i>ACC units: 1/512 G</i><br><i>Gyro units: 0,06103701895 degree/sec.</i>                   |
| DEBUG                                                                         | 2s |        |       | debug variables                                                                                                       |
| RC_ROLL<br>RC_PITCH<br>RC_YAW                                                 | 2s | 1000   | 2000  | RC control channels values (PWM or normalized analog)                                                                 |
| RC_CMD                                                                        | 2s | 1000   | 2000  | RC command channel value (PWM or normalized analog)                                                                   |
| EXT_FC_ROLL<br>EXT_FC_PITCH                                                   | 2s | 1000   | 2000  | External FC PWM values. May be zero if their inputs are mapped to RC control or command.                              |
| ANGLE_ROLL<br>ANGLE_PITCH<br>ANGLE_YAW                                        | 2s | -32768 | 32767 | Camera angles in 14-bit resolution per full turn<br><br><i>Units: 0,02197265625 degree</i>                            |
| RC_ANGLE_ROLL<br>RC_ANGLE_PITCH<br>RC_ANGLE_YAW                               | 2s | -32768 | 32767 | RC angles, in 14-bit resolution<br><br><i>Units: 0,02197265625 degree</i>                                             |
| FRAME_ANGLE_ROLL<br>FRAME_ANGLE_PITCH<br>FRAME_ANGLE_YAW                      | 2s | -32768 | 32767 | Frame angles detected by the second IMU (if present), in 14-bit resolution.<br><br><i>Units: 0,02197265625 degree</i> |
| CYCLE_TIME                                                                    | 2u |        |       |                                                                                                                       |
| I2C_ERROR_COUNT                                                               | 2u |        |       | Number of registered errors on I2C bus                                                                                |
| SYSTEM_ERROR                                                                  | 2u |        |       | Set of bits ( 0 – no error):<br>ERR_NO_SENSOR (1<<0)<br>ERR_CALIB_ACC (1<<1)<br>ERR_SET_POWER (1<<2)                  |

|                                                                |    |      |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------------------------------------------------------------|----|------|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                |    |      |     | ERR_CALIB_POLES (1<<3)<br>ERR_PROTECTION (1<<4)<br>ERR_SERIAL (1<<5)<br><i>Beside that, extended error contains bits:</i><br>ERR_LOW_BAT1 (1<<6)<br>ERR_LOW_BAT2 (1<<7)<br>ERR_GUI_VERSION (1<<8)<br>ERR_MISS_STEPS (1<<9)<br>ERR_SYSTEM (1<<10)<br>ERR_EMERGENCY_STOP (1<<11)                                                                                                                                                                                  |
| SYSTEM_SUB_ERROR                                               | 1u |      |     | Specifies the reason of emergency stop<br><br>SUB_ERR_I2C_ERRORS = 1<br>SUB_ERR_DRV_OTW = 2<br>SUB_ERR_DRV_FAULT = 3<br>SUB_ERR_ENCODER_IMU_ANGLE = 4<br>SUB_ERR_CALIBRATION_FAILED = 5<br>SUB_ERR_INTERNAL_SYSTEM_ERROR = 6<br>SUB_ERR_ENCODER_CALIB_BAD_SCALE = 7<br>SUB_ERR_OVER_TEMPERATURE = 8<br>SUB_ERR_BAD_MOTOR_POLES_INVERT = 9<br>SUB_ERR_NOT_ENOUGH_MEMORY = 10<br>SUB_ERR_IMU_SENSOR_NOT_RESPONDING = 11<br>SUB_ERR_MOTOR_OVERHEAT_PROTECTION = 13 |
| BAT_LEVEL                                                      | 2u |      |     | Battery voltage<br><i>Units: 0.01 volt</i>                                                                                                                                                                                                                                                                                                                                                                                                                      |
| OTHER_FLAGS                                                    | 1u |      |     | bit0 set - motors turned ON<br>bit1..7 - reserved                                                                                                                                                                                                                                                                                                                                                                                                               |
| CUR_PROFILE                                                    | 1u | 0    |     | Active profile, 0..4                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| CUR_IMU                                                        | 1u |      |     | Currently selected IMU<br>IMU_TYPE_MAIN=1<br>IMU_TYPE_FRAME=2<br><br><i>(BOARD_VER&gt;=30 only)</i>                                                                                                                                                                                                                                                                                                                                                             |
| <b>CMD_REALTIME_DATA_4</b>                                     |    |      |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| STATOR_ROTOR_ANGLE                                             | 2s |      |     | Relative angle for joints between two arms of gimbal structure, measured by encoder (with offset and gearing calibration is applied), by 2 <sup>nd</sup> IMU or by other algorithms. Value 0 corresponds to normal position (each arms forms 90 degrees with the next order arm).<br><i>Units: 0,02197265625 degree</i>                                                                                                                                         |
| BALANCE_ERROR_ROLL<br>BALANCE_ERROR_PITCH<br>BALANCE_ERROR_YAW | 2s | -512 | 512 | Error in balance (0 – perfect balance, 512 - 100% motor power is required to hold camera)                                                                                                                                                                                                                                                                                                                                                                       |
| CURRENT                                                        | 2u |      |     | Actual current consumption.<br><i>Units: mA</i>                                                                                                                                                                                                                                                                                                                                                                                                                 |
| MAG_DATA_ROLL<br>MAG_DATA_PITCH                                | 2s |      |     | Raw data from magnetometer                                                                                                                                                                                                                                                                                                                                                                                                                                      |

|                                                                                                      |    |      |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------|----|------|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MAG_DATA_YAW                                                                                         |    |      |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| IMU_TEMPERATURE<br>FRAME_IMU_TEMPERATURE                                                             | 1s | -127 | 127 | Temperature of IMU boards.<br><i>Units: Celsius</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| FRAME_CAM_ANGLE_ROLL<br>FRAME_CAM_ANGLE_PITCH<br>FRAME_CAM_ANGLE_YAW                                 | 2s |      |     | Deprecated starting from version 2.55, see STATOR_ROTOR_ANGLE instead                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| IMU_G_ERR                                                                                            | 1u | 0    | 255 | Error between estimated gravity vector and reference vector for currently active IMU<br><i>Units: 0.1 degree</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| IMU_H_ERR                                                                                            | 1u | 0    | 255 | Error between estimated heading vector and reference vector for currently active IMU<br><i>Units: 0.1 degree</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>CMD_CONTROL - Control</b>                                                                         |    |      |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| CONTROL_MODE*<br><br>extended format:<br>CONTROL_MODE_ROLL<br>CONTROL_MODE_PITCH<br>CONTROL_MODE_YAW | 1u |      |     | <p>Bits 0..3 for mode, bits 4..7 for flags.</p> <p>MODE_NO_CONTROL=0<br/>MODE_SPEED=1<br/>MODE_ANGLE=2<br/>MODE_SPEED_ANGLE=3<br/>MODE_RC=4<br/>MODE_ANGLE_REL_FRAME=5</p> <ul style="list-style-type: none"> <li>MODE_SPEED – camera travels with the given speed in the Euler coordinates until the next CMD_CONTROL command comes. Given angle is ignored.</li> <li>MODE_ANGLE – camera travels to the given point in the Euler coordinates with the given speed. If speed=0, default speed is used (set in the GUI).</li> <li>MODE_SPEED_ANGLE – camera travels with the given speed while the actual angle matches the given angle. Additionally, PID controller keeps the given angle. This mode allows the most precise and error-proof control. See fig.1 for example.</li> <li>MODE_RC - angle parameter overrides RC signal input data. Should be in range -500...500. Speed parameter is ignored.</li> <li>MODE_ANGLE_REL_FRAME – first, neutral point of a camera relative to a frame is found in the Euler coordinates. Then, given angle value is add to this point, and camera travels to it with the given speed. If speed=0, default speed is used (set in the GUI). For example, if the ANGLE parameter = 0 and camera made 2 full turns by YAW, it will make 2 turns back and returns to neutral point. This mode may be helpful in untwisting cables, for example.</li> </ul> <p>CONTROL_FLAG_HIGH_RES_SPEED=(1&lt;&lt;7)</p> <ul style="list-style-type: none"> <li>CONTROL_FLAG_HIGH_RES_SPEED – speed units changed to 0.001 deg/sec for extremely slow motion (timelapse shooting) (<i>frw.ver 2.59+</i>)</li> </ul> |

|                                                                                                                                                                                                                                                                                                           |    |             |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|-------------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SPEED_ROLL<br>SPEED_PITCH<br>SPEED_YAW                                                                                                                                                                                                                                                                    | 2s | -<br>-<br>- | -<br>-<br>- | Speed of rotation. If acceleration limiter is enabled in the settings, given speed may be limited.<br><br><i>Units: 0,1220740379 degree/sec<br/>or 0.001 degree/sec, if<br/>CONTROL_FLAG_HIGH_RES_SPEED is set</i>                                                                                                                                                                                                                                                                                                                                                                          |
| ANGLE_ROLL<br>ANGLE_PITCH<br>ANGLE_YAW                                                                                                                                                                                                                                                                    | 2s | -32768      | 32767       | Target angle. Ignored in the MODE_SPEED mode. If mode=MODE_RC, it specifies RC data in range -500..500<br><br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Notes:                                                                                                                                                                                                                                                                                                    |    |             |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <ul style="list-style-type: none"> <li>Serial control overrides RC control. To switch back to RC, send this command with the mode=MODE_NO_CONTROL and all data set to zeros.</li> <li>Send this command with rate 50Hz or less</li> <li>See <a href="#">Appendix A</a> for source code example</li> </ul> |    |             |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>CMD_TRIGGER_PIN - Trigger pin</b>                                                                                                                                                                                                                                                                      |    |             |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| PIN_ID                                                                                                                                                                                                                                                                                                    | 1u |             |             | Triggers pin only if it is not used for input<br><br>RC_INPUT_ROLL = 1<br>RC_INPUT_PITCH = 2<br>EXT_FC_INPUT_ROLL = 3<br>EXT_FC_INPUT_PITCH = 4<br>RC_INPUT_YAW = 5 (BOARD_VER >= 30)<br>PIN_AUX1* = 16<br>PIN_AUX2* = 17<br>PIN_AUX3* = 18<br>PIN_BUZZER* = 32<br>PIN_SSAT_POWER** = 33<br><br>* On boards v1.x (based on Atmega328p) PIN_AUX1..3 are not present as outputs, and should be soldered to pin2, pin11, pin12 of MCU correspondingly. PIN_BUZZER is mapped to pin32 of MCU.<br>** PIN_SSAT_POWER triggers 3.3V power line in the Spektrum connector (low state enables power) |
| STATE                                                                                                                                                                                                                                                                                                     | 1u |             |             | LOW = 0<br>HIGH = 1<br><br>LOW - pin can sink up to 40mA<br>HIGH - pin can source up to 40mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>CMD_GET_ANGLES – information about angles in system</b>                                                                                                                                                                                                                                                |    |             |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| IMU_ANGLE                                                                                                                                                                                                                                                                                                 | 2s | -32768      | 32767       | Actual angle measured by IMU. After 2 full turns, angle is cycled<br><br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| RC_TARGET_ANGLE                                                                                                                                                                                                                                                                                           | 2s | -32768      | 32767       | Target angle that gimbal should keep. Angle is set by RC or control command 'C'.<br><br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| RC_SPEED                                                                                                                                                                                                                                                                                                  | 2s | -<br>-<br>- | -<br>-<br>- | Target speed that gimbal should keep. Speed is set by RC or control command 'C'. Zero speed means control is idle (target is reached)                                                                                                                                                                                                                                                                                                                                                                                                                                                       |



|                                                                                  |    |        |       |                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------------------------------------------------|----|--------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                  |    |        |       | <i>Units: 0,1220740379 degree/sec</i>                                                                                                                                                                                                                                                                                       |
| <b>CMD_GET_ANGLES_EXT – information about angles in system, different format</b> |    |        |       |                                                                                                                                                                                                                                                                                                                             |
| IMU_ANGLE                                                                        | 2s | -32768 | 32767 | Actual angle measured by IMU. After 2 full turns, angle is cycled<br><br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                |
| RC_TARGET_ANGLE                                                                  | 2s | -32768 | 32767 | Target angle that gimbal should keep.<br><br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                                            |
| STATOR_ROTOR_ANGLE                                                               | 4s |        |       | Relative angle for joints between two arms of gimbal structure, measured by encoder or 2 <sup>nd</sup> IMU. Value 0 corresponds to normal position of a gimbal. This angle does not overflow after multiple turns.<br><br><i>Units: 0,02197265625 degree</i>                                                                |
| <b>CMD_EXECUTE_MENU - Execute menu command</b>                                   |    |        |       |                                                                                                                                                                                                                                                                                                                             |
| CMD_ID                                                                           | 1u |        |       | Executes a menu command (acts like the menu button or RC control channel)<br>See the RC_CMD_LOW parameter inside the CMD_READ_PARAMS_3 command for available menu commands.                                                                                                                                                 |
| <b>CMD_SELECT_IMU_3 - Select IMU to configure</b>                                |    |        |       |                                                                                                                                                                                                                                                                                                                             |
| IMU_TYPE                                                                         | 1u |        |       | IMU_TYPE_MAIN=1<br>IMU_TYPE_FRAME=2<br>If selected IMU is not connected, command is ignored.                                                                                                                                                                                                                                |
| <b>CMD_SET_ADJ_VARS_VAL – Set the values of multiple adjustable parameters</b>   |    |        |       |                                                                                                                                                                                                                                                                                                                             |
| NUM_PARAMS                                                                       | 1u | 1      | 40    | Number of parameters in command                                                                                                                                                                                                                                                                                             |
| PARAM<N>_ID                                                                      | 1u |        |       | ID of parameter. Full list is in Appendix B.                                                                                                                                                                                                                                                                                |
| PARAM<N>_VALUE<br>...                                                            | 4b |        |       | Value depends on type of parameter. Types and min, max range should be requested from board by CMD_GET_PARAMS_3 command.<br><br>Values are packed according to C-language memory model, little-endian order. 1- or 2-byte types converted to 4-byte using C-language type conversions. Floats packed according to IEEE-754. |
| <b>CMD_GET_ADJ_VARS_VAL – Query the values of multiple adjustable parameters</b> |    |        |       |                                                                                                                                                                                                                                                                                                                             |
| NUM_PARAMS                                                                       | 1u | 1      | 40    | Number of parameters in command                                                                                                                                                                                                                                                                                             |
| PARAM<N>_ID                                                                      | 1u |        |       | ID of parameter. Full list is in Appendix B.                                                                                                                                                                                                                                                                                |
| <b>CMD_AUTO_PID - Start automatic PID calibration</b>                            |    |        |       |                                                                                                                                                                                                                                                                                                                             |
| PROFILE_ID                                                                       | 1u |        |       |                                                                                                                                                                                                                                                                                                                             |
| CFG_FLAGS                                                                        | 1u |        |       | Set of bits:<br>AUTO_PID_STOP = 0<br>AUTO_PID_CFG_ROLL = 1                                                                                                                                                                                                                                                                  |

|                                                                                                                                                                                                         |        |      |       |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                         |        |      |       | AUTO_PID_CFG_PITCH = 2<br>AUTO_PID_CFG_YAW = 4<br>AUTO_PID_CFG_SEND_GUI = 8<br>AUTO_PID_CFG_KEEP_CURRENT = 16<br>AUTO_PID_CFG_TUNE_LPF_FREQ = 32<br>AUTO_PID_CFG_ALL_PROFILES = 64                                                                                                                                                                                                                                               |
| GAIN_VS_STABILITY                                                                                                                                                                                       | 1u     | 0    | 255   |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>CMD_SERVO_OUT - Output PWM signal on the specified pin</b>                                                                                                                                           |        |      |       |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| SERVO1_TIME<br>SERVO2_TIME<br>SERVO3_TIME<br>SERVO4_TIME<br>SERVO5_TIME<br>SERVO6_TIME<br>SERVO7_TIME<br>SERVO8_TIME                                                                                    | 2s     | -1   | 20000 | value < 0: free up this pin and make it floating<br>value = 0: configure this pin as output and set it to 'Low' state<br>value > 0: PWM pulse time, us. Should be less than PWM period, configured by the "SERVO_RATE" parameter. Regular servo accept values in range about 500..2500 us, 1500 us is neutral position, PWM period is 20000 us or less.                                                                          |
| <b>CMD_DEBUG_VARS_INFO_3 – definition of debug variables passed in CMD_DEBUG_VARS_3</b>                                                                                                                 |        |      |       |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| DEBUG_VARS_NUM                                                                                                                                                                                          | 1u     | 1    | 255   |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| VAR_NAME                                                                                                                                                                                                | string |      |       | 1 <sup>st</sup> byte is size, following by ASCII characters                                                                                                                                                                                                                                                                                                                                                                      |
| VAR_TYPE                                                                                                                                                                                                | 1u     |      |       | <i>Type (0..3 bits):</i><br>VAR_TYPE_UINT8 = 1<br>VAR_TYPE_INT8 = 2<br>VAR_TYPE_UINT16 = 3<br>VAR_TYPE_INT16 = 4<br>VAR_TYPE_UINT32 = 5<br>VAR_TYPE_INT32 = 6<br>VAR_TYPE_FLOAT = 7 (IEEE-754)<br><br><i>Flags (4..7 bits):</i><br>VAR_FLAG_ROLL = 16 its belong to ROLL axis<br>VAR_FLAG_PITCH = 32 its belong to PITCH axis<br>VAR_FLAG_YAW = 48 its belong to YAW axis<br>VAR_FLAG_ANGLE14 = 64 its an angle (14bit per turn) |
| ARR_SIZE                                                                                                                                                                                                | 2u     |      |       |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>CMD_API_VIRT_CH_CONTROL – update a state of all virtual channels that named "API_VIRT_CHXX" in the GUI</b>                                                                                           |        |      |       |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| VAL_CH1<br>..<br>VAL_CH32                                                                                                                                                                               | 2s     | -500 | 500   | Value may go outside these limits and will be clipped. Use a special value "-10000" to mark that channel has "undefined" state (its treated as "signal lost" like with RC inputs)                                                                                                                                                                                                                                                |
| <b>CMD_AHRS_HELPER – get or set attitude of main or frame IMU (use to set or correct attitude from external high-grade IMU and to receive attitude in rotation matrix form instead of Euler angles)</b> |        |      |       |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| MODE                                                                                                                                                                                                    | 1u     |      |       | bit0: 0 – get, 1 – set<br>bit1: 0 – main IMU, 1 – frame IMU<br>bit2: if set, use as reference only<br>bit3: if set, translate from camera to frame (or back) and use as a reference<br>bit4: if set, use Z1 only<br>bit5: if set, use H1 only                                                                                                                                                                                    |

|                                                                                      |      |       |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------|------|-------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                      |      |       |      | <p>Below some useful combinations of flags are described in details.</p> <p><i>GET modes (provided data and other flags are ignored):</i></p> <p>0 - request the main IMU attitude<br/>2 - request the frame IMU attitude</p> <p><i>SET modes:</i></p> <p>1 - use as a camera attitude (replace the attitude estimated by the main IMU)<br/>3 - use as a frame attitude (regardless of 2<sup>nd</sup> IMU is enabled or not)<br/>5 - use as a reference for the main IMU (to correct gyro drift using GYRO_TRUST factor)<br/>7 - use as a reference for the frame IMU<br/>11 - use as a frame attitude, translate to the camera coordinates and use as a reference for the main IMU.<br/>15 – use as a reference for the frame IMU, translate to the camera coordinates and use as a reference for the main IMU.</p> <p><i>Modes 1,5 should be used if an external AHRS source is installed on the camera's platform. Modes 3,7,11,15 should be used if an external AHRS source is installed on the frame (above all motors).</i></p> <p><i>Bit3 is taken into account only if all motor angles are known from encoders or may be estimated using other ways.</i></p> <p><i>Bits 4..5 can be combined with the previous values to selectively correct/replace only H1 or Z1 attitude vectors. For example, you can leave Z1 corrected by the internal accelerometer, and correct only H1 (heading) by an external magnetometer.</i></p> |
| Z1_VECT[3]                                                                           | 4f*3 | -1.0f | 1.0f | Unit vector that points Up (Z-axis in normal position)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| H1_VECT[3]                                                                           | 4f*3 | -1.0f | 1.0f | Unit vector that points towards North (Y-axis in normal position)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>CMD_GYRO_CORRECTION – correct gyro sensor manually</b>                            |      |       |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| IMU_TYPE                                                                             | 1u   |       |      | 0 – main IMU, 1 – frame IMU                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| GYRO_ZERO_CORR[X]<br>GYRO_ZERO_CORR[X]<br>GYRO_ZERO_CORR[X]                          | 2s   |       |      | Zero offset for each axis<br><i>Units: 0.001 gyro sensor unit</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| GYRO_ZERO_HEADING_CORR                                                               | 2s   |       |      | Zero offset for global Z axis to correct a heading only. This correction is distributed to all axes automatically.<br><i>Units: 0.001 gyro sensor unit</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>CMD_DATA_STREAM_INTERVAL - register or update <i>data stream (ver. 2.59+)</i></b> |      |       |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| CMD_ID                                                                               | 1u   |       |      | Command ID to be sent by this data stream. All possible commands are listed below.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| INTERVAL_MS                                                                          | 2u   |       |      | Interval between messages, in milliseconds.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

|                                                                                        |       |       |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------|-------|-------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                        |       |       |      | Value 1 means each cycle (0.8ms)<br>If set to 0 – unregister data stream                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| CONFIG                                                                                 | 8b    |       |      | Configuration specific to each command:<br><br><b>CMD_REALTIME_DATA_3</b> – no parameters<br><br><b>CMD_REALTIME_DATA_4</b> – no parameters<br><br><b>CMD_REALTIME_DATA_CUSTOM</b> <ul style="list-style-type: none"> <li>flags – 4u, see command specification</li> </ul> <b>CMD_AHRS_HELPER</b> <ul style="list-style-type: none"> <li>imu_type – 1u (0 – main IMU, 1 – frame IMU)</li> </ul>                                                                                                                                                        |
| <b>CMD_REALTIME_DATA_CUSTOM – request for configurable realtime data (ver. 2.59+)</b>  |       |       |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| FLAGS                                                                                  | 4u    |       |      | Bit set, each bit specify which data to include in response <ul style="list-style-type: none"> <li>bit0: IMU angles</li> <li>bit1: RC target angles</li> <li>bit2: RC target speed</li> <li>bit3: Stator-rotor angle</li> <li>bit4: IMU sensor gyro data</li> <li>bit5: RC signal assigned to standard inputs</li> <li>bit6: IMU attitude as rotation matrix</li> <li>bit7: All RC channels captured from s-bus, Sum-PPM or spektrum input.</li> <li>bit8: IMU sensor ACC data</li> </ul> <p><i>See specification of response for more details</i></p> |
| <b>CMD_REALTIME_DATA_CUSTOM – response for configurable realtime data (ver. 2.59+)</b> |       |       |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| TIMESTAMP_MS                                                                           | 2u    |       |      | Timestamp in milliseconds                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| IMU_ANGLES[3]                                                                          | 2s*3  |       |      | Main IMU angles (Euler)<br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| TARGET_ANGLES[3]                                                                       | 2s*3  |       |      | Target angles that gimbal should keep (Euler)<br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| TARGET_SPEED[3]                                                                        | 2s*3  |       |      | Target speed that gimbal should keep, over Euler axes<br><i>Units: 0,06103701895 degree/sec</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| STATOR_ROTOR_ANGLE[3]                                                                  | 2s*3  |       |      | Relative angle of joints (motors)<br><i>Units: 0,02197265625 degree.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| GYRO_DATA[3]                                                                           | 2s*3  |       |      | Gyro sensor data after calibrations are applied                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| RC_DATA[6]                                                                             | 2s*6  |       |      | RC data in high resolution, assigned to the ROLL, PITCH, YAW, CMD, FC_ROLL, FC_PITCH inputs.<br><i>Units: normal range is -16384..16384, -32768 is for 'undefined' signal</i>                                                                                                                                                                                                                                                                                                                                                                          |
| Z1_VECTOR[3]<br>H1_VECTOR[3]                                                           | 4f*6  | -1.0f | 1.0f | IMU attitude in a form of rotation matrix (2 rows as gravity and heading vectors, 3 <sup>rd</sup> row can be calculated as cross-product of them).                                                                                                                                                                                                                                                                                                                                                                                                     |
| RC_CHANNELS[18]                                                                        | 2s*18 |       |      | All RC channels captured from s-bus, spektrum or Sum-PPM inputs.<br><i>Mapped to -16384..16384, -32768 is for 'undefined' signal</i>                                                                                                                                                                                                                                                                                                                                                                                                                   |
| ACC_DATA[3]                                                                            | 2s*3  |       |      | Accelerometer sensor data with calibrations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

| <b>CMD_BEEP_SOUND – play melody by motors or emit standard beep sound (ver.2.59+)</b>                                                                                                                                                                                                                                                                                                       |    |      |       |                                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MODE                                                                                                                                                                                                                                                                                                                                                                                        | 2u |      |       | BEEPER_MODE_CALIBRATE = (1<<0)<br>BEEPER_MODE_CONFIRM = (1<<1)<br>BEEPER_MODE_ERROR = (1<<2)<br>BEEPER_MODE_CLICK = (1<<4)<br>BEEPER_MODE_COMPLETE = (1<<5)<br>BEEPER_MODE_INTRO = (1<<6)<br>BEEPER_MODE_CUSTOM_MELODY = (1<<15)                                                        |
| NOTE_LENGTH                                                                                                                                                                                                                                                                                                                                                                                 | 1u | 1    | 255   | The length of each note in the custom melody mode.<br><i>Units: 8ms</i>                                                                                                                                                                                                                 |
| DECAY_FACTOR                                                                                                                                                                                                                                                                                                                                                                                | 1u | 0    | 15    | Set the envelope "attack-decay" after each pause, that makes sound more natural. The bigger value, the longer decay. 0 - no decay.<br>*Note: envelope takes effect only in the encoder-enabled firmware or when motors are OFF. The same is true for the 'volume' parameter in the GUI. |
| NOTE_FREQ_HZ[0..30]                                                                                                                                                                                                                                                                                                                                                                         | 2u | 554  | 21000 | Array of 2u elements, size 0..30, - melody to play if mode=BEEPER_MODE_CUSTOM_MELODY. Special value 21000 used to make pause and restart envelope.<br><i>Units: Hz</i>                                                                                                                  |
| <p>Example1: simple melody with short B5, D6, G6 notes and envelope:<br/>00 80 05 03 00 00 00 00 00 00 00 00 00 DB 03 DB 03 08 52 DB 03 DB 03 08 52 96 04 96 04 08 52 1F 06 1F 06 1F 06 1F 06 1F 06</p> <p>Example2: standard "calibration" sound:<br/>01 00 00 03 00 00 00 00 00 00 00 00</p> <p>Example3: single beep 1 second at 3kHz:<br/>00 80 7D 00 00 00 00 00 00 00 00 00 B8 0B</p> |    |      |       |                                                                                                                                                                                                                                                                                         |
| <b>CMD_ADJ_VARS_STATE – the state of the adjustable variable in the slots, requested by the corresponding outgoing command.</b>                                                                                                                                                                                                                                                             |    |      |       |                                                                                                                                                                                                                                                                                         |
| TRIGGER_RC_DATA                                                                                                                                                                                                                                                                                                                                                                             | 2s | -500 | 500   | RC signal for the "trigger" variable slot                                                                                                                                                                                                                                               |
| TRIGGER_ACTION                                                                                                                                                                                                                                                                                                                                                                              | 1u | 0    | 255   | ID of the triggered action. The full set of actions is given in the specification of MENU_CMD_1..5 parameters                                                                                                                                                                           |
| ANALOG_RC_DATA                                                                                                                                                                                                                                                                                                                                                                              | 2s | -500 | 500   | RC signal for the "analog" variable slot                                                                                                                                                                                                                                                |
| ANALOG_VALUE                                                                                                                                                                                                                                                                                                                                                                                | 4s |      |       | Current value of the variable after all calculations                                                                                                                                                                                                                                    |
| <b>CMD_CALIB_INFO – information required for the "Calibration helper" dialog window</b>                                                                                                                                                                                                                                                                                                     |    |      |       |                                                                                                                                                                                                                                                                                         |
| PROGRESS                                                                                                                                                                                                                                                                                                                                                                                    | 1u | 0    | 100   | Progress of operation in percents                                                                                                                                                                                                                                                       |
| IMU_TYPE                                                                                                                                                                                                                                                                                                                                                                                    | 1u |      |       | 1 – main IMU, 2 – frame IMU                                                                                                                                                                                                                                                             |
| ACC_DATA[3]                                                                                                                                                                                                                                                                                                                                                                                 | 2s |      |       | See ACC_DATA in CMD_REALTIME_DATA_3                                                                                                                                                                                                                                                     |
| GYRO_ABS_VAL                                                                                                                                                                                                                                                                                                                                                                                | 2u |      |       | Amplitude of gyro signal                                                                                                                                                                                                                                                                |
| ACC_CUR_AXIS                                                                                                                                                                                                                                                                                                                                                                                | 1u | 0    | 2     | ACC axis to be calibrated                                                                                                                                                                                                                                                               |
| ACC_LIMITS_INFO                                                                                                                                                                                                                                                                                                                                                                             | 1u |      |       | Bit set of calibrated limits, where bits 0...5 corresponds to the index in array [+X,-X,+Y,-Y,+Z,-Z]                                                                                                                                                                                    |
| IMU_TEMP_CELS                                                                                                                                                                                                                                                                                                                                                                               | 1s | -127 | 127   | IMU temperature, Celsius                                                                                                                                                                                                                                                                |
| TEMP_CALIB_GYRO_EN                                                                                                                                                                                                                                                                                                                                                                          | 1u | 0    | 1     | Set to 1 if temperature calibration is enabled                                                                                                                                                                                                                                          |

|                                     |  |  |  |  |
|-------------------------------------|--|--|--|--|
| ABLED<br>TEMP_CALIB_ACC_ENA<br>BLED |  |  |  |  |
|-------------------------------------|--|--|--|--|

|                                                                                                                    |          |        |       |                                                                                                                                                                                                                                                             |
|--------------------------------------------------------------------------------------------------------------------|----------|--------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TEMP_CALIB_GYRO_T_MIN_CELS<br>TEMP_CALIB_GYRO_T_MAX_CELS<br>TEMP_CALIB_ACC_T_MIN_CELS<br>TEMP_CALIB_ACC_T_MAX_CELS | 1s       | -127   | 127   | Range of temperature calibration, Celsius                                                                                                                                                                                                                   |
| TEMP_CALIB_ACC_SLO_T_NUM[6]                                                                                        | 1u*<br>6 | 0      | 3     | The number of calibrated temperature slots for accelerometer for each limit, in order [+X,+Y,+Z,-X,-Y,-Z]                                                                                                                                                   |
| H1_ERR_LENGTH                                                                                                      | 1u       | 0      | 255   | The length of error vector between estimated and referenced heading vectors.<br><i>Unit vector=100</i>                                                                                                                                                      |
| <b>CMD_HELPER_DATA - Pass helper data from an outer system</b><br>Used to increase precision of the stabilization  |          |        |       |                                                                                                                                                                                                                                                             |
| FRAME_ACC[3]                                                                                                       | 2s       | -      | -     | Linear acceleration of the frame, [X,Y,Z] components in a given coordinate system (see below). Helps to keep horizon during accelerated motion.<br><br><i>Units: 1g/512 ≈ 0,019160156 m/s<sup>2</sup></i>                                                   |
| FRAME_ANGLE_ROLL<br>FRAME_ANGLE_PITCH                                                                              | 2s       | -32768 | 32767 | Inclination of the outer frame in a given coordinate system. Pass zero values to not use this information.<br><br><i>Units: 0,02197265625 degree.</i>                                                                                                       |
| COORD_SYS                                                                                                          | 1u       |        |       | <b>COORD_SYS_GROUND_YAW_ROTATED=1</b> (default)<br>Ground system rotated with the camera over Z axis. Z points Up, X points right, Y points forward.                                                                                                        |
| FRAME_SPEED[3]                                                                                                     | 2s       | -      | -     | Angular speed of the frame, [X,Y,Z] components in a given coordinate system. Helps to increase a precision of stabilization in systems w/out encoders or 2 <sup>nd</sup> IMU. Pass zero values to not use it.<br><br><i>Units: 0,06103701895 degree/sec</i> |
|                                                                                                                    |          |        |       |                                                                                                                                                                                                                                                             |
|                                                                                                                    |          |        |       |                                                                                                                                                                                                                                                             |

\* The difference between control modes is illustrated on the picture below:

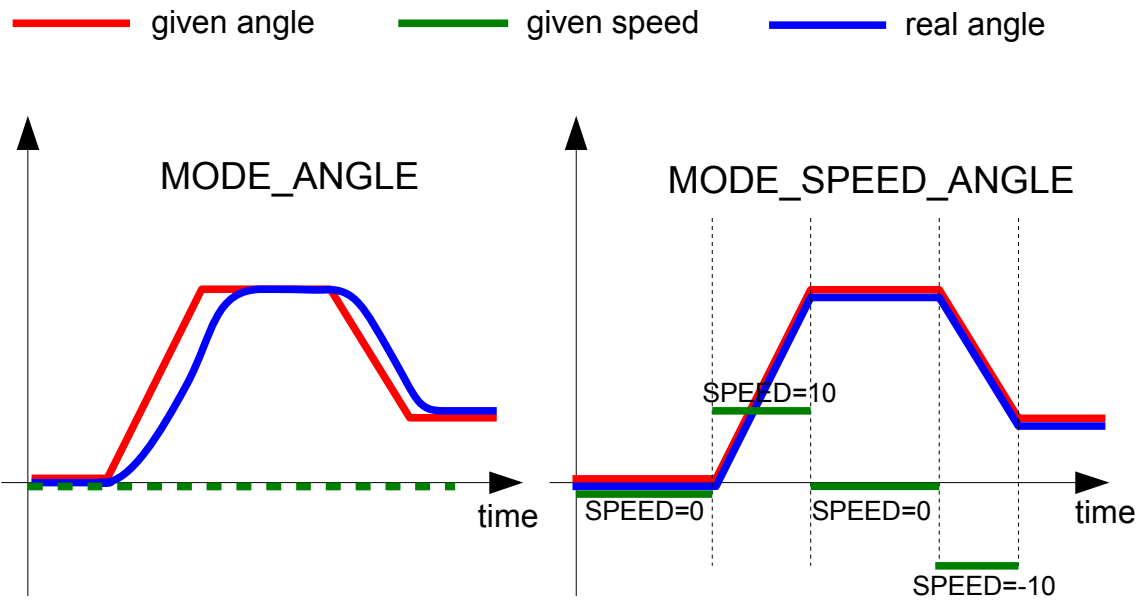


Fig.1 – Control modes



## **Appendix A: Examples and libraries**

Examples can be downloaded from the link:

<https://github.com/alexmos/sbgc-api-examples>

See README for details.

Currently, examples provided for Arduino platform only.

### **Libraries**

C++ library included as a part of examples folder.

# Appendix B: Definition of dynamically configurable parameters

Used in CMD\_SET\_ADJ\_VARS, CMD\_GET\_PARAMS\_3, CMD\_READ\_ADJ\_VARS\_CFG, CMD\_WRITE\_ADJ\_VARS\_CFG

**WARNING: this is not final and complete specification. Use CMD\_GET\_PARAMS\_3 to receive actual list of parameters supported by current firmware.**

| NAME               | ID | TYPE | MIN  | MAX  | REMARK                                       |
|--------------------|----|------|------|------|----------------------------------------------|
| P_ROLL             | 0  | 1u   | 0    | 255  |                                              |
| P_PITCH            | 1  | 1u   | 0    | 255  |                                              |
| P_YAW              | 2  | 1u   | 0    | 255  |                                              |
| I_ROLL             | 3  | 1u   | 0    | 255  |                                              |
| I_PITCH            | 4  | 1u   | 0    | 255  |                                              |
| I_YAW              | 5  | 1u   | 0    | 255  |                                              |
| D_ROLL             | 6  | 1u   | 0    | 255  |                                              |
| D_PITCH            | 7  | 1u   | 0    | 255  |                                              |
| D_YAW              | 8  | 1u   | 0    | 255  |                                              |
| POWER_ROLL         | 9  | 1u   | 0    | 255  |                                              |
| POWER_PITCH        | 10 | 1u   | 0    | 255  |                                              |
| POWER_YAW          | 11 | 1u   | 0    | 255  |                                              |
| ACC_LIMITER        | 12 | 2s   | 0    | 1275 | Units: degrees/sec <sup>2</sup>              |
| FOLLOW_SPEED_ROLL  | 13 | 1u   | 0    | 255  |                                              |
| FOLLOW_SPEED_PITCH | 14 | 1u   | 0    | 255  |                                              |
| FOLLOW_SPEED_YAW   | 15 | 1u   | 0    | 255  |                                              |
| FOLLOW_LPF_ROLL    | 16 | 1u   | 0    | 16   |                                              |
| FOLLOW_LPF_PITCH   | 17 | 1u   | 0    | 16   |                                              |
| FOLLOW_LPF_YAW     | 18 | 1u   | 0    | 16   |                                              |
| RC_SPEED_ROLL      | 19 | 1u   | 0    | 255  |                                              |
| RC_SPEED_PITCH     | 20 | 1u   | 0    | 255  |                                              |
| RC_SPEED_YAW       | 21 | 1u   | 0    | 255  |                                              |
| RC_LPF_ROLL        | 22 | 1u   | 0    | 16   |                                              |
| RC_LPF_PITCH       | 23 | 1u   | 0    | 16   |                                              |
| RC_LPF_YAW         | 24 | 1u   | 0    | 16   |                                              |
| RC_TRIM_ROLL       | 25 | 1s   | -127 | 127  |                                              |
| RC_TRIM_PITCH      | 26 | 1s   | -127 | 127  |                                              |
| RC_TRIM_YAW        | 27 | 1s   | -127 | 127  |                                              |
| RC_DEADBAND        | 28 | 1u   | 0    | 255  |                                              |
| RC_EXPO_RATE       | 29 | 1u   | 0    | 100  |                                              |
| FOLLOW_MODE        | 30 | 1u   | 0    | 2    | 0 – disabled<br>1 – Follow flight controller |

|                         |    |    |        |       |                                                    |
|-------------------------|----|----|--------|-------|----------------------------------------------------|
|                         |    |    |        |       | 2 – “Follow PITCH,ROLL” mode                       |
| RC_FOLLOW_YAW           | 31 | 1u | 0      | 1     | 0 – disabled<br>1 - “Follow YAW” mode              |
| FOLLOW_DEADBAND         | 32 | 1u | 0      | 255   |                                                    |
| FOLLOW_EXPO_RATE        | 33 | 1u | 0      | 100   |                                                    |
| FOLLOW_ROLL_MIX_START   | 34 | 1u | 0      | 90    |                                                    |
| FOLLOW_ROLL_MIX_RANGE   | 35 | 1u | 0      | 90    |                                                    |
| GYRO_TRUST              | 36 | 1u | 0      | 255   |                                                    |
| FRAME_HEADING_ANLGE     | 37 | 2s | -1800  | 1800  | Units: 0.1 degrees                                 |
| GYRO_HEADING_CORRECTION | 38 | 2s | -20000 | 20000 | Units: 0.001 of gyro sensor units                  |
| ACC_LIMITER_ROLL        | 39 | 2s | 0      | 1275  | Units: degrees/sec <sup>2</sup>                    |
| ACC_LIMITER_PITCH       | 40 | 2s | 0      | 1275  |                                                    |
| ACC_LIMITER_YAW         | 41 | 2s | 0      | 1275  |                                                    |
| PID_GAIN_ROLL           | 42 | 1u | 0      | 255   | Gain is calculated as<br>0.1 + PID_GAIN[axis]*0.02 |
| PID_GAIN_PITCH          | 43 | 1u | 0      | 255   |                                                    |
| PID_GAIN_YAW            | 44 | 1u | 0      | 255   |                                                    |
| LPF_FREQ_ROLL           | 45 | 2u | 10     | 400   | Units: Hz                                          |
| LPF_FREQ_PITCH          | 46 | 2u | 10     | 400   |                                                    |
| LPF_FREQ_YAW            | 47 | 2u | 10     | 400   |                                                    |