# TM-UAVCAN-V2.2

## 1 Scope and Version Definition

1：This document primarily describes the communication protocol between the Electronic Speed Controller (ESC) and external devices.

2：The CAN protocol complies with the UAVCAN/DRONECAN protocol specifications. For more details on the protocol and to access related examples, please visit https://github.com/dronecan/libcanard.

## 2 Terminology

**Table 2-1 Document Terminology**

| Terminology | Explanation and Description |
|---|---|
| ESC | Electric Speed Controller ESC |
| CAN | Controller Area Network a communication protocol |

## 3 Reference Documents

《CANBus Specifications v2.0》

## 4 Protocol Definition

### 4.1 TM-UAVCAN protocol

TM-UAVCAN protocol is based on the standard CANBus 2.0B protocol, utilizing 29-bit extended frame data frames.

| TM-UAVCAN Hardware Layer Configuration | |
|---|---|
| CAN_SJW | CAN_SJW_1tq |
| CAN_BS1 | CAN_BS1_4tq |
| CAN_BS2 | CAN_BS2_1tq |
| SamplePoint | 83.3% |
| BusCloclError | 0% |

#### 4.1.1 Concepts

1：Message Frame - It is a broadcast frame, and all nodes can receive this message.

2：Service Frame - It is a non-broadcast frame, with a specified node ID, where the node requesting the service expects a service response. Note: All transmission frames include both single-frame and multi-frame formats.

### 4.1.2 ID field

In the TM-UAVCAN protocol, we use only the data frame type from the five frame types defined in CANBus 2.0B. All data is transmitted via data frames. We define the arbitration segment ID code of the data frame in the following format:

**Message frame**

| Field name | Priority | | | | | Message type ID | | | | | | | | | | | Service not message | Source node ID | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAN ID bits | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Allowed values | | | | | | | | | | | | | | | | | | | | | | 0 | 1...127 | | | | | | |
| CAN ID bytes | 3 | | | | | 2 | | | | | | | | 1 | | | | | | | | 0 | | | | | | | |

**Anonymous message frame**

| Field name | Priority | | | | | Discriminator | | | | | | | | Lower bits of message type ID | | | | | | | | Service not message | Source node ID | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAN ID bits | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Allowed values | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | | | | | | |
| CAN ID bytes | 3 | | | | | 2 | | | | | | | | 1 | | | | | | | | 0 | | | | | | | |

**Service frame**

| Field name | Priority | | | | | Service type ID | | | | | | | | Request not response | Destination node ID | | | | | | | Service not message | Source node ID | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAN ID bits | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Allowed values | | | | | | | | | | | | | | | 1...127 | | | | | | | 1 | 1...127 | | | | | | |
| CAN ID bytes | 3 | | | | | 2 | | | | | | | | 1 | | | | | | | | 0 | | | | | | | |

For ESC's CAN bus communication application, only the Message frame and Service frame are currently used. Therefore, the following text will not cover the explanation of the Anonymous Message frame.

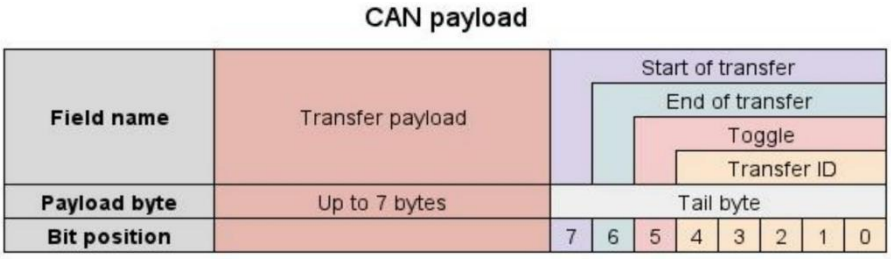
**Bit Definition and Terminology Explanation**

<table>
<tr><th>Bit Definition</th><th colspan="3">Explanation and Description</th></tr>
<tr><td rowspan="6">Priority</td><td rowspan="6">1:Priority indicates the priority of the CAN data frame.<br>2:The priority value range is 0 to 31.<br>3:The highest priority is 0, and the lowest priority is 31.<br>4：The TM-UAVCAN protocol defines priorities as shown in the table below:</td><td>Priority</td><td>Value</td></tr>
<tr><td>HIGHEST</td><td>0x00</td></tr>
<tr><td>HIGH</td><td>0x8</td></tr>
<tr><td>MEDIUM</td><td>0x10</td></tr>
<tr><td>LOW</td><td>0x18</td></tr>
<tr><td>LOWEST</td><td>0x1F</td></tr>
<tr><td>Message type ID</td><td colspan="3">The range of the Message Type ID is from 0 to 65535, inclusive of both 0 and 65535.</td></tr>
<tr><td>Service type ID</td><td colspan="3">The range of the Service Type ID is from 0 to 255, inclusive of both 0 and 255.</td></tr>
<tr><td rowspan="2">Service not message</td><td rowspan="2">Indicates the type of the data frame</td><td>0</td><td>Indicates that the data frame is a Message frame.</td></tr>
<tr><td>1</td><td>Indicates that the data frame is a Service frame.</td></tr>
<tr><td rowspan="2">Request not response</td><td rowspan="2">Indicates whether the data frame is a request frame or a response frame.</td><td>0</td><td>Indicates that the frame is a Response frame.</td></tr>
<tr><td>1</td><td>Indicates that the frame is a Request frame.</td></tr>
</table>

| | |
|---|---|
| Node ID | 1： The Node ID consists of 7 bits, where 0 is a reserved ID representing an unknown node.<br>2： The Node ID values range from 1 to 127, inclusive, with 126 and 127 being reserved IDs.<br>3： Node ID is divided into Source Node ID and Destination Node ID.<br>4： Source Node ID represents the ID of the node itself.<br>5： Destination Node ID represents the ID of the other node.<br>6： Only Service frames have a Destination Node ID, as they require a response. |

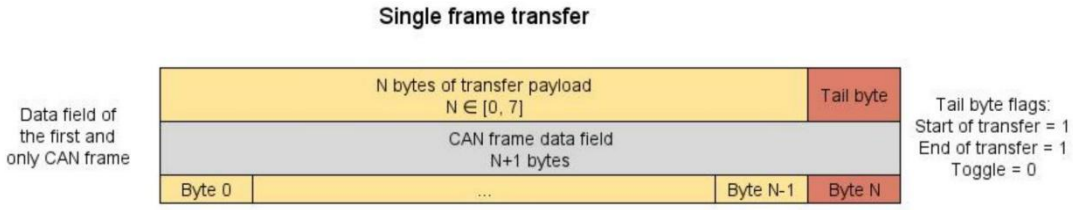
#### 4.1.3 CAN Payload

CANBus 2.0B specifies that each CAN bus frame can transmit up to 8 bytes of data. The TM-UAVCAN protocol divides the 8-byte payload into two parts: Transfer Payload and Tail byte, as shown in the diagram below:




Some data packets may have valid data that exceeds 7 bytes. The TM-UAVCAN protocol specifies that data frames of up to 7 bytes use the Single Frame Transfer format, while data frames exceeding 7 bytes use the Multi-Frame Transfer format. Below are the definitions of Single Frame Transfer and Multi-Frame Transfer.

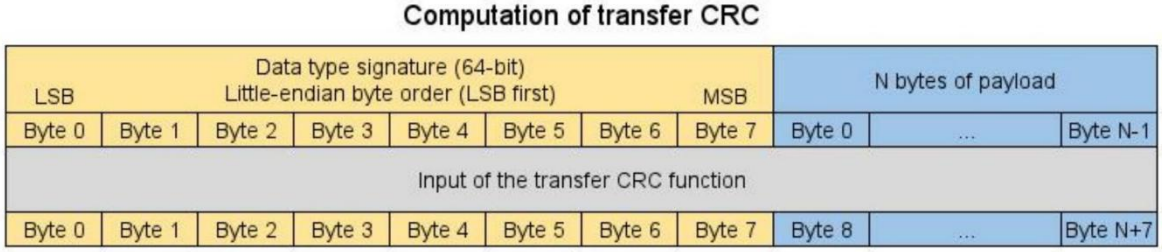
**Single frame Transfer：** Single Frame Transfer is used to handle data streams where the transmitted data does not exceed 7 bytes.




**Multi frame Transfer：** Multi-Frame Transfer is used to handle data streams where the transmitted data exceeds 7 bytes. This introduces two concepts:

1. CRC (Cyclic Redundancy Check)
2. Inversion Bit

As shown in the diagram below, CRC is calculated for all payload data and requires the addition of a data signature.




Note: The CRC calculation method with data signature is as shown in the diagram above. Add a

64-bit data signature value before the valid data (N bytes of payload), then use the CRC algorithm provided in the appendix to compute the checksum from Signature Byte 0 to Payload Byte N-1. When calculating this CRC value using the appendix algorithm, follow these steps:

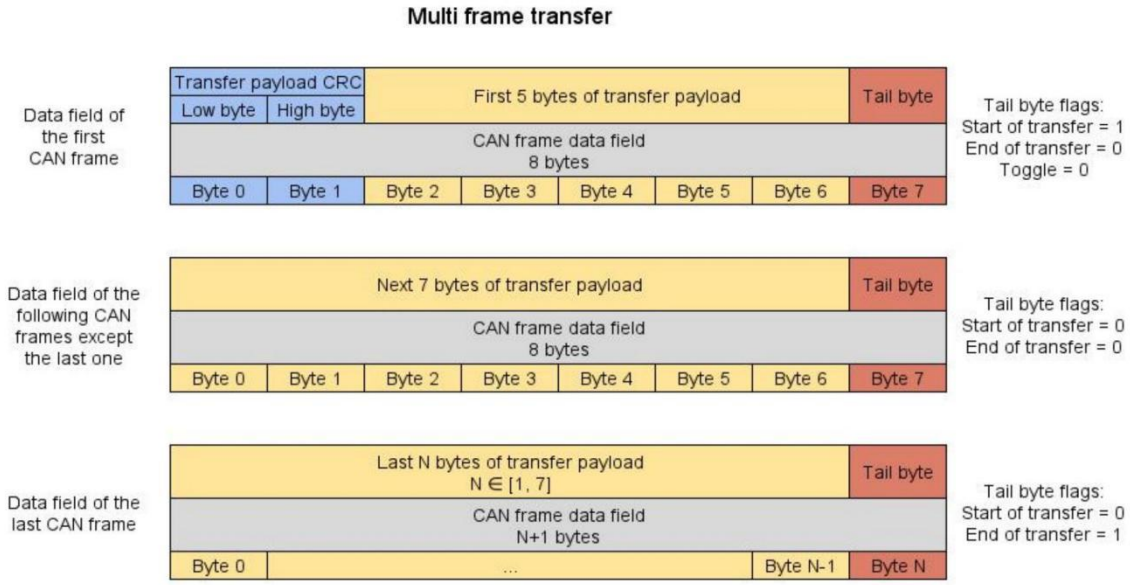
1. Add the 64-bit data signature:

   `SignatureCrc = crcAddSignature (0xFFFF, SignatureValue);`

2. Add the Payload segment data:

   `CRC = crcAdd(SignatureCrc, NBytesOfPayload, N);

**Multi frame Transfer ：**




**Glossary of Terms**

| Terms | Explanation and Description |
|---|---|
| Data Frame | 1：CAN can transmit up to 8 bytes of data in a single frame. |
| Data Packet | 1：A data packet may contain multiple data frames, with the number of frames determined by the amount of data being transmitted. |
| Transfer Payload | 1：Each data frame in the transmission carries valid data ranging from 0 to 7 bytes. |
| Tail byte | 1：In each data frame, the last byte of the Payload contains additional protocol layer field information. |
| Signature | 1：Each different data frame type has a 64-bit data signature value.<br>2：When a data packet requires multi-frame transmission, this signature value must be used in the CRC check.<br>3：Specific values for each data type can be found in the data frame type table in the ESC communication section. |
| Start of transfer | 1：For Single Frame Transfer, the Start of Transfer bit is always set to 1.<br>2：For Multi-Frame Transfer, if the current frame is the first frame of the data packet, this bit is set to 1; otherwise, it is set to 0. |
| End of transfer | 1：For Single Frame Transfer, the End of Transfer bit is always set to 1.<br>2：For Multi-Frame Transfer, if the current frame is the last frame of the data packet, this bit is set to 1; otherwise, it is set to 0. |

| | |
|---|---|
| Toggle bit | 1: For Single Frame Transfer, the Toggle Bit is always set to 0.<br>2: For Multi-Frame Transfer, the Toggle Bit is set to 0 in the first frame of the data packet. For each subsequent frame, this bit alternates between 0 and 1. |
| Transfer ID | 1: Value range: 0 to 31.<br>2: For data with the same Data Type ID, each time a data packet is sent, the Transfer ID is incremented by 1, with values ranging from 0 to 31 in a cyclic manner.<br>3: For multiple data frames within the same data packet, this value remains unchanged. |

## 4.2 CAN ESC Working Mechanism

All ESCs are connected via the CAN bus, with common connection topologies being T-shaped or star-shaped. The throttle input can be provided using PWM for analog throttle or CAN for digital throttle. You can set a priority between PWM throttle and CAN throttle. For example, if PWM throttle is set to take priority, it will be used first. If PWM throttle is abnormal but CAN throttle is functioning normally, the system will automatically switch to CAN throttle. If both PWM and CAN throttles are abnormal, the system will consider the throttle as faulty.

### 4.2.1 Features

- The ESC has its own unique serial number (SN).
- When powered on, the ESC performs an automatic self-check. The self-check status can be queried by sending a self-check query command.
- Supports setting the ESC node ID.
- Supports setting the CAN bus baud rate.
- The data reporting rate is adjustable.
- Other features depend on the specific ESC model.
- Analog and digital dual throttle input.

### 4.2.2 Bus Bandwidth

TM-UAVCAN supports various bus baud rates. You can set the rate according to the number of devices and the cable configuration, with the default rate being 1 MHz.

## 4.3 Data Frame Type List

### 4.3.1 Data Frame Type List

| Data Frame Type List | | | | | |
|---|---|---|---|---|---|
| **Frame Types** | **Frame ID** | **Signature Code** | **Priority** | **Maximum Data Field Length** | **Data Frame Description** |
| RawCommand | **1030** | 0x217F5C87D7EC951D | **LOWEST** | **36Byte** | **Raw Throttle Command Data for Channels 1-20** |
| ParamCfg | **1033** | 0x948F5E0B33E0EDEE | **LOWEST** | **27Byte** | **ESC Parameter Setting Command** |
| ESCStatus | **1034** | 0xA9AF28AEA2FBB254 | **LOWEST** | **14Byte** | **ESC Operational Status Feedback Data** |
| PUSHSCI | **1038** | 0xCE2B6D6B6BDC0AE8 | **LOWEST** | **260Byte** | **Commands Issued from the Ground Control Station to the ESC** |
| PUSHCAN | **1039** | 0xAACF9B4B2577BC6E | **LOWEST** | **260Byte** | **ESC Data Feedback Command** |
| ParamGet | **1332** | 0x462875A0ED874302 | **LOWEST** | **74Byte** | **ESC Parameter Setting Feedback Command** |

## 4.4 Data Frame Type Description

### 4.4.1 RawCommand(1030)

**RawCommand Transmit Frame (N-axis multi-frame, 14*N bit valid data)**

| Data frame byte index | Parameter name | Number of bytes | Data type | Content |
|---|---|---|---|---|
| 1-N | Throttle command | N(<=20) | INT14 | 14-bit throttle data, arranged in order from 0 to N, with the remaining bits automatically padded to 8-bit boundaries |

After receiving the throttle data, the motor parses the information according to its ESC ID and performs the corresponding action.

**Explanation:**

1: RawCommand sends the throttle command as a broadcast frame, requiring no acknowledgment. All ESCs on the bus receive and parse it simultaneously.

2: Each throttle channel occupies 14 bits, with the highest bit (bit 13) as the sign bit. The digital throttle range is -8191 to 8191, where 0 represents no throttle and 8191 represents full throttle. Negative throttle values are not supported by the protocol; negative values are considered throttle anomalies, and the status bit will return a throttle error. If the erroneous throttle does not reach the timeout period, the last valid throttle will be maintained. If the timeout is reached, the throttle will automatically return to zero.

3: Users should select the N-axis RawCommand data frame based on the actual number of ESCs. It is recommended to connect a maximum of 8 CAN nodes per CAN channel to ensure communication quality.

4: RawCommand Data Transmission Format Analysis (Example for a Quadrotor):

a: Assume we need to send a throttle value of 1000 (0x03E8) to four channels.

Data to be sent (HEX): [3E8, 3E8, 3E8, 3E8]

Memory format (HEX): [E8, 03, E8, 03, E8, 03, E8, 03]

Memory format (BIN): [11101000, 00000011, 11101000, 00000011, 11101000, 00000011, 11101000,00000011]

b: Throttle transmission involves converting the original 16-bit throttle data to 14-bit throttle data (removing the highest 2 bits of the original 16-bit data).

Original 16-bit data:

HEX: [ 0xE8 0x03 0xE8 0x03 0xE8 0x03 0xE8 0x03 ]

BIN: [1110_ 1000_0000_0011_ 1110_1000_0000_0011_1110_ 1000_0000_0011_ 1110_1000_0000_0011]

Convert to 14-bit data (remove the highest 2 bits of the original data's high byte, as highlighted in red):

HEX: [1110_1000_0000_1111_1010_0000_0011_1110_1000_0000_1111_1010_0000_0011]

BIN: [ 0xE8 0x0F 0xA0 0x3E 0x80 0xFA 0x03 ]

Send digital throttle data:

Throttle Data[7]={ 0xE8 , 0x0F , 0xA0 , 0x3E , 0x80 , 0xFA , 0x03}

c: The data format for Octo is consistent with that of Quad, and requires adding a data signature for verification.

5：The mapping relationship between CAN digital throttle and PWM throttle is as follows:

CAN throttle period: 2.5 ms, 400 Hz

PWM throttle frequency: 50-500 Hz

Spraying Drone：Throttle pulse width range is 1050-1950 μs

UAV：Throttle pulse width range: 1040-1940 μs

a:Throttle data is represented in 14 bits with a range of -1 to 1 (-8191 to +8191) (resolution of 1/16384). Zero represents 0 throttle, 1 represents maximum clockwise throttle, and -1 represents maximum counterclockwise throttle. Currently, the ESC supports both PWM and CAN throttle control methods. For traditional PWM throttle, the fixed throttle pulse width is 1040 μs to 1940 μs (the recognizable throttle pulse width range is 800-2200 μs). For CAN digital throttle, negative throttle is not currently supported (negative digital throttle will result in a throttle error).

B:The ESC internally maps the digital throttle range of 0-8191 to a PWM throttle range of 1040 μs to 1940 μs, and then controls the motor's rotation. When set to CAN throttle mode, the original PWM input will produce a PWM pulse width corresponding to the digital throttle.

### 4.4.2 ParamCfg(1033)

**ParamCfg Send frame (27 bytes of valid data)**

Parameter setting send command(1033)

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1 | Esc ID | 1 | UINT8 | Esc ID0-19 |
| 2-5 | ESC to be configured UUID | 4 | UINT32 | Unique Esc 32Bits ID |
| 6-7 | Esc ID | 2 | UINT16 | Configure Esc ID |
| 8-9 | Over-voltage protection threshold | 2 | UINT16 | Set Over-voltage protection threshold |
| 10-11 | Over-current protection threshold | 2 | UINT16 | Set Over-current protection threshold |
| 12-13 | Over-temperature protection threshold | 2 | UINT16 | Set Over-temperature protection threshold |
| 14-15 | Acceleration limit | 2 | UINT16 | Set Acceleration limit |
| 16-17 | Deceleration limit | 2 | UINT16 | Set Deceleration limit |
| 18-19 | Rotation direction | 2 | UINT16 | Set Rotation direction |
| 20 | Timing setting | 1 | UINT8 | Set the timing, with a range of 1-29 mapping to 1-29°. |
| 21 | Throttle priority | 1 | UINT8 | 0：PWM 1：CAN |
| 22-23 | LED Seting | 2 | UINT16 | 0-2 bits: RGB light enable switch; 3 bit: light flashing switch; 4-15 bits: light flashing frequency (0.1 Hz) |
| 24 | Bus rate | 1 | UINT8 | 0-1Mbps<br>1-500Kbps<br>2-250Kbps<br>3-125Kbps<br>4-100Kbps<br>5-50Kbps |
| 25-26 | Data reporting rate | 2 | UINT16 | Reporting rate 0-400HZ |

| | | | | |
|---|---|---|---|---|
| 27 | Save | 1 | UINT8 | 0-Temporary set<br>1-Permanent set |

Explanation：

1：Set ESC parameters; 0xFF is the default value, and if the current value is 0xFF/0xFFFF, no modification is made. After setting is complete, respond with the parameter setting feedback command (1332).

2：You can send a data frame with all values set to 0xFF to retrieve parameter information from all ESCs on the bus.

#### 4.4.3 ESC Status(1034)

**EscStatus Return Frame（14Byte valid data）**

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-4 | Status Bit | 4 | UINT32 | Status Bit |
| 5-6 | Voltage Value | 2 | FLOAT16 | Voltage Value, in volts |
| 7-8 | Current Value | 2 | FLOAT16 | Current Value, in amperes |
| 9-10 | Temperature Value | 2 | FLOAT16 | Temperature Value, in degrees Celsius |
| 11-13 | Speed Value | 2~3 | INT18 | Speed Value, in RPM |
| 13-14 | Throttle Value | <1 | UINT7 | Throttle Value, 0-100 represents 0-100% |
| 14 | ESC Serial Number | <1 | UINT5 | ESC Number, 0-19 represents channels 1-20 |

Status Byte Structure:

| Status Byte Structure Table | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bit16-31 | Bit12-15 | | | Bit11 | Bit10 | Bit9 | Bit8 |
| Encoder value 0-16383 represents 0-360° | 1-Off mode<br>2-Idle mode<br>3-Soft start mode<br>4-Operating mode<br>5-Coast-down mode<br>6-Error mode<br>7-Low-speed forward rotation propeller folding mode<br>8-Low-speed reverse folding mode | | | Encoder error | Low bridge fault | Up bridge fault | Operational amplifier fault |
| Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
| Stall | Capacitor Overtemperature | MOS Overtemperature | Throttle Abnormal | Throttle Loss | Overcurrent | Undervoltage | Overvoltage |

Explanation:

1：The `EscStatus` sending frame is a broadcast frame and does not require acknowledgment. All nodes on the bus receive it simultaneously, and only the flight controller or programmer participates in the analysis.

2：Each ESC provides status data according to its node ID and ESC number. It is necessary to pre-set each ESC's ID to avoid conflicts.

3：Users should set the return rate based on actual needs to avoid high bus load and processing load caused by excessively high reporting rates.

#### 4.4.4 PUSHSCI(1038)

**PUSHSCI Send frame (up to 260 bytes of valid data)**

PUSHSCI Host computer transmits data to ESC command data structure

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-4 | Data sequence number | 4 | UINT32 | Data packet sequence number |
| 5-N | Raw data value | 0-255 | UINT8 | Data packet data |

Data packet structure:

1. Set the motor's current position to zero

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-2 | Frame header | 2 | UINT16 | 0xEC、0x96 |
| 3 | Frame ID | 1 | UINT8 | 0x08 |
| 4 | Frame count | 1 | UINT8 | 0-255 cyclic increment |
| 5 | Power unit ID | 1 | UINT8 | 0xA1~0xA9: corresponding to 1~9 |
| 6 | Frame Length | 1 | UINT8 | 0x07 |
| 7 | Checksum | 1 | UINT8 | The sum of bytes (1~6) takes the lower 8 bits. |

After receiving the command, the motor sets the current position as the zero point.

2.FOC parameter setting data packet

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-2 | Frame header | 2 | UINT16 | 0xEC、0x96 |
| 3 | Frame ID | 1 | UINT8 | 0x1E |
| 4 | Frame count | 1 | UINT8 | 0-255 cyclic increment |
| 5 | Power unit ID | 1 | UINT8 | The aircraft has 9 power units. 0xA1~0xA9 correspond to units 1~9. The ESC addresses in the power system can be set to correspond to the actual assembly positions. (28027 defaults to 0xA1; 103 should be set according to the actual ID.) |
| 6 | Frame Length | 1 | UINT8 | 0x1F |
| 7-8 | ESC ID | 2 | UINT16 | Set ESC ID |
| 9-10 | Over-voltage protection threshold | 2 | UINT16 | Set Over-voltage protection threshold |
| 11-12 | Over-current protection threshold | 2 | UINT16 | Set Over-current protection threshold |
| 13-14 | Over-temperature protection threshold | 2 | UINT16 | Set Over-temperature protection threshold |
| 15-16 | Beep volume | 2 | UINT16 | Set Beep volume |
| 17-18 | Acceleration limit | 2 | UINT16 | Set Acceleration limit |
| 19-20 | Deceleration limit | 2 | UINT16 | Set Deceleration limit |
| 21-22 | Rotation direction | 2 | UINT16 | Set Rotation direction |

| | | | | |
|---|---|---|---|---|
| 23-24 | Throttle priority | 2 | UINT16 | 0: PWM<br>1: CAN (24-bit: Position Loop Enabled) |
| 25-26 | LED Settings | 2 | UINT16 | 0-2 bits: RGB light enable switch; 3 bit: light flashing switch; 4-15 bits: light flashing frequency (0.1 Hz) |
| 27 | Bus rate | 1 | UINT8 | 0-1Mbps<br>1-500Kbps<br>2-250Kbps<br>3-125Kbps<br>4-100Kbps<br>5-50Kbps |
| 28-29 | Data report rate | 2 | UINT16 | Feedback rate: 0-400 Hz |
| 30 | Save options | 1 | UINT8 | 0-Temporary settings<br>1-Permanent settings |
| 31 | Checksum | 1 | UINT8 | Checksum: Sum of bytes (1 to 28), taking the lower 8 bits |

3. FOC 参数及状态信息获取数据包

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-2 | Frame header | 2 | UINT16 | 0xEC、0x96 |
| 3 | Frame ID | 1 | UINT8 | 0x1A |
| 4 | Frame count | 1 | UINT8 | 0-255 cyclic accumulation |
| 5 | Power unit ID | 1 | UINT8 | 0xA1~0xA9: Correspond to 1~9, or 0xFF to retrieve all parameters on the bus. |
| 6 | Frame lenth | 1 | UINT8 | 7 |
| 7 | Checksum | 1 | UINT8 | The checksum is the lower 8 bits of the sum of bytes 1 to 6. |

FOC parameter and status information retrieval data packet

4.Controller output control data frame (Controller → Power System).

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-2 | Frame header | 2 | UINT16 | 0xEC、0x96 |
| 3 | Frame ID | 1 | UINT8 | 0x06 |
| 4 | Frame count | 1 | UINT8 | 0-255 cyclic accumulation |
| 5 | Power unit ID | 1 | UINT8 | There are 9 power units on the aircraft.<br>0xA1 to 0xA9: Correspond to motor units 1 to 9.<br>The ESC addresses in the power system can be set to correspond to the actual assembly positions. |
| 6 | Frame length | 1 | UINT8 | 0x0C |
| 7 | Control mode | 1 | UINT8 | 0x00: No rotor locking mode, responds normally to flight control PWM and also serves as the power system query command.<br>0xEE: Motor low-speed forward rotation and blade retraction.<br>0x22: Motor low-speed reverse rotation and blade retraction.<br>0x88: Rotor locks current position.<br>0x66: Motor is in free mode.<br>0x55: Motor duty cycle loop. |

| | | | | |
|---|---|---|---|---|
| | | | | 0x5A: Motor reverse duty cycle loop<br>0x44: Motor current loop<br>0x4A: Motor reverse current loop<br>0x33: Motor speed loop<br>0x3A: Motor reverse speed loop<br>0x11: Motor position loop<br>0x1A: Motor reverse position loop<br>0xBB: Motor current brake loop |
| 8-9 | Control the motor to the encoder position/duty cycle/speed/current | 2 | UINT16 | 0-360°, resolution: 0.1°<br>0-10000 corresponds to 0-100% duty cycle<br>0-10000 corresponds to 0-100A<br>0-10000 corresponds to 0-10000 RPM<br>0-3600 corresponds to 0-360° |
| 10-11 | Reserved | 2 | UINT16 | 0x00 |
| 12 | Checksum | 1 | UINT8 | Checksum: Sum of bytes 1 to 11, taking the lower 8 bits |

Explanation:

1. The PUSHSCI transmission data to ESC command frame is a broadcast frame and does not require acknowledgment. All nodes on the bus receive and parse it simultaneously.

2. The data frame contains an ID field. Each ESC parses the command according to its node ID and ESC number, so it is necessary to set the ID numbers for each ESC in advance to avoid incorrect responses.

3. Users should set the transmission rate based on actual needs. The total frame rate on the bus should be controlled within 2400 frames (CAN rate 1 Mbps) to avoid high bus and processing load caused by excessive reporting rates.

#### 4.4.5 PUSHCAN(1039)

**PUSHCAN return frame (up to 260 bytes of valid data)**

PUSHCAN ESC data feedback instruction data structure

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-4 | Data serial number | 4 | UINT32 | Data packet sequence number |
| 5-N | Raw data value | 0-255 | UINT8 | Data packet data |

Data packet structure:

1. Power system feedback status data frame (Power system → Controller)

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-2 | Frame header | 2 | UINT16 | 0x7B、0x8C |
| 3 | Frame ID | 1 | UINT8 | 0x15 |
| 4 | Frame count | 1 | UINT8 | 0-255 cyclic accumulation |
| 5 | Power unit ID | 1 | UINT8 | There are 9 power units on the aircraft. 0xA1~0xA9 correspond to units 1~9. The ESC addresses in the power system can be set to match the actual assembly positions. |
| 6 | Frame length | 1 | UINT8 | 0x1C |
| 7 | System status of the power unit ID | 1 | UINT8 | 0x00：No rotor lock state<br>0x11：Rotor lock state<br>0xCC: System fault |

| | | | | |
|---|---|---|---|---|
| 8-9 | Motor current position | 2 | UINT16 | 0-360°, resolution: 0.01° |
| 10-11 | Receive PWM value | 2 | UINT16 | resolution：0.1us |
| 12 | Actual output throttle value | 1 | UINT8 | resolution：0.4% |
| 13-14 | Motor speed | 2 | INT16 | resolution：1rpm |
| 15-16 | Voltage | 2 | UINT16 | resolution：0.01V |
| 17-18 | Current | 2 | INT16 | resolution：0.01A |
| 19-20 | Temperature | 2 | UINT16 | resolution：0.01℃ |
| 21-22 | Motor fault | 2 | UINT16 | Error flag data |
| 23 | Motor status | 1 | UINT8 | 0x00 |
| 24-25 | ESC power-on count | 2 | UINT16 | Unit:times. |
| 26-27 | The runtime of the ESC. | 2 | UINT16 | Unit: seconds |
| 28 | Checksum | 1 | UINT8 | The sum of bytes 1 to 27, taking the lower 8 bits |

2. FOC parameter setting feedback data packet

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1-2 | Frame header | 2 | UINT16 | 0x7B、0x8C |
| 3 | Frame ID | 1 | UINT8 | 0x1E |
| 4 | Frame count | 1 | UINT8 | 0-255 cyclic accumulation |
| 5 | Power unit ID | 1 | UINT8 | There are 9 power units on the aircraft. 0xA1~0xA9 correspond to units 1~9. The ESC addresses in the power system can be set to match the actual assembly positions. |
| 6 | Frame length | 1 | UINT8 | 0x37 |
| 7-22 | ESC hardware version | 16 | UINT16 | ESC version number |
| 23-38 | ESC software version | 16 | UINT16 | ESC software version |
| 39-40 | Acceleration limit | 2 | UINT16 | Acceleration limit |
| 41-42 | Deceleration limit | 2 | UINT16 | Deceleration limit |
| 43-44 | Rotation direction | 2 | UINT16 | Rotation direction |
| 45-46 | Position loop enable flag | 2 | UINT16 | Position loop enable flag |
| 47-48 | Throttle priority | 2 | UINT16 | 0：PWM 1：CAN |
| 49-50 | LED setting | 2 | UINT16 | 0-2 bits: RGB light enable switch, 3 bit: light blinking switch, 4-15 bits: light blinking frequency (0.1 Hz) |
| 51 | Bus rate | 1 | UINT8 | 0-1Mbps<br>1-500Kbps<br>2-250Kbps<br>3-125Kbps<br>4-100Kbps<br>5-50Kbps |
| 52-53 | Data feedback rate | 2 | UINT16 | Return rate: 0-400Hz |
| 54 | Save options | 1 | UINT8 | 0-Temporary settings<br>1-Permanent setting<br>2- |
| 55 | Checksum | 1 | UINT8 | (1~54) Take the lower 8 bits of the sum of bytes |

#### 4.4.6 ParamGet(1332)

**ParamGet returns frame (maximum 74Byte valid data)**

**Parameter setting report command (1332) data structure**

| No | Parameter | Byte count | Data Type | Content |
|---|---|---|---|---|
| 1 | ESC ID | 1 | UINT8 | ESC ID0-19 |
| 2-5 | UUID of the ESC to be configured | 4 | UINT32 | Unique 32-bit ID of the ESC |
| 6-7 | ESC ID | 2 | UINT16 | To obtain the ESC ID, 0XFF means simultaneous feedback from all ESCs on the bus. |
| 8-9 | Over-voltage protection threshold | 2 | UINT16 | Get the ESC over-voltage protection threshold |
| 10-11 | Over-current protection threshold | 2 | UINT16 | Get Over-current protection threshold |
| 12-13 | Over-temperature protection threshold | 2 | UINT16 | Get Over-temperature protection threshold |
| 14-15 | acceleration limit | 2 | UINT16 | Get acceleration limit |
| 16-17 | Deceleration limit | 2 | UINT16 | Get deceleration limit |
| 18-19 | Rotation direction | 2 | UINT16 | Get rotation direction |
| 20 | Timing setting | 1 | UINT8 | Get the timing, with 1-29 mapping to 1-29°. |
| 21-22 | Power-up count | 2 | UINT16 | Get the total number of times the ESC is powered on |
| 23-26 | Power on time | 4 | UINT32 | Get the total power-on time of the ESC (seconds) |
| 27-30 | Production time | 4 | UINT32 | Get the ESC production date |
| 31-34 | Number of failures | 4 | UINT32 | Get the cumulative number of ESC failures |
| 35 | Throttle priority | 1 | UINT8 | 0-0：PWM 1：CAN |
| 36-37 | LED setting | 2 | UINT16 | 0-2bit: RGB light enable switch, 3bit: light flashing switch, 4-15bit: light flashing frequency (0.1HZ) |
| 38 | Bus rate | 1 | UINT8 | 0-1Mbps<br>1-500Kbps<br>2-250Kbps<br>3-125Kbps<br>4-100Kbps<br>5-50Kbps |
| 39-40 | Data report rate | 2 | UINT16 | Report rate 0-400HZ |
| 41 | Save options | 1 | UINT8 | 0-Temporary settings<br>1-Permanent settings |
| 42-73 | Reserved data | 32 | UINT32 | Manufacturer reserved data |

Explanation:

1. The ParamGet parameter retrieval return instruction is a broadcast frame and does not require a response. All nodes on the bus receive it simultaneously.

2. The data frame includes an ID bit, and only the flight controller or parameter adjuster needs to parse and process the data. This frame is for parameter setting and retrieval feedback. Users can select as needed.

3. Users should set the transmission rate according to actual needs. During operation, the total frame rate on the bus should be controlled within 2400 frames (CAN rate 1Mbps). When not operating, the total frame rate should be controlled within 4000 frames (CAN rate 1Mbps) to avoid high bus load and processing load due to excessive feedback rates.

# 5 Attachment

## 5.1. CRC support：

CRC algorithm description:

Name: CRC- 16-CCITT-FALSE
Description: http://reveng.sourceforge.net/crc-catalogue/16.htm#crc.cat.crc-16-ccitt-false

Initial value: 0xFFFF

Poly: 0x1021

Reverse: no

Output XOR: 0

Check: 0x29B1

```
/*
 * CRC functions
 */
 uint16_t crcAddByte(uint16_t crc_val, uint8_t byte)
{
   crc_val ^= (uint16_t) ((uint16_t) (byte) << 8);
   for (uint8_t j = 0; j < 8; j++)
   {
      if (crc_val & 0x8000U)
      {
         crc_val = (uint16_t) ((uint16_t) (crc_val << 1) ^ 0x1021U);
      }
      else
      {
         crc_val = (uint16_t) (crc_val << 1);
      }
   }
   return crc_val;
}

 uint16_t crcAddSignature(uint16_t crc_val, uint64_t data_type_signature)
{
   for (uint16_t shift_val = 0; shift_val < 64; shift_val = (uint16_t)(shift_val + 8U))
   {
      crc_val = crcAddByte(crc_val, (uint8_t) (data_type_signature >> shift_val));
   }
   return crc_val;
}
```

```
uint16_t crcAdd(uint16_t crc_val, const uint8_t* bytes, size_t len)
{
   while (len--)
   {
      crc_val = crcAddByte(crc_val, *bytes++);
   }
   return crc_val;
}
```

## 5.2. float16 support：

```
/*
UAVCAN floating-point data type conversion
*/
  union FP32
  {
    uint32_t u;
    float f;
  };
const union FP32 f32inf = { 255UL << 23 };
const union FP32 f16inf = { 31UL << 23 };
const union FP32 magic  = { 15UL << 23 };
const uint32_t sign_mask = 0x80000000U;
const uint32_t round_mask = ~0xFFFU;
 uint16_t ConvertFloatToFloat16(float value)
 {
    union FP32 in;
    in.f = value;
    uint32_t sign = in.u & sign_mask;
    in.u ^= sign;
    uint16_t out = 0;

    if (in.u >= f32inf.u)
    {
        out = (in.u > f32inf.u) ? (uint16_t)0x7FFFU : (uint16_t)0x7C00U;
    }
    else
    {
          in.u &= round_mask;
```

```
            in.f *= magic.f;
            in.u -= round_mask;
            if(in.u > f16inf.u)
            {
                in.u = f16inf.u;
            }
             out = (uint16_t)(in.u >> 13U);
     }
     out |= (uint16_t)(sign >> 16U);
     return out;
  }
float ConvertFloat16ToFloat(u16 value)
{
   const union FP32 magic = { (254UL - 15UL) << 23U };
   const union FP32 was_inf_nan = { (127UL + 16UL) << 23U };
   union FP32 out;

   out.u = (value & 0x7FFFU) << 13U;
   out.f *= magic.f;
   if (out.f >= was_inf_nan.f)
   {
      out.u |= 255UL << 23U;
   }
   out.u |= (value & 0x8000UL) << 16U;
   return out.f;
}
```

## 5.3 DSDL configuration reference

### 5.3.1 1030.RawCommand

struct { uint8_t len; int14_t data[20]; }cmd;

### 5.3.2 1033.ParamCfg

uint8 esc_index
uint32 esc_uuid
uint16 esc_id_set
uint16 esc_ov_threshold
uint16 esc_oc_threshold
uint16 esc_ot_threshold
uint16 esc_acc_threshold
uint16 esc_dacc_threshold
int16 esc_rotate_dir
uint8 esc_timing
uint8 esc_signal_priority
uint16 esc_led_mode
uint8 esc_can_rate
uint16 esc_fdb_rate
uint8 esc_save_option

### 5.3.3 1034.ESC_STATUS

uint32 error_count
float16 voltage
float16 current
float16 temperature
int18 rpm
uint7 power_rating_pct
uint5 esc_index

### 5.3.4 1038.PUSHSCI

uint32 data_sequence
struct { uint8_t len; uint8_t data[255]; }data;

### 5.3.5 1039.PUSHCAN

uint32 data_sequence
struct { uint8_t len; uint8_t data[255]; }data;

#### 5.3.6 1332.ParamGet

uint8 esc_index
uint32 esc_uuid
uint16 esc_id_req
uint16 esc_ov_threshold
uint16 esc_oc_threshold
uint16 esc_ot_threshold
uint16 esc_acc_threshold
uint16 esc_dacc_threshold
int16 esc_rotate_dir
uint8 esc_timing
uint16 esc_startup_times
uint32 esc_startup_duration
uint32 esc_product_date
uint32 esc_error_count
uint8 esc_signal_priority
uint16 esc_led_mode
uint8 esc_can_rate
uint16 esc_fdb_rate
uint8 esc_save_option
struct { uint8_t len; uint8_t data[32]; }rsvd;

## 5.4 Reference link

1.Dronecan project:https://dronecan.github.io
2.Dronecan configuration example:https://github.com/dronecan/libcanard/tree/master/examples
3.ardupilot project:https://ardupilot.org
4.PX4 project:https://px4.io

## 6 Version history

| Date | Version | Change log |
|---|---|---|
| 2024.5.16 | V2.1 | The first version of the protocol is released |
| 2024.7.3 | V2.2 | 1.Fixed some document layout errors<br>2.Added version history<br>3.Deleted some unavailable data frame types in Chapter 4.3 |
| | | |