Aerobits

**Subsystems for the**
**UAS integration into the airspace**

# *trkME*

## Data sheet - User manual

# Contents

# 1 Introduction

The **trkME** tracker is a versatile, multi-system tracking device designed to enhance the safety and operational efficiency of UAS. It features a comprehensive range of RF systems, including ADS-B receiver. This ensures robust communication and positioning capabilities, essential for navigating congested airspaces. It is available in three different functional variants: **trkME**, **trkME+** and **trkME-PRO**

Table 1: Product Variants

| Feature | trkME | trkME+ | trkME PRO |
|---|---|---|---|
| |  |  |  |
| Role | Remote identification | Remote identification<br>Anti-collision | Remote identification<br>Anti-collision - surrounding awareness<br>Cooperation with bigger aviation |
| RF type | transmitter | transmitter<br>receiver | transmitter<br>receiver |
| RemoteID – LTE | ✓ (Cat. 1) | ✓ (Cat. 1) | ✓ (Cat. 1) |
| RemoteID OUT [Wi-Fi, BT] | ✓ | ✓ | ✓ |
| RemoteID IN [Wi-Fi, BT] | × | ✓ (Up to 1km) | ✓ |
| FLARM IN/OUT | × | ✓ | ✓ |
| ADS-B IN | × | ✓ (up to 15km) | ✓ |
| ADS-B OUT | × | × | ✓ |
| Built-in GNSS | ✓ | ✓ | ✓ |
| Built-in pressure sensor | ✓ | ✓ | ✓ |
| Transmitter power [dBm] | +18 (BT)<br>+20 (Wi-Fi) | +18 (BT)<br>+20 (Wi-Fi)<br>+14 (FLARM) | +33 (ADS-B)<br>+18 (BT)<br>+20 (Wi-Fi)<br>+14 (FLARM) |
| Receiver sensitivity [dBm] | -167 (GNSS) | -94 (ADS-B)<br>-109 (FLARM)<br>-167 (GNSS)<br>-103 (BT)<br>-103 (Wi-Fi) | -94 (ADS-B)<br>-109 (FLARM)<br>-167 (GNSS)<br>-103 (BT)<br>-103 (Wi-Fi) |
| UART interface [baud] | (115k / 921k / 3M) | (115k / 921k / 3M) | (115k / 921k / 3M) |
| USB interface | (2.0) | (2.0) | (2.0) |
| Power supply [V] | 5 | 5 | 5 |
| Current consumption [mA] | 320 | 400 | 450 |
| Weight [g] | 50 | 50 | 50 |
| Dimensions [mm] | 65x46x12 | 65x46x12 | 65x46x12 |

**Note:**

× - not included in this variant, ✓ - included

**Note:**

Currently available is the **trkME** product variant. Products **trkME+** and **trkME PRO** will be available soon. Check availability with our sales department at: **sales@aerobits.pl**

**trkME** has FLARM IN/OUT transceiver, BLE/Wi-Fi RemoteID transmitter and also has multi-constellation GNSS sensor on board to provide best accuracy. The LTE connectivity allows usage in all LTE/4G rich environments without the need for any additional cabling to send data.

**trkME** opens the way to the safe integration of UAS into non-segregated airspace, implementation of the **Detect and Avoid** algorithms and reduce separation between airspace users.

Aerobits **trkME** is designed to meet requirements of direct remote drone identification and localization in **ASTM/ASD-STAN** standard. Using the BLE broadcast and WiFi Nan, Beacon frames technology the device provides surveillance and drone operator identification capability based on any modern mobile devices such as smartphone or tablet. Our device fits in with the concept of Network Remote Identification and allow broadcast remote drone identification via LTE.

It is a perfect solution for conducting VLOS/BVLOS operation where safety is critical.

**Note:**

The device to operate on FLARM frequency requires FLARM UAS license. The license must be obtained with the device from Aerobits upon purchase.

**Important:**

Each firmware version becomes its own documentation. This document is relevant for firmware version v2.89.8. If your firmware version is different please find relevant documentation on our website aerobits.pl.

## 1.1 Features

- **Real-time aircraft tracking on 1090 MHz and 868 MHz**
- **Nationwide traffic management systems (manned and unmanned)**
- **Integrated GNSS source and pressure sensor**
- **Licensed FLARM transceiver (0.025 Watt output power)**
- **Remote drone identification BLE and Wi-Fi standards**
- **Network based Remote Identification (central monitoring)**
- **Programming via AT commands**
- **LTE modem to track aircraft via LTE 4G Cat1**

For more information please contact support@aerobits.pl.

# 2 Technical parameters

## 2.1 Basic technical information

Table 2: General technical parameters

| Parameter | Description | Typ. | Unit |
|---|---|---|---|
| First Band | ADS-B | 1090 | MHz |
| Second Band | FLARM | 868 or 915 | MHz |
| Third Band | RID BLE | 2400 | MHz |
| Fourth Band | RID Wi-Fi | 2400 | MHz |
| Fifth Band | GNSS | 1575 | MHz |
| Sensitivity (ADS-B) | | -94 | dBm |
| Sensitivity (FLARM) | | -109 | dBm |
| Sensitivity (BLE) | | -103 | dBm |
| Sensitivity (Wi-Fi) | | -103 | dBm |
| Sensitivity (GNSS) | | -167 | dBm |
| RF Output power (ADS-B) | | +33 | dBm |
| RF Output power (FLARM) | | +14 | dBm |
| RF Output power (BLE) | | +18 | dBm |
| RF Output power (Wi-Fi) | | +20 | dBm |
| LTE Cat. 1 | Data transport layer (global bands) | | |

## 2.2 Electrical specification

### 2.2.1 Basic electrical parameters

Table 3: General electrical parameters

| Parameter | Value |
|---|---|
| Power connector | USB-C and JST GH 6 pin |
| Power supply | 5 V |
| Power consumption | < 600 mA |

### 2.2.2 JST PIN definition

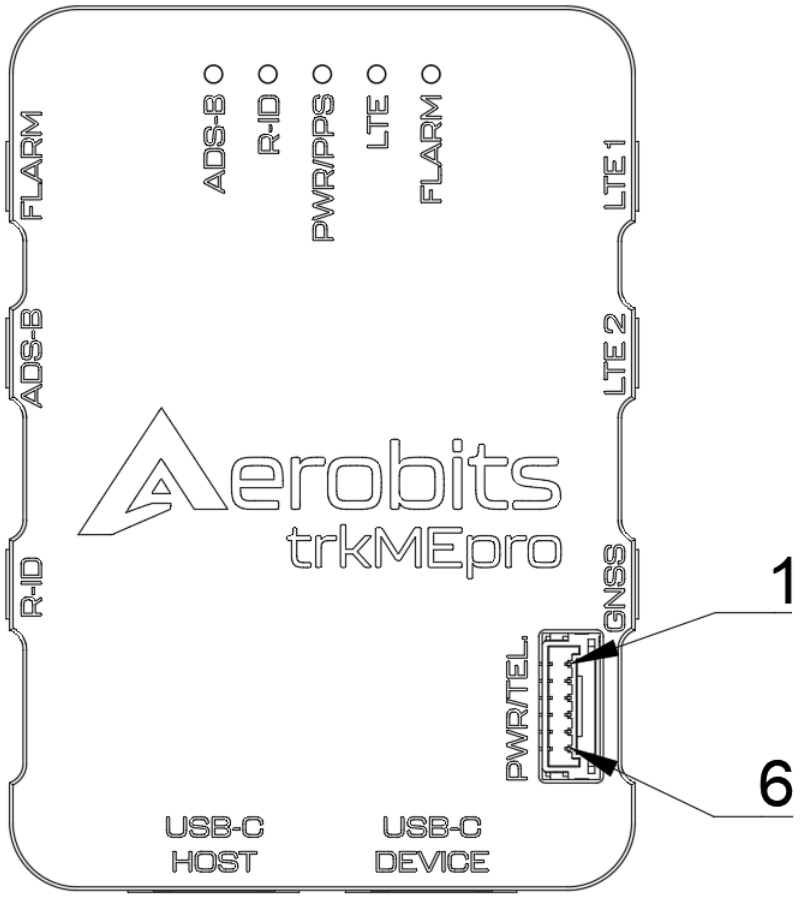


Table 4: Descriptions of JST connector pins.

| PIN | Name | Function |
|---|---|---|
| 1 | +5 V | Power supply |
| 2 | RX | MAVLink, AERO RXD |
| 3 | TX | MAVLink, AERO TXD |
| 4 | NC | Not connected |
| 5 | NC | Not connected |
| 6 | GND | Ground |

### 2.2.3 LED indicators

Table 5: Descriptions of LEDs.

| LED | Color | Function |
|---|---|---|
| ADS-B | Green | Flashing – reception of 1090 MHz avionics frame (ADS-B) |
| ADS-B | Red | Flashing – sent 1090 MHz avionics frame (ADS-B) |
| FLARM | Green | Flashing – reception of FLARM frame |
| FLARM | Red | Flashing – sent FLARM frame |
| RID | Green | Flashing – reception of RID frame |
| RID | Red | Flashing – sent RID frame |

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Table 5 – continued from previous page

| LED | Color | Function |
|---|---|---|
| PWR/PPS | Green | Constant light - Power supply presence<br>Off – No power, connect or recharge power source |
| PWR/PPS | Red | Flashing – reception of PPS signal |
| LTE | Red | Flashing – LTE communication initialized<br>Constant light – LTE communication in progress<br>Off – No mobile network, wait or change position for better network coverage |

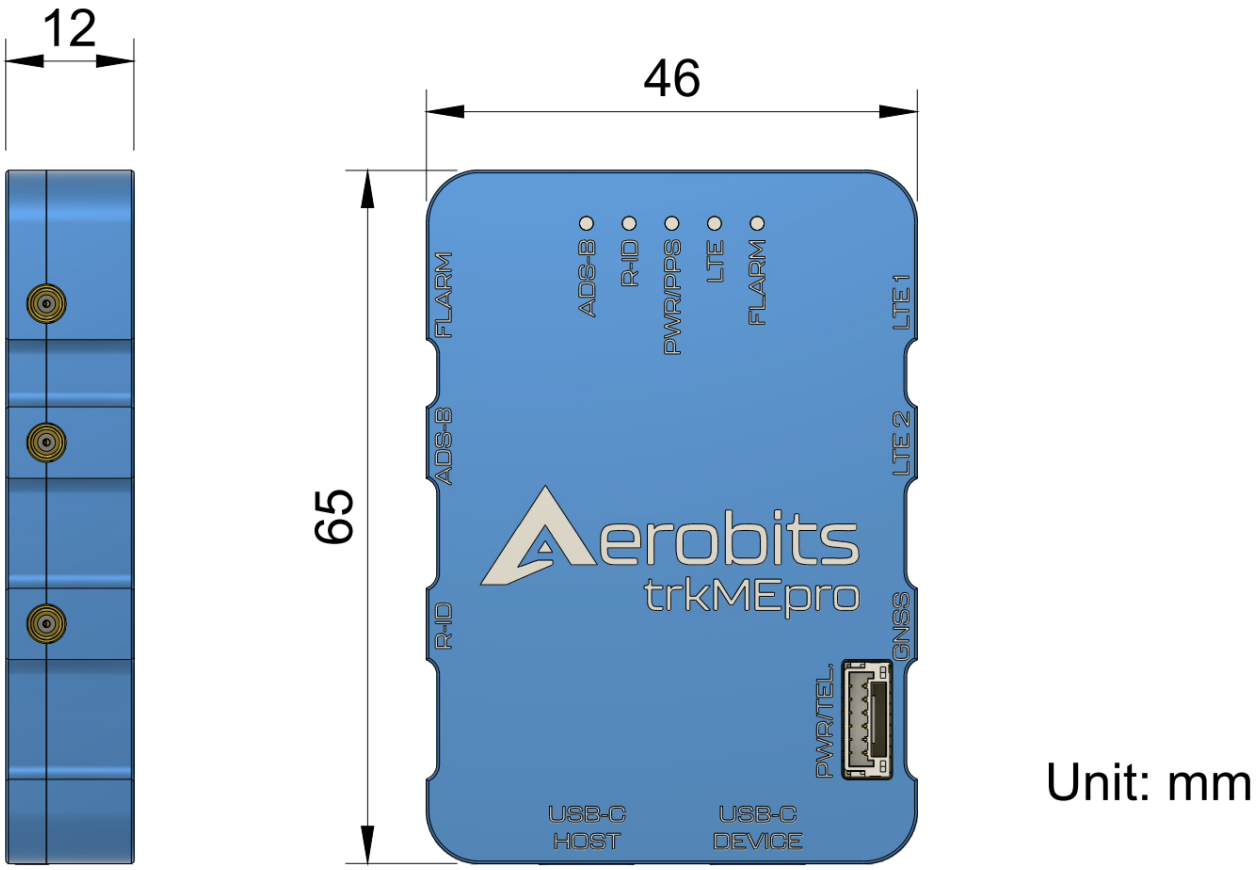
## 2.3 Mechanical specification

### 2.3.1 Mechanical parameters

Table 6: Mechanical parameters of the trkME

| Parameter | Value |
|---|---|
| Dimensions | 65 mm x 46 mm x 12 mm |
| Weight | 60 g |

### 2.3.2 Dimensions



### 2.3.3 Connectors

Table 7: Descriptions of used connectors.

| Description | Type | Function | Mating connector |
|---|---|---|---|
| USB-C Device | USB4110-GF-A | Power and Data | USB-C |
| USB-C Host | USB4110-GF-A | Data | USB-C |
| PWR/TEL. | BM06B-GHS-TBT | Power and Data | JST GH 6 pin |
| ADS-B<br>FLARM<br>RID<br>GNSS<br>LTE1<br>LTE2 | MMCX-4058JEGR | Antenna | ASMK025X174S11 |

# 3 UART configuration

Communication between module and host device is done using UART interface.

In CONFIGURATION and BOOTLOADER state transmission baud is fixed at 115200bps.

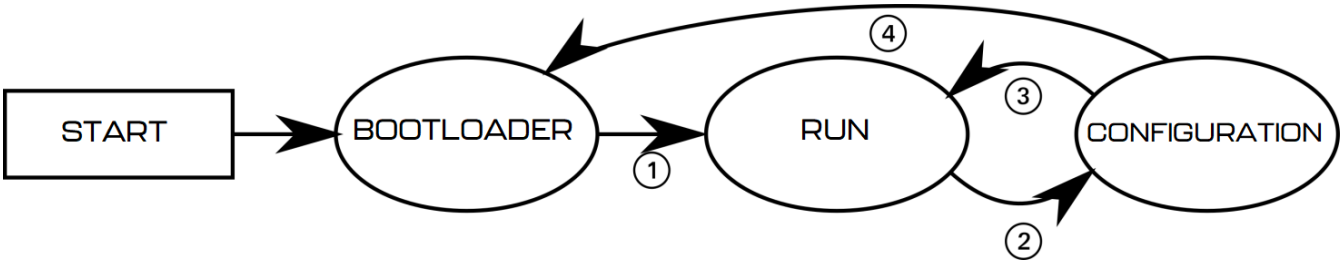
The UART interface uses settings as described in table below:

Table 8: Descriptions of UART settings.

| Parameter | Min. | Typ. | Max | Unit |
|---|---|---|---|---|
| Baud | 57600 | 921600 | 3000000 | bps |
| Stop Bits Number | – | 1 | – | – |
| Flow Control | – | None | – | – |
| Parity Bit | – | None | – | – |

# 4 Principle of operation

During work module goes through multiple states. In each state operation of the module is different. Each state and each transition is described in paragraphs below.




## 4.1 States of operation

### 4.1.1 BOOTLOADER state

This is an initial state of after restart. Firmware update is possible here. Typically module transitions automatically to RUN state. It is possible to lock module in this state (prevent transition to RUN state) using one of BOOTLOADER triggers. UART baud is constant and is set to 115200bps. After powering up module, it stays in this state for 3 seconds. If no BOOTLOADER trigger is present, module will transition to RUN state. Firmware upgrade is possible using Micro ADS-B App software. For automated firmware upgrading scenarios, aerobits_updater software is available. To acquire this program, please contact: support@aerobits.pl.

### 4.1.2 RUN state

In this state module is broadcasting drone identification data. In this state module is working and receiving the data from aircrafts. It uses selected protocol to transmit received and decoded data to the host system. In this state of operation module settings are loaded from non-volatile internal memory, including main UART interface's baud.

### 4.1.3 CONFIGURATION state

In this mode change of stored settings is possible. Operation of the module is stopped and baud is set to fixed 115200bps. Change of settings is done by using AT-commands. Changes to settings are stored in non-volatile memory on exiting this state. Additional set of commands is also available in this state, allowing to e.g. reboot module into BOOTLOADER state, check serial number and firmware version. It is possible to lock module in this state (similarly to BOOTLOADER) using suitable command.

## 4.2 Transitions between states

For each state transition, different conditions must be met, which are described below. Generally, the only stable state is RUN. Module always tends to transition into this state. Moving to other states requires host to take some action.

### 4.2.1 BOOTLOADER to RUN transition

BOOTLOADER state is semi-stable: the module requires additional action to stay in BOOTLOADER state. The transition to RUN state will occur automatically after a short period of time if no action is taken. To prevent transition from BOOTLOADER state, one of following actions must be taken:

- Send `AT+LOCK=1` command while device is in BOOTLOADER state (always after power on for up to 3s)
- Send `AT+REBOOT_BOOTLOADER` command in CONFIGURATION state. This will move to BOOTLOADER state and will lock module in this state.

If none of above conditions are met, the module will try to transition into RUN state. Firstly it will check firmware integrity. When firmware integrity is confirmed, module will transition into RUN state, if not, it will stay in BOOTLOADER state.

To transition into RUN state:

- If module is locked, send `AT+LOCK=0` command

When module enters RUN mode, it will send `AT+RUN_START` command.

### 4.2.2 RUN to CONFIGURATION transition

To transition from RUN into CONFIGURATION state:

- Send `AT+CONFIG=1` (using current baud).

When module leaves RUN state, it sends `AT+RUN_END` message, then `AT+CONFIG_START` message on entering CONFIGURATION state. The former is sent using baud from settings, the latter always uses 115200bps baud.

### 4.2.3 CONFIGURATION to RUN transition

To transition from CONFIGURATION into RUN state:

- Send `AT+CONFIG=0` command.

When module leaves CONFIGURATION state, it sends `AT+CONFIG_END` message, then `AT+RUN_START` message on entering RUN state. The former is always sent using 115200bps baud, the latter uses baud from settings.

### 4.2.4 CONFIGURATION to BOOTLOADER transition

To transit from CONFIGURATION into BOOTLOADER state, host should do one of the following:

- Send `AT+REBOOT_BOOTLOADER` command.
- Send `AT+REBOOT` and when module enters BOOTLOADER state, prevent transition to RUN state.

When entering the bootloader state, the module sends `AT+BOOTLOADER_START` .

# 5 System configuration

In RUN state, operation of the module is determined based on stored settings. Settings can be changed in CONFIGURATION state using AT-commands. Settings can be written and read.

**Note:**

New values of settings are saved in non-volatile memory when transitioning from CONFIGURATION to RUN state.

Settings are restored from non-volatile memory during transition from BOOT to RUN state. If settings become corrupted due to memory fault, power loss during save, or any other kind of failure, the settings restoration will fail, loading default values and displaying the `AT+ERROR (Settings missing, loaded default)` message as a result. This behavior will occur for each device boot until new settings are written by the user.

## 5.1 System settings

### 5.1.1 Write settings

After writing a new valid value to a setting, an `AT+OK` response is always sent.

`AT+SETTING=VALUE`

For example `AT+SYSTEM_STATISTICS=1`

Response: `AT+OK`

### 5.1.2 Read settings

`AT+SETTING?`

For example: `AT+SYSTEM_STATISTICS?`

Response: `AT+SYSTEM_STATISTICS=1`

### 5.1.3 Settings description

`AT+SETTING=?`

For example: `AT+SYSTEM_STATISTICS=?`

Response:

```
Setting: SYSTEM_STATISTICS
Description: System statistics protocol(0:none, 1:CSV, 2:JSON)
Access: Read Write
Type: Integer decimal
Range (min.): 0
Range (max.): 2
Preserved: 1
Requires restart: 0
```

### 5.1.4 Errors

Errors are reported using following structure:

```
AT+ERROR (DESCRIPTION)
```

DESCRIPTION is optional and contains information about error.

### 5.1.5 Command endings

Every command must be ended with one of the following character sequences: `"\n"`, `"\r"` or `"\r\n"`. Commands without suitable ending will be ignored.

### 5.1.6 Uppercase and lowercase

All characters (except preceding `AT+`) used in command can be both uppercase and lowercase, so following commands are equal:

```
AT+SYSTEM_STATISTICS?

AT+sYSTEM_staTISTICS?
```

**Note:**

This statement is true in configuration state, not in bootloader state. In bootloader state all letters must be uppercase.

### 5.1.7 Settings

Table 9: Descriptions of system settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| BAUDRATE | 0 | 3 | 0 | Baudrate in RUN state<br>0 - 115200bps<br>1 - 921600bps<br>2 – 3000000bps<br>3 – 57600bps |
| SYSTEM_LOG | 0 | 1 | 0 | System logs<br>0 - disable<br>1 - enable |
| SYSTEM_STATISTICS | – | – | None | System statistics protocol:<br>None<br>CSV |

### 5.1.8 Example

As an example, to switch the Aerobits device to CSV protocol, one should send following commands: “<<” indicates command sent to module, “>>” is a response.

```
<< AT+CONFIG=1\r\n
>> AT+OK\r\n
<< AT+ADSB_RX_PROTOCOL_DECODED=1\r\n
>> AT+OK\r\n
<< AT+CONFIG=0\r\n
>> AT+OK\r\n
```

## 5.2 Commands

Apart from settings, module supports a set of additional commands. Format of these commands is similar to those used for settings, but they do not affect operation of module in RUN state.

### 5.2.1 Commands in BOOTLOADER and CONFIGURATION state

#### AT+LOCK

`AT+LOCK=1` - Set lock to enforce staying in BOOTLOADER or CONFIGURATION state

`AT+LOCK=0` - Remove lock

`AT+LOCK?` - Check if lock is set

#### AT+BOOT

`AT+BOOT?` - Check if module is in BOOTLOADER state

Response:

`AT+BOOT=0` - module in CONFIGURATION state

`AT+BOOT=1` - module in BOOTLOADER state

### 5.2.2 Commands in CONFIGURATION state

#### AT+CONFIG

`AT+CONFIG=0` - Transition to RUN state.

`AT+CONFIG?` - Check if module is in CONFIGURATION state.

Response:

`AT+CONFIG=0` - module in RUN state

`AT+CONFIG=1` - module in CONFIGURATION state (baudrate 115200)

`AT+CONFIG=2` - module in CONFIGURATION state (baudrate as set)

#### AT+SETTINGS?

`AT+SETTINGS?` - List all settings. Example output:

```
AT+BAUDRATE=0
AT+BOOT=0
AT+CONFIG=1
AT+DEVICE=TR-1F
AT+FIRMWARE_VERSION=2.72.1.0 (Jun 17 2024)
AT+LOCK=0
AT+SERIAL_NUMBER=22-0000309
AT+SYSTEM_LOG=0
AT+SYSTEM_STATISTICS=0
```

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```
AT+ADSB_RX_PROTOCOL_DECODED=1
AT+ADSB_RX_PROTOCOL_INC=0
AT+ADSB_RX_PROTOCOL_RAW=0
AT+ADSB_STATISTICS=1
AT+ADSB_TX_EMITTER_CAT=0
AT+ADSB_TX_ENABLED=1
AT+ADSB_TX_ICAO=000000
AT+ADSB_TX_IDENT=
AT+ADSB_TX_ON_BOOT=1
AT+ADSB_TX_PWR=2
AT+ADSB_TX_SQUAWK=0000
AT+ADSB_TX_SURFACE=0
AT+ADSB_TX_TRANSPONDER_PRESENT=0
AT+FLARM_INFO=LIBFLARM-2.03, expires: 2025-03-01, status: OK
AT+FLARM_RX_PROTOCOL_DECODED=1
AT+FLARM_STATISTICS=0
AT+FLARM_TX=1
AT+FLARM_TX_AIRCRAFT_TYPE=13
AT+GNSS_RX_PROTOCOL_RAW=0
AT+SENSOR_PROTOCOL_DECODED=0
AT+ASTERIX_SAC=1
AT+ASTERIX_SIC=129
```

### AT+HELP

`AT+HELP` - Show all settings and commands with descriptions. Example output:

```
SETTINGS:
SYSTEM:
    AT+BAUDRATE=0 [Baudrate of serial interface (0:115200, 1:921600, 2:3000000,
↪3:57600)]
    AT+BOOT=0 [Is firmware in bootloader mode]
    AT+CONFIG=1 [CONFIG mode (0:disable, 1:baudrate 115200, 2:baudrate as set)]
    AT+DEVICE=IDME-PRO [Device type's name]
    AT+LOCK=0 [Device in CONFIG mode (0:no lock, 1:lock)]
    AT+SERIAL_NUMBER=18099300000323 [Device's serial number]
    AT+SYSTEM_LOG=0 [System logs (0:disable, 1:enable)]
    AT+SYSTEM_STATISTICS=0 [System statistics protocol(0:none, 1:CSV, 2:JSON)]
    AT+FIRMWARE_VERSION=1.22.5.0 (Aug 7 2024) [Device's firmware version]
GNSS:
    AT+GNSS_RX_PROTOCOL_RAW=0 [GNSS_RX RAW protocol (0:none, 5:NMEA)]
SENSORS:
    AT+SENSORS_PROTOCOL_DECODED=0 [SENSORS decoded protocol (0:none, 1:CSV,3:JSON)]
COMMANDS:
    AT+3RD_PARTY_LICENSES [Displays licenses of third party software]
    AT+BLUETOOTH_MAC [Bluetooth device mac address]
    AT+DRONE_ID_OPERATOR_ID [Operator message payload]
    AT+HELP [Show this help]
    AT+INFO [Display device information]
    AT+REBOOT [Reboot system]
    AT+REBOOT_BOOTLOADER [Reboot to bootloader]
    AT+SETTINGS_DEFAULT [Loads default settings]
    AT+TEST [Responds "AT+OK"]
    AT+WIFI_MAC [WiFI device mac address]
```

#### AT+SETTINGS_DEFAULT

`AT+SETTINGS_DEFAULT` - Set all settings to their default value.

#### AT+SERIAL_NUMBER

`AT+SERIAL_NUMBER?` - Read serial number of module.

Response:

`AT+SERIAL_NUMBER=07-0001337`

#### AT+FIRMWARE_VERSION

`AT+FIRMWARE_VERSION?` - Read firmware version of module.

Response:

`AT+FIRMWARE_VERSION=2.73.1.0 (Jun 27 2024)`

#### AT+REBOOT

`AT+REBOOT` - Restart module.

#### AT+REBOOT_BOOTLOADER

`AT+REBOOT_BOOTLOADER` - Restart module to BOOTLOADER state.

**Note:**

NOTE: This command also sets lock.

### 5.2.3 Commands in RUN state

`AT+CONFIG=1` - transition to CONFIGURATION state (baudrate 115200). `AT+CONFIG=2` - transition to CONFIGURATION state (baudrate as set).

**Note:**

NOTE: This command also sets lock.

# 6 Protocols

Each system has protocols unique to it, but protocols common to all systems such as the CSV protocol are also used. All the protocols used in our products will be presented below.

## 6.1 Decoded protocols

- CSV - comma separated values as plain text
- Mavlink - binary protocol used by Pixhawk and other flights controllers
- JSON - text based format represents data as structured text
- GDL90 - binary protocol for ingestion into `Electronic Flight Bag` applications
- ASTERIX - binary protocol used for exchanging surveillance-related information in air traffic management

## 6.2 RAW protocols

- HEX - hexadecimal protocol is unprocessed data sended by aircraft
- BEAST - binary protocol used by program like dump1090
- JSON - it is JSON standard format with raw HEX frames inside structures
- HEXd - it is HEX protocol without extra fields, special prepared for dump1090

## 6.3 Statistics protocol

- CSV - comma separated values as plain text

## 6.4 CSV protocol (AERO)

CSV protocol is simple text protocol, that allows fast integration and analysis of tracked aircrafts. CSV messages start with '`#`' character and ends with "`\r\n`" characters. There are following types of messages:

1. ADS-B Aircraft message,
2. FLARM Aircraft message,
3. UAT Aircraft message,
4. RID Aircraft message,
5. Systems statistics messages,
6. Sensors messages.

**Note:**

In future versions, additional comma-separated fields may be introduced to any CSV protocol message, just before CRC field, which is guaranteed to be at the end of message. All prior fields are guaranteed to remain in same order.

### 6.4.1 CRC

Each CSV message includes CRC value for consistency check. CRC value is calculated using standard CRC16 algorithm and its value is based on every character in frame starting from '#' to last comma ',' (excluding last comma). After calculation, value is appended to frame using hexadecimal coding. Example function for calculating CRC is shown below.

```
uint16_t crc16(const uint8_t* data_p, uint32_t length){
    uint8_t x;
    uint16_t crc = 0xFFFF;
    while (length--){
        x = crc>>8 ^ *data_p++;
        x ^= x>>4;
        crc = (crc<<8) ^ ((uint16_t)(x<<12)) ^ ((uint16_t)(x<<5)) ^ ((uint16_t)x);
    }
    return swap16(crc);
}
```

## 6.5 MAVLink protocol

MAVLink (Micro Air Vehicle Link) is a lightweight, efficient communication protocol designed primarily for unmanned aerial vehicles (UAVs), but it is also used in other robotic systems, including ground and marine vehicles. MAVLink facilitates communication between a ground control station (GCS) and an onboard autopilot, as well as between onboard components such as sensors, cameras, and controllers.(here).

### 6.5.1 Common Use Cases

- Flight Control: Communicating flight commands and receiving telemetry from UAVs.
- Sensor Integration: Transmitting data from onboard sensors to the ground station or other components.
- Mission Planning: Sending waypoints and mission plans to the UAV from the ground station.
- Remote Monitoring: Monitoring the health and status of the UAV during flight.

Overall, MAVLink is a versatile and robust protocol that has become the standard for UAV communication, particularly in the open-source community.

## 6.6 JSON protocols

JSON (JavaScript Object Notation) is a lightweight, text-based data interchange format that is easy for humans to read and write and easy for machines to parse and generate. JSON is widely used for transmitting data between a server and a web application, as well as for configuration files, data storage, and APIs.

Each message is encoded as separate JSON object, without any excess whitespace, consisting of fields described in table below:

```
{
    "src": "ID-0000001",
    "ts": 69061337,
    "ver": 1,
    "gnss": {
    }
}
```

Table 10: Description of main JSON fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| src | – | ID-0000001 | OEM TT serial number. |
| ts | milliseconds | 69061337 | Timestamp in milliseconds, relative to last UTC midnight. Value 69061337 encodes 19:11:01.337. Omitted if unknown. |
| ver | – | 1 | JSON protocol version. See details below. |
| gnss | – | {…} | One or more of the data fields, described in subchapters below. |

**Note:**

The order of JSON object fields in any part of message may vary between firmware revisions and messages.

Some JSON objects have fields, of which values may sometimes be unknown. In this case, they are skipped in JSON output. In following chapters, each of those fields are explicitly marked as omittable.

**Note:**

In case of JSON objects consisting of only omittable fields, if none of them are set, the whole object may be omitted.

The *ver* field indicates JSON protocol version. Future ICD versions may introduce additional fields without chang- ing the version number. If a breaking change occurs in Ground Station with Linux JSON specification, the version number is guaranteed to be incremented.

**Note:**

The version number of JSON protocol described in this document is 1.

### 6.6.1 Status section

The “status” section contains status information related to OEM TT-Multi-RF itself. The example JSON message with this section fields described:

```
{
    "src": "ID-0000001",
    "ts": 69061337,
    "ver": 1,
    "status": {
        "fw": "30903679(Jan 15 2021)",
    }
}
```

Table 11: Description of status JSON fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| src | – | ID-0000001 | See table *Description of main JSON fields.* (page 20). |
| ts | milliseconds | 69061337 | See table *Description of main JSON fields.* (page 20). |
| ver | – | 1 | See table *Description of main JSON fields.* (page 20). |
| status | – | type of message | |
| fw | – | 30903679(Jan 15 2021) | Firmware version, with same syntax as AT+FIRMWARE_VERSION command. Value 30903679 is version 3.9.3.679. |

## 6.7 Statistics protocol

Statistic protocols contains system information. These information can be used to diagnose system health.

### 6.7.1 CSV statistic protocol

Format of that frame is shown below:

`#S:CPL,UPT,CRC\r\n`

CPL - CPU load in %

UPT - Time since statistic was enabled

CRC - Value is calculated using standard CRC16 algorithm

# 7 MAVLink custom messages

In MAVLink protocol there are special fields and messages being used.

## 7.1 HEARTBEAT 0

Device sends a regular HEARTBEAT frame every second. But in this frame field *custom_mode* is being used as a bitfield to send confirmation about some current settings.

Table 12: Descriptions of custom_mode field.

| Value | Flag name | Description |
|---|---|---|
| 0x0001 | FLARM_TX | FLARM_TX is set to 1 |
| 0x0002 | FLARM_RX_PROTOCOL_DECODED_IS_MAVLINK | FLARM decoding set to MAVLink |
| 0x0004 | ADSB_RX_PROTOCOL_DECODED_IS_MAVLINK | ADS-B decoding set to MAVLink |

## 7.2 AEROBITS_FLARM_TX_STATE 9999

Custom message that can be send to device to turn FLARM transmission on and off. The CRC_EXTRA value is 147.

```
<?xml version="1.0"?>
<mavlink>
  <!-- Aerobits contact info: -->
  <!-- company URL: www.aerobits.pl -->
  <!-- email contact: michal.gojtowski@aerobits.pl or mateusz.wdowiak@aerobits.pl␣
↪or mateusz.spychala@aerobits.pl -->
  <!-- mavlink ID range: 9999 -->
  <include>common.xml</include>
  <enums>
    <enum name="AEROBITS_CUSTOM_MODE_FLAG" bitmask="true">
      <description>Flags to report Aerobits state through heartbeat custom_mode flag
↪</description>
      <entry value="1" name="FLARM_TX">
        <description>FLARM_TX is set to 1 (enabled)</description>
      </entry>
      <entry value="2" name="FLARM_RX_PROTOCOL_DECODED_IS_MAVLINK">
        <description>FLARM decoding set to use MAVLink</description>
      </entry>
      <entry value="4" name="ADSB_RX_PROTOCOL_DECODED_IS_MAVLINK">
        <description>ADS-B decoding set to use MAVLink</description>
      </entry>
    </enum>
    <enum name="AEROBITS_FLARM_TX_STATE">
      <description>FLARM TX control flag</description>
      <entry value="0" name="AEROBITS_FLARM_TX_STATE_DISABLED"/>
      <entry value="1" name="AEROBITS_FLARM_TX_STATE_ENABLED"/>
    </enum>
  </enums>
  <messages>
    <message id="9999" name="AEROBITS_SET_FLARM_TX">
      <description>Sets FLARM sending status.</description>
      <field type="uint8_t" name="flarm_tx" enum="AEROBITS_FLARM_TX_STATE">Flarm TX␣
↪(1 sending, 0 is off, anything else is ignored).</field>
    </message>
  </messages>
```

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```
</mavlink>
```

Example of FLARM_TX **ON** message:

```
0xFD, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00, 0x0F, 0x27, 0x00, 0x01, 0xFE, 0xA8
```

Example of FLARM_TX **OFF** message:

```
0xFD, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00, 0x0F, 0x27, 0x00, 0x00, 0x26, 0xB1
```

# 8 ADS-B receiver or transceiver subsystem

## 8.1 Settings

Table 13: Descriptions of ADS-B settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| ADSB_RX_PROTOCOL_DECODED | – | – | CSV | ADS-B decoded protocol:<br>None<br>CSV<br>Mavlink<br>JSON<br>GDL90<br>ASTERIX |
| ADSB_RX_PROTOCOL_INC | 0 | 2 | 0 | Reporting mode of decoded ADS-B targets:<br>0 - once per second, always<br>1 – once per second, if data updated<br>2 – immediately, only after position update |
| ADSB_RX_PROTOCOL_RAW | – | – | None | ADS-B raw protocol:<br>None<br>HEX<br>BEAST<br>JSON<br>HEXd – dump1090 |
| ADSB_STATISTICS | – | – | CSV | ADS-B statistics protocol:<br>None<br>CSV<br>JSON |
| ADSB_TX_EMITTER_CAT | 0 | 21 | 0 | See *ADS-B emitter category values in CSV protocol.* (page 27) |
| ADSB_TX_ENABLED | 0 | 1 | 1 | Enable ADS-B out<br>0 - disable<br>1 - enable |
| ADSB_TX_ICAO | – | – | 0 | ICAO number broadcasted by this device |
| ADSB_TX_IDENT | – | – | – | Identificator broadcasted by this device |
| ADSB_TX_ON_BOOT | | | | Enable ADS-B out on device boot<br>0 - disable<br>1 - enable |
| ADSB_TX_PWR | 0 | 2 | 2 | Trasmiting power of ADS-B<br>0 - 0.5W<br>1 - 1W<br>2 – 2W |
| ADSB_TX_SQUAWK | – | – | 0 | Squawk broadcasted by this device |
| ADSB_SHOW_SELF_ICAO | 0 | 1 | 1 | Show self ICAO:<br>0 - Ignore<br>1 - Show |

continues on next page

Table 13 – continued from previous page

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| ADSB_TX_SURFACE | 0 | 1 | 0 | ADSB out mode<br>0 - airborne<br>1 - surface |
| ADSB_TX_TRANSPONDER_PRESENT | 0 | 1 | 0 | ADS-B out format<br>0 - DF=18<br>1 - DF=17 |

**Important:**

Settings ADSB_TX_PWR=2 (2W) output power available only for trkME PRO device.

### 8.1.1 ADS-B reports

ADS-B reports update received data per aircraft, not per all received airplanes.

For example:

If we have *ADSB_RX_PROTOCOL_INC = 1*, then all received ADS-B airplanes will be updated once per second, one by one, rather than all at the same time.

Another example:

If we have *ADSB_RX_PROTOCOL_INC = 2*, then all received ADS-B airplanes will be updated ASAP, but only if the position data has been changed.

### 8.1.2 ASTERIX settings

**Note:**

Works only if `ADSB_RX_PROTOCOL_DECODED=ASTERIX` is selected

Table 14: Descriptions of Asterix settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| ASTERIX_SAC | 0 | 255 | 1 | Setting SAC for ASTERIX protocol (Visible when ADSB_DECODED_PROTOCOL=5) |
| ASTERIX_SIC | 0 | 255 | 129 | Setting SIC for ASTERIX protocol (Visible when ADSB_DECODED_PROTOCOL=5) |

## 8.2 Protocols

### 8.2.1 ADS-B decoded protocols

#### ADS-B CSV protocol

This message describes state vector of aircraft determined from ADS-B messages and is sent once per second. The message format is as follows:

```
#A:ICAO,FLAGS,CALL,SQ,LAT,LON,ALT_BARO,TRACK,VELH,VELV,SIGS,SIGQ,FPS,NICNAC,ALT_GEO,
ECAT,CRC\r\n
```

Table 15: Descriptions of ADS-B fields.

| #A | Aircraft message start indicator | Example value |
|---|---|---|
| ICAO | ICAO number of aircraft (3 bytes) | 3C65AC |
| FLAGS | Flags bitfield, see table below *Descriptions of ADS-B FLAGS field.* (page 26) | 1 |
| CALL | Callsign of aircraft | N61ZP |
| SQ | SQUAWK of aircraft | 7232 |
| LAT | Latitude, in degrees | 57.57634 |
| LON | Longitude, in degrees | 17.59554 |
| ALT_BARO | Barometric altitude, in feet | 5000 |
| TRACK | Track of aircraft, in degrees [0,360) | 35 |
| VELH | Horizontal velocity of aircraft, in knots | 464 |
| VELV | Vertical velocity of aircraft, in ft/min | -1344 |
| SIGS | Signal strength, in dBm | -92 |
| SIGQ | Signal quality, in dB | 2 |
| FPS | Number of raw MODE-S frames received from aircraft during last second | 5 |
| NICNAC | NIC/NAC bitfield, see table 11 (v2.6.0+) | 31B |
| ALT_GEO | Geometric altitude, in feet (v2.6.0+) | 5000 |
| ECAT | Emitter category, *ADS-B emitter category values in CSV protocol.* (page 27) (v2.7.0+) | 14 |
| CRC | CRC16 (described in CRC section) | 2D3E |

Table 16: Descriptions of ADS-B FLAGS field.

| Value | Flag name | Description |
|---|---|---|
| 0x0001 | PLANE_ON_THE_GROUND | The aircraft is on the ground |
| 0x0002 | PLANE_IS_MILITARY | The aircraft is military object |
| 0x0100 | PLANE_UPDATE_ALTITUDE_BARO | During last second, barometric altitude of this aircraft was updated |
| 0x0200 | PLANE_UPDATE_POSITION | During last second, position (LAT & LON) of this aircraft was updated |
| 0x0400 | PLANE_UPDATE_TRACK | During last second, track of this aircraft was updated |
| 0x0800 | PLANE_UPDATE_VELO_H | During last second, horizontal velocity of this aircraft was updated |
| 0x1000 | PLANE_UPDATE_VELO_V | During last second, vertical velocity of this aircraft was updated |
| 0x2000 | PLANE_UPDATE_ALTITUDE_GEO | During last second, geometric altitude of this aircraft was updated |

The NIC/NAC bitfield is transmitted in big endian hexadecimal format without leading zeros. Table 11 describes its bitfield layout. The meaning of NIC/NAC indicators is exactly the same as described in ED-102A.

Table 17: Structure of NIC/NAC bitfield in CSV protocol.

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Reserved* | | | | $NAC_p$ | | | | $NAC_v$ | | | $NIC_{baro}$ | $NIC$ | | | |

The emitter category values returned in ecat field is shown in table below:

Table 18: ADS-B emitter category values in CSV protocol.

| "ecat" value | Description |
|---|---|
| 0 | Unknown. |
| 1 | Light (below 15500 lbs.). |
| 2 | Small (15500 - 75000 lbs.). |
| 3 | Large (75000 - 300000 lbs.). |
| 4 | High-Vortex Large (aircraft such as B-757). |
| 5 | Heavy (above 300000 lbs.). |
| 6 | High performance (above 5g acceleration and above 400 knots). |
| 7 | Rotorcraft. |
| 8 | Reserved. |
| 9 | Glider, Sailplane. |
| 10 | Lighter-Than-Air. |
| 11 | Parachutist, Skydiver. |
| 12 | Ultralight, hang-glider, paraglider. |
| 13 | Reserved. |
| 14 | Unmanned Aerial Vehicle. |
| 15 | Space, Trans-atmospheric Vehicle. |
| 16 | Reserved. |
| 17 | Surface Vehicle - Emergency Vehicle. |
| 18 | Surface Vehicle - Service Vehicle. |
| 19 | Point Obstacle (includes Tethered Balloons). |
| 20 | Cluster obstacle. |
| 21 | Line obstacle. |

If data of any field of frame is not available, then it is transmitted as empty. For example:

```
#A:4D240E,3F00,,7273,53.47939,14.55892,28550,23,510,1408,-71,5,9,938,28850,,A9FE\r\n
```

```
#A:4D240E,3F00,,7273,53.52026,14.58906,29075,23,506,1600,,,,,,,C1EC\r\n
```

**Note:**

**SIGS** and **SIGQ** fields are updated based on raw MODE-S frames. They are calculated from frames received in last second. If there were no receiver frames (FPS=0), those fields will not be updated.

**Note:**

**LAT** and **LON** are transmitted differently for aircraft on the surface and in airborne. ADSB messages send from airborne aircrafts are unambiguous. Surface messages needs reference position which is used to determine final position of the aircraft. Aerobits devices if it is possible use their own position as reference. For devices without GNSS functionality reference position is set using last received airborne aircraft.

### ADS-B MAVLink protocol

The device can be switched to use MAVLink protocol. This can be achieved by altering ADSB_RX_PROTO- COL_DECODED setting. When MAVLink protocol is used, module is sending list of aircraft's every second. MAVLink messages have standardized format, which is well described on official protocol webpage (here).

### ADS-B Aircraft message

Aircrafts are encoded using ADSB_VEHICLE message (ADSB_VEHICLE). MAVLink message contains several data fields which are described below.

Table 19: MAVLink ADSB_VEHICLE message description.

| Field Name | Type | Description |
|---|---|---|
| ICAO_address | uint32_t | ICAO address |
| lat | int32_t | Latitude, expressed as degrees * 1E7 |
| lon | int32_t | Longitude, expressed as degrees * 1E7 |
| altitude | int32_t | Barometric/Geometric Altitude (ASL), in millimeters |
| heading | uint16_t | Course over ground in centidegrees |
| hor_velocity | uint16_t | The horizontal velocity in centimeters/second |
| ver_velocity | uint16_t | The vertical velocity in centimeters/second, positive is up |
| flags | uint16_t | Flags to indicate various statuses including valid data fields |
| squawk | uint16_t | Squawk code |
| altitude_type | uint8_t | Type from ADSB_ALTITUDE_TYPE enum |
| callsign | char[9] | The callsign, 8 chars + NULL |
| emitter_type | uint8_t | Type from ADSB_EMITTER_TYPE enum |
| tslc | uint8_t | Time since last communication in seconds |

### ADS-B ASTERIX protocol

The device can be switched to use ASTERIX binary protocol. This can be achieved by altering ADSB_RX_PROTOCOL_DECODED setting. When ASTERIX protocol is used, module is sending list of aircrafts every second. Aircrafts are encoded using I021 ver. 2.1 message. Also, once per second the device sends a heartbeat message using I023 ver. 1.2 format in Ground Station Status variant. When running Transceiver TR-1F with ASTERIX, ASTERIX_SIC and ASTERIX_SAC settings are available.

For further reference of parsing ASTERIX frames, please see relevant official documentation:

- I021 messages: CAT021 - EUROCONTROL Specification for Surveillance Data Exchange Part 12: Category 21
- I023 messages: CAT023 - EUROCONTROL Specification for Surveillance Data Exchange Part 16: Category 23

### ADS-B GDL90 protocol

The device can be configured to use GDL90 binary protocol. This can be achieved by altering ADSB_RX_PROTOCOL_DECODED setting. When GDL90 protocol is used, module is sending list of aircrafts every second. Aircrafts are encoded using Traffic Report (#20) message. Also, once per second device sends Heartbeat (#0), Ownship Report (#10) and Ownship Geometric Altitude (#11) messages.

For further reference of parsing GDL90 frames see relevant documentation: GDL90 Data Interface Specification

The ADS-B vehicle may transmit barometric, as well as geometric altitude.The ADSB_RX_PROTOCOL setting allows for

toggling Traffic Report altitude transmit priority:

- When set to 0, altitude field will be filled with geometric altitude first. If not available, barometric altitude will be used.
- When set to 1, barometric altitude wil be preferred.

**Note:**

Currently, only ADS-B aircrafts are reported via this protocol. To obtain information about aircrafts reported from FLARM hardware, please use any other supported protocol.

### ADS-B Decoded JSON protocol

The "adsb" section contains aircraft information determined by OEM TT-Multi-RF internal ADS-B processing engine. The messages are encoded as JSON array with at least one entry. Each entry is an object consisting of fields denoted in table *adsb* (page 30).. Reports for each ADS-B aircraft are updated once every second.


```
{
    "src": "33-0000683",
    "ts": 69061337,
    "ver": 1,
    "adsb": [
        {
            "icao": "780A3F",
            "flags": {
                "groundState": false,
                "updAltBaro": true,
                "updAltGeo": true,
                "updPosition": true,
                "updTrack": true,
                "updVeloH": true,
                "updVeloV": true
            },
            "sigStr": -67,
            "sigQ": 9,
            "lat": 34.39696,
            "lon": -85.1055,
            "altBaro": 35000,
            "geoAlt": 36975,
            "track": 143.78,
            "velH": 528,
            "velV": 0,
            "mag_heading": 123.1,
            "true_heading": 125.5,
            "ias": 100,
            "tas": 100,
            "roll": 2.1,
            "nav_qnh": 1013.59,
            "nav_altitude_mcp": 35008,
            "nav_altitude_fms": 35008,
            "nav_modes": {
                "althold": false,
                "approach": false,
                "autopilot": false,
```


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```
                "lnav": false,
                "tcas": true,
                "vnav": false
            },
            "nav_heading": 151.17,
            "call": "CPA3174",
            "ecat": 5,
            "squawk": "5730",
            "nacp": 9,
            "nacv": 1,
            "nicBaro": 1,
            "nic": 8,
            "gva": 2,
            "ts1s": 1157704704,
        }
    ]
}
```


Table 20: Descriptions of JSON ADS-B section fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| src | – | ID-0000001 | See table *Description of main JSON fields.* (page 20). |
| ts | milliseconds | 69061337 | See table *Description of main JSON fields.* (page 20). |
| ver | – | 1 | See table *Description of main JSON fields.* (page 20). |
| adsb | – | type of message | |
| icao | – | DABABE | ICAO address, 24-bit value encoded in uppercase hexadecimal, with leading zeros. |
| flags | – | type of message | |
| ground-State | bool | True | |
| updPosi-tion | bool | True | |
| updTrack | bool | True | |
| updVeloH | bool | True | |
| updVeloV | bool | True | |
| updAlt-Geo | bool | True | |
| sigStr | dBm | -95 | Signal strength, in dBm. |
| sigQ | dB | 2 | Signal quality, in dB. |
| lat | – | 53.42854 | Latitude. Omitted if position is unknown. |
| lon | – | 14.55281 | Longitude. Omitted if position is unknown. |
| altBaro | ft | 1725 | Barometric altitude, in feet. Omitted if unknown. |
| geoAlt | ft | 1712 | Geometric altitude, in feet. Omitted if unknown. |
| track | degree ° | 72.18 | Track angle, 0°..360°. Omitted if unknown. |
| velH | knots | 10.5 | Horizontal velocity, in knots. Omitted if unknown. |
| velV | ft/min | 50 | Vertical velocity, in ft/min, positive value is upwards. Omitted if unknown. |
| mag_head-ing | degree ° | 123.1 | Magnetic Heading. |
| true_head-ing | degree ° | 125.5 | True Heading. |
| ias | knots | 100 | Indicated airspeed. |

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Table 20 – continued from previous page

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| tas | knots | 100 | True airspeed. |
| roll | degree ° | 2.1 | Aircraft roll angle. |
| nav_qnh | hPa | 1013.59 | Aviation "Q" Code for "Nautical Height" |
| nav_altitude_mcp | ft | 35008 | Refence altitude manually entered into the MCP/FCU |
| nav_altitude_fms | ft | 35008 | Altitude selected by the Flight Management System |
| nav_modes | – | type of message | |
| althold | bool | False | |
| approach | bool | False | |
| autopilot | bool | False | |
| lnav | bool | False | |
| tcas | bool | False | |
| vnav | bool | False | |
| nav_heading | degree ° | 43.1 | Heading selected by the Flight Management System |
| call | – | TEST8 | Callsign, up to 8 chars. Omitted if unknown. |
| ecat | – | 13 | Emitter category code, see table *ecat* (page 31).. Omitted if unknown. |
| squawk | – | 7232 | Squawk, 8 octal digits. Omitted if unknown. |
| nacp | – | 3 | $NAC_p$ value, as described in ED-102A. Omitted if value is 0 (unknown). |
| nacv | – | 1 | $NAC_v$ value, as described in ED-102A. Omitted if value is 0 (unknown). |
| nicBaro | – | 1 | $NIC_BARO$ value, as described in ED-102A. Omitted if value is 0 (unknown). |
| nic | – | 2 | NIC value, as described in ED-102A. Omitted if value is 0 (unknown). |
| gva | – | 2 | GVA value, as described in ED-102A. Omitted if value is 0 (unknown). |
| ts1s | – | 1157704704 | MLAT TS value: number of nanoseconds elapsed from the last PPS pulse |
| ts24h | – | 1157704704 | MLAT TS value: number of nanoseconds elapsed from midnight |

The emitter category values returned in *ecat* field is shown in table below:

Table 21: ADS-B emitter category values in JSON protocol.

| "ecat" value | Description |
|---|---|
| 0 | Unknown. |
| 1 | Light (below 15500 lbs.). |
| 2 | Small (15500 - 75000 lbs.). |
| 3 | Large (75000 - 300000 lbs.). |
| 4 | High-Vortex Large (aircraft such as B-757). |
| 5 | Heavy (above 300000 lbs.). |
| 6 | High performance (above 5g acceleration and above 400 knots). |
| 7 | Rotorcraft. |
| 8 | Reserved. |
| 9 | Glider, Sailplane. |
| 10 | Lighter-Than-Air. |
| 11 | Parachutist, Skydiver. |
| 12 | Ultralight, hang-glider, paraglider. |

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Table 21 – continued from previous page

| "ecat" value | Description |
|---|---|
| 13 | Reserved. |
| 14 | Unmanned Aerial Vehicle. |
| 15 | Space, Trans-atmospheric Vehicle. |
| 16 | Reserved. |
| 17 | Surface Vehicle - Emergency Vehicle. |
| 18 | Surface Vehicle - Service Vehicle. |
| 19 | Point Obstacle (includes Tethered Balloons). |
| 20 | Cluster obstacle. |
| 21 | Line obstacle. |

### 8.2.2 ADS-B raw protocols

#### ADS-B HEX protocol

This protocol is dedicated for raw Mode-A/C/S frames acquisition. In this special mode of operation, output frames are not processed, nor validated in any way. All processing, checksum validation, etc. must be done on user's side. All raw frames, regardless of type, start with '*' and end with ';' ASCII characters, whereas their content is encoded in hexadecimal format, MSB first. At the end, extended fields are appended to frame.

```
*RAW_FRAME;(SIGS,SIGQ,TS1s,TS24h)\r\n
```

Table 22: Descriptions of RAW extended messages.

| Var. | Description | Example |
|---|---|---|
| SIGS | Signal strength in dBm | -95 |
| SIGQ | Signal quality in dB | 2 |
| TS1s | Timestamp for multilateration. Time from last PPS pulse, hex format, in nanoseconds. | 75BCD15 (0.123456789s) |
| TS24h | Timestamp for multilateration. Time from midnight, hex format, in nanoseconds. | 2B5792B49315 (47655.123456789s = 13:14:15.123456789) |

**Note:**

To use multilateration, TS value must be calibrated using calibration value from statistics message.

**Note:**

TS field is available when precise PPS signal from GNSS source is applied to module to 1PPS pin.

### Mode-S raw frames

Short and long frames consist accordingly of 7 or 14 data bytes. Examples of raw MODE-S frames:

- Short frame: `*5D4B18FFFC710B;(-70,3,75BCD15, 2B5792B49315)\r\n`
- Long frame: `*8D4CA7E858B9838206BA422BBD7B;(-71,4,75BCD15, 2B5792B49315)\r\n`

### Mode-AC raw frames

**Note:**

It is impossible to reliably distinguish between MODE-A and MODE-C frames based only on received signal on 1090MHz.

Starting with firmware 2.7.0, each frame is interpreted as squawk and formatted as 4 octal digits. They can also be read as binary frame with 4 hexadecimal digits, with bits being set as shown in table below.

Table 23: Description of bits in raw Mode-A/C frames in new protocol version.

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A4 | A2 | A1 | | B4 | B2 | B1 | | C4 | C2 | C1 | | D4 | D2 | D1 |

Examples of raw MODE-A/C frames using this format are as follows:

- `*0363;(979,151,75BCD15, 2B5792B49315)\r\n`
- `*7700;(995,167,75BCD15, 2B5792B49315)\r\n`

### ADS-B HEXd protocol

**Important:**

This is RAW HEX protocol standardized for dump1090, without additional fields after `;`.

### ADS-B Beast protocol

Original specification: documentation

### Format

All data is escaped: real byte `0x1a` becomes `0x1a 0x1a` in a message. Note that synchronization is still complex, since `0x1a 0x31` may be the start of a frame or mid-data, depending on what preceded it. To synchronize, you must see, in order:

- anything else but `0x1a`
- `0x1a`
- `0x31` or `0x32` or `0x33`

Escaping makes frame length for a given type variable, up to `2 + (2 * data_length_sum)`

### Frame structure

- `0x1a`
- 1 byte frame type (see types below)
- 6 byte MLAT timestamp (see below)

### Frame types

- `0x31`: Mode-AC frame
  - 1 byte RSSI
  - 2 byte Mode-AC data
- `0x32`: Mode-S short frame
  - 1 byte RSSI
  - 7 byte Mode-S short data
- `0x33`: Mode-S long frame
  - 1 byte RSSI
  - 14 byte Mode-S long data

### MLAT timestamp

The MLAT timestamp included in each frame is the big-endian value of a 12 MHz counter at the time of packet reception. This counter isn't calibrated to external time, but receiving software can calculate its offset from other receiving stations across multiple packets, and then use the differences between station receive timing to calculate signal source position.

FlightAware's dump1090 fork sends `0x00 0x00 0x00 0x00 0x00 0x00` when it has no MLAT data.

### RSSI

FlightAware's dump1090 fork sends `0xff` when it has no RSSI data.

### Examples

- `0x1a 0x32 0x08 0x3e 0x27 0xb6 0xcb 0x6a 0x1a 0x1a 0x00 0xa1 0x84 0x1a 0x1a 0xc3 0xb3 0x1d`
  - `0x1a`: Frame start
  - `0x32`: Mode-S short frame
  - `0x08 0x3e 0x27 0xb6 0xcb 0x6a`: MLAT counter value
    - Decimal: 9063047285610
  - `0x1a 0x1a`: Signal level
    - Unescaped: `0x1a`
    - Decimal: 26
    - `26 / 255 * 100% = 10%`
  - `0x00 0xa1 0x84 0x1a 0x1a 0xc3 0xb3 0x1d`: Mode-S short data
    - Unescaped: `0x00 0xa1 0x84 0x1a 0xc3 0xb3 0x1d`

### ADS-B raw JSON protocol

The "raw" section contains raw, unprocessed and unfiltered ADS-B frames gathered by OEM TT-Multi-RF , which can be used e.g. for multilateration and other low-level analysis. Raw messages are encoded as JSON array with at least one entry. Each array entry is a separate array containing values as described below

```
{
    "src": "ID-0000001",
    "ts": 69061337,
    "ver": 1,
    "raw": [
        [
            "18A9725A4C842D",
            -78,
            2,
            "295CAB573A77"
```

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```
            ]
        ]
}
```

Table 24: Descriptions of JSON ADS-B Raw section fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| src | – | ID-0000001 | See table *Description of main JSON fields.* (page 20). |
| ts | milliseconds | 69061337 | See table *Description of main JSON fields.* (page 20). |
| ver | – | 1 | See table *Description of main JSON fields.* (page 20). |
| raw | – | type of message | |
| | hexadecimal | 18A9725A4C842D | Raw frame bytes, formatted as uppercase hexadecimal. Short Mode-S frames encode 7 bytes, long frames contain 14 bytes. |
| | dBm | -78 | Signal strength, in dBm. |
| | dB | 2 | Signal quality, in dB. |
| | nanoseconds | 295CAB573A77 | UTC-calibrated time of reception, formatted as uppercase hexadecimal, in nanoseconds. Example translates to 12:37:57.988350583 |

**Warning:**

Due to constrained throughput of device communication, transmission of some raw frames may be skipped in heavy aircraft traffic situations.

### 8.2.3 ADS-B statstics protocols

#### ADS-B CSV statistic protocol

This message contains some useful statistics about operation of module. Format of that frame is shown below:

`#AS:FPSS,FPSAC,CALIB,CRC\r\n`

FPSS - All received mode S frames per second

FPSAC - All received mode A/C frames per second

CALIB - Real uC frequency based on GNSS module (PPS)

CRC - Value is calculated using standard CRC16 algorithm

# 9 FLARM receiver or transceiver subsystem

**Important:**

This part of documentation is relevant only for devices which have **FLARM IN/OUT** functionality

**Attention:**

The DRS-1 or MP1 devices are receivers only. Despite possible availability of FLARM out settings, some products such as the MP1, GS2L and DRS-1 do not support FLARM out. Any settings will not affect the transmit system, it is recommended to set all transmit settings to 0.

## 9.1 FLARM ID calculation

Aerobits device equipped with FLARM out has a unique FLARM ID which consist of fixed Aerobits prefix 30 (hex) and a unique part. Unique part can be calculated using the formula:

$$Unique\ part = Device_{SN} + Offset$$

where the offsets for Aerobits devices are as follows:

| Device | Number (dec) |
|---|---|
| TT-SF1 | 1024 |
| TT-SF2 | 2048 |
| TR-1F | 4046 |
| DRS-1F | 5096 |
| TR-2F | 6096 |
| trkME | 8096 |
| TT-SF2n | 10096 |
| trkME PRO | 12096 |

$$FLARM\ ID = 30 < Unique\ part\ (hex) >$$

**Note:**

Flarm ID needs to be 6 digit hexadecimal. When unique value is smaller than 4 digit it will be filled with leading 0.

Example:

Device TT-SF1 with SN = 99

Unique part = 1024 + 99 = 1123 (dec) = 463 (hex)

Flarm ID = 300463

## 9.2 Settings

Table 25: Descriptions of FLARM settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| FLARM_RX_PROTOCOL_DECODED | – | – | CSV | FLARM decoded protocol:<br>None<br>CSV<br>Mavlink<br>JSON<br>ASTERIX |
| FLARM_STATISTICS | – | – | CSV | FLARM statistics protocol:<br>None<br>CSV<br>JSON |
| FLARM_TX | 0 | 1 | 1 | Enable FLARM out:<br>0 - disable<br>1 – enable |
| FLARM_TX_AIRCRAFT_TYPE | 0 | 15 | 13 | Flarm aircraft type:<br>0 – UNKNOWN<br>1 – GLIDER<br>2 – TOWPLANE<br>3 – HELICOPTER<br>4 – PARACHUTE<br>5 – DROPPLANE<br>6 – FIXED_HG<br>7 – SOFT_HG<br>8 – ENGINE<br>9 – JET<br>10 – RESERVED<br>11 – BALLOON<br>12 – AIRSHIP<br>13 – UAV<br>15 - STATIC |

## 9.3 Protocols

### 9.3.1 FLARM decoded protocols

#### FLARM CSV protocol

This message describes state vector of aircraft received through FLARM radio and is sent once per second.

```
#ALRM:TYPE,ID,ID_TYPE,AIRCRAFT_TYPE,ALARM_LVL,LAT,LON,ALT,TRACK,VELH,VELV,MOVE_MODE,
REL_N,REL_E,R_DIST_H,REL_DIST_V,NEAR_DIST,DIR,STEALTH,NOTRACK\r\n
```

Table 26: Descriptions of FLARM fields.

| #ALRM | FLARM Aircraft message start indicator | Example value |
|---|---|---|
| TYPE | Target type. 0: stationary, 2: regular aircraft. | 0 |
| ID | Id value, in hexadecimal format. | 1600BF |
| ID_TYPE | Id type: 0: randomized id value, 1: ICAO, 2: FLARM id | 2 |
| AIRCRAFT_TYPE | Target type *Descriptions of FLARM aircraft types field.* (page 39) | 13 |

continues on next page

Table 26 – continued from previous page

| #ALRM | FLARM Aircraft message start indicator | Example value |
|---|---|---|
| ALARM_LVL | Alarm threat level (0-3). 0: no danger, 3: high danger. | 0 |
| LAT | Latitude, in 1−7 degrees. | 535668736 |
| LON | Longitude, in 1−7 degrees. | 163101952 |
| ALT | Altitude, in meters. | 61 |
| TRACK | Track angle, in degrees. | 90 |
| VELH | Ground speed, in m/s. | 0 |
| VELV | Climbing rate, in m/s. | 20 |
| MOVE_MODE | Movement mode. 1: Stationary (not flying), 4: circling right, 5: cruising, 7: circling left. | 1 |
| REL_N | Distance to target on South-North axis, in meters. | 2 |
| REL_E | Distance to target on West-East axis, in meters. | -3 |
| REL_DIST_H | Relative horizontal distance, in meters. | 3 |
| REL_DIST_V | Relative vertical separation, in meters. Value is positive if target is on higher altitude. | 8 |
| NEAR_DIST | Target proxy distance, for priority sorting in NEAREST mode. | 9 |
| DIR | Relative bearing in degrees from the own position and true ground track to the target's position. Value ranges from -180 to 180, positive values are clockwise. | -56 |
| STEALTH | Set to 1 if target has stealth (privacy) flag set, otherwise 0. | 0 |
| NOTRACK | Set to 1 if target has notrack flag set, otherwise 0. | 0 |

Table 27: Descriptions of FLARM aircraft types field.

| Aircraft type index | Description |
|---|---|
| 0 | Reserved. |
| 1 | Glider, Motor glider. |
| 2 | Tow plane, tug plane. |
| 3 | Helicopter, gyrocopter, rotocraft. |
| 4 | Skydiver, parachute. |
| 5 | Drop plane for skydivers. |
| 6 | Hang glider (hard). |
| 7 | Hang glider (soft). |
| 8 | Aircraft with reciprocating engine. |
| 9 | Aircraft with jet / turboprop engine. |
| 10 | Reserved. |
| 11 | Balloon (hot, gas, weather, static). |
| 12 | Airship, blimp, zeppelin. |
| 13 | Unmanned Aerial Vehicle (UAV). |
| 14 | Reserved. |
| 15 | Static obstacle. |

### FLARM MAVLink protocol

Aircrafts reported by FLARM use ADSB_VEHICLE message in same format as described in *MAVLink ADSB_VEHICLE message description.* (page 28) section, with following restrictions:

- The FLARM "Aircraft Type" field is translated to MAVLink "Emitter Category" field as shown in table below.
- ICAO field contains FLARM id value.

Table 28: FLARM Aircraft Type to Emitter Category translation.

| Aircraft Type Index | Aircraft Type description | Emitter Category Index | Emitter Category description |
|---|---|---|---|
| 0 | Reserved | 0 | No information |
| 1 | Glider, Motor glider | 9 | Glider |
| 2 | Tow plane, tug plane | 1 | Light |
| 3 | Helicopter, gyrocopter, rotocraft | 7 | Rotorcraft |
| 4 | Skydiver, parachute | 11 | Parachute |
| 5 | Drop plane for skydivers | 1 | Light |
| 6 | Hang glider (hard) | 12 | Ultra light |
| 7 | Hang glider (soft) | 12 | Ultra light |
| 8 | Aircraft with reciprocating engine | 1 | Light |
| 9 | Aircraft with jet / turboprop engine | 3 | Large |
| 10 | Reserved | 0 | No information |
| 11 | Balloon (hot, gas, weather, static) | 10 | Lighter than air |
| 12 | Airship, blimp, zeppelin. | 10 | Lighter than air |
| 13 | Unmanned Aerial Vehicle (UAV) | 14 | UAV |
| 14 | Reserved | 0 | No information |
| 15 | Static obstacle | 0 | No information |

### FLARM Collision message

Apart from ADS-B messages, FLARM subsystem emits COLLISION messages (Mavlink documentation). Detailed information about given aircraft can be obtained from ADSB_VEHICLE message directly preceding given COLLISION message.

### FLARM ASTERIX protocol

All aircrafts detected by FLARM hardware are reported in same way as ADS-B vehicles, with following restrictions:

- FLARM messages are using SIC = 161, SAC = 0 values. This is the preferred way to distinguish FLARM messages from ADS-B.
- The I021/040 (Target Report Descriptor) field has ATP subfield set to 3 if aircraft id is not ICAO-based (e.g. FLARM id, random id).
- The I021/210 (MOPS Version) field has VNS subfield set to 1.
- The I021/170 (Target Identification) is filled with `STEALTH` value if FLARM "stealth" flag is set, or `NOTRACK` value if "notrack" flag is set.
- The I021/020 Emitter Category value is determined from FLARM "Aircraft Type" field as shown below.

Table 29: FLARM Aircraft Type to ASTERIX Emitter Category translation.

| Aircraft Type Index | Aircraft Type description | Emitter Category Index | Emitter Category description |
|---|---|---|---|
| 0 | Reserved | 0 | No information |
| 1 | Glider, Motor glider | 9 | Glider |
| 2 | Tow plane, tug plane | 1 | Light |
| 3 | Helicopter, gyrocopter, rotocraft | 7 | Rotorcraft |
| 4 | Skydiver, parachute | 11 | Parachute |
| 5 | Drop plane for skydivers | 1 | Light |
| 6 | Hang glider (hard) | 12 | Ultra light |
| 7 | Hang glider (soft) | 12 | Ultra light |
| 8 | Aircraft with reciprocating engine | 1 | Light |
| 9 | Aircraft with jet / turboprop engine | 3 | Large |
| 10 | Reserved | 0 | No information |
| 11 | Balloon (hot, gas, weather, static) | 10 | Lighter than air |
| 12 | Airship, blimp, zeppelin. | 10 | Lighter than air |
| 13 | Unmanned Aerial Vehicle (UAV) | 14 | UAV |
| 14 | Reserved | 0 | No information |
| 15 | Static obstacle | 0 | No information |

### FLARM JSON protocol

The “flarm” section contains aircraft information determined by OEM TT-Multi-RF internal FLARM processing engine. The messages are encoded as JSON array with at least one entry. Each entry is an object consisting of fields denoted in table *FLARM* (page 42).. Reports for each FLARM aircraft are updated once every second.

```
{
    "src": "ID-0000001",
    "ts": 69061337,
    "ver": 1,
    "flarm": [
        {
            "idType": 1,
            "id": "DABABE",
            "type": 13,
            "danger": 1,
            "lat": 53.42854,
            "lon": 14.55281,
            "alt": 1725,
            "track": 72.18,
            "hVelo": 10.5,
            "vVelo": 50,
            "movMode": 5,
            "stealth": 1,
            "notrack": 1

        }
    ]
}
```

Table 30: Descriptions of JSON FLARM section fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| src | – | ID-0000001 | See table *Description of main JSON fields.* (page 20). |
| ts | milliseconds | 69061337 | See table *Description of main JSON fields.* (page 20). |
| ver | – | 1 | See table *Description of main JSON fields.* (page 20). |
| flarm | – | type of message | |
| idType | – | 1 | Aircraft id type. 0: randomized, 1: ICAO, 2: FLARM. |
| id | – | DABABE | Aircraft id, 32-bit value encoded in uppercase hexadecimal, with leading zeros. |
| type | – | 13 | Aircraft type, see table *FLARM aircraft type category values in JSON protocol.* (page 42). |
| fps | fps | 2 | Number of raw Mode-S frames received from aircraft during last second. |
| lat | – | 53.42854 | Latitude. Omitted if position is unknown. |
| lon | – | 14.55281 | Longitude. Omitted if position is unknown. |
| alt | m | 1725 | Geodetic altitude, in meters. |
| track | degree ° | 72.18 | Track angle, 0°..360°. Omitted if unknown. |
| hVelo | m/s | 10.5 | Horizontal velocity, in m/s. Omitted if unknown. |
| vVelo | m/s | 50 | Vertical velocity, in m/s., positive value is upwards. Omitted if unknown. |
| movode | – | 5 | Movement mode.1: stationary, 4: circling right, 5: flying,7: circling left. |
| stealth | – | 1 | Set to 1 if target has Stealth flag set, otherwise omitted. |
| notrack | – | 1 | Set to 1 if target has Notrack flag set, otherwise omitted. |

The list of possible FLARM “Aircraft type” values returned in *type* field is shown in table *ECAT-FLARM* (page 42).

Table 31: FLARM aircraft type category values in JSON protocol.

| “ecat” value | Description |
|---|---|
| 0 | Reserved. |
| 1 | Glider, Motor glider. |
| 2 | Tow plane, tug plane. |
| 3 | Helicopter, gyrocopter, rotocraft. |
| 4 | Skydiver, parachute. |
| 5 | Drop plane for skydivers. |
| 6 | Hang glider (hard). |
| 7 | Hang glider (soft). |
| 8 | Aircraft with reciprocating engine. |
| 9 | Aircraft with jet / turboprop engine. |
| 10 | Reserved. |
| 11 | Balloon (hot, gas, weather, static). |
| 12 | Airship, blimp, zeppelin. |
| 13 | Unmanned Aerial Vehicle (UAV). |
| 14 | Reserved. |
| 15 | Static obstacle. |

### 9.3.2 FLARM statstics protocols

#### FLARM CSV statistic protocol

This message contains some useful statistics about operation of module. Format of that frame is shown below:

```
#FS:FPS,VFR,ERD,ERI,ERW,ERR,FTX\r\n
```

FPS - All received frames per second

VFR - All valid received frames per second

ERD - For developer purpose only

ERI - For developer purpose only

ERW - For developer purpose only

ERR - For developer purpose only

FTX - All sent frames per second

#### FLARM JSON statistic protocol

Format of that frame is shown below:

```
{"ver":1,"src":"32-0000009","flarm_statistics":[{"errorDebug":ERD,"errorInfo":ERI,
"errorWarning":ERW,"errorReal":ERR,"frameReceived":VFR,"frameReceivedAll":FPS,
"frameSent":FTX}]}\r\n
```

FPS - All received frames per second

VFR - All valid received frames per second

ERD - For developer purpose only

ERI - For developer purpose only

ERW - For developer purpose only

ERR - For developer purpose only

FTX - All sent frames per second

# 10 GNSS receiver subsystem

## 10.1 Settings

Table 32: Descriptions of GNSS settings

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| GNSS_RX_PROTOCOL_RAW | NONE | NMEA | NMEA | GNSS_RX RAW protocol select<br>NONE<br>NMEA |
| GNSS_RX_PROTOCOL_DECODED | NONE | JSON | NONE | GNSS_RX Decoded protocol select<br>NONE<br>JSON |

## 10.2 Protocols

### 10.2.1 GNSS NMEA RAW protocol

**Note:**

For more information about all NMEA GNSS fields go to docs.

### 10.2.2 GNSS JSON DECODED protocol

The *gnss* section contains basic GNSS information. This message is sent once per second. The example JSON message with "gnss" section fields described:

```
{
    "src": "ID-0000001",
    "ts": 69061337,
    "ver": 1,
    "gnss": {
        "fix": 1,
        "lat": 53.42854,
        "lon": 14.55281,
        "altWgs84": 499.6,
        "altMsl": 508.6,
        "track": 127.3,
        "hVelo": 10.5,
        "vVelo": 25,
        "gndSpeed": [
            5.2,
            2.1
        ],
        "acc": {
            "lat": 5.2,
            "lon": 2.1,
            "alt": 3.6
        },
        "nacp": 12,
        "nacv": 2,
```

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```
        "nic": 12
    }
}
```

Table 33: Descriptions of JSON GNSS section fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| gnss | | | Type of message |
| fix | – | 1 | Set to 1 if onboard GNSS currently has fix, otherwise 0. |
| lat | – | 53.42854 | Last known latitude. Omitted if there was no GNSS fix since device boot. |
| lon | – | 14.55281 | Last known longitude. Omitted if there was no GNSS fix since device boot. |
| altWgs84 | – | 499.6 | Last known WGS-84 Altitude, in meters. Omitted if there was no GNSS fix since device boot. |
| altMsl | – | 508.6 | Last known MSL Altitude, in meters. Omitted if there was no GNSS fix since device boot. |
| track | – | 127.3 | Track angle, 0°..360°, relative to true north. Omitted if unknown. |
| hVelo | – | 10.5 | Horizontal velocity, in knots. Omitted if unknown. |
| vVelo | – | 25 | Vertical velocity, in m/s. Positive value is upwards. Omitted if unknown. |
| gndSpeed | knots | [5.2,2.1] | Ground speed in east-west and north-south axes respectively, in knots. Positive value is East and North. Derived from track / hVelo values. Omitted if unknown. |
| acc | m/s2 | struct | Acceleration in all 3 dimensions |
| lat | – | 5.2 | Accuracy of latitude, in meters. Omitted if unknown. |
| lon | – | 2.1 | Accuracy of longitude, in meters. Omitted if unknown. |
| alt | – | 3.6 | Accuracy of altitude, in meters. Omitted if unknown. |
| nacp | – | 12 | Navigational Accuracy Category for Position value, as defined in ED-282. Omitted if unknown. |
| nacv | – | 2 | Navigational Accuracy Category for Velocity value, as defined in ED-282. Omitted if unknown. |
| nic | – | 12 | Navigation Integrity Category as defined in ED-282. Omitted if unknown. |

# 11 RemoteID transmitter subsystem

Aerobits devices with **RemoteID OUT** functionality broadcast UAV data using Bluetooth and/or WiFi interface. These data can be captured by any device with RemoteID IN functionality which supports ASTM/ASD-STAN standard including modern smartphones with proper mobile applications.

## 11.1 Settings

The following settings allow users to control the broadcasting feature and configure specific Remote ID data.

Table 34: Descriptions of RemoteID settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| DRONE_ID_ADVERTISING_ENABLE | 0 | 1 | 1 | Advertising enable |
| DRONE_ID_BASIC_BROADCAST_PERIOD | 200 | 3000 | 1500 | Basic frame broadcast period in [ms] |
| DRONE_ID_BROADCAST_BLUETOOTH_4 | 0 | 1 | 1 | Enable Bluetooth 4.0 broadcast |
| DRONE_ID_BROADCAST_BLUETOOTH_5 | 0 | 1 | 1 | Enable Bluetooth 5.0 broadcast |
| DRONE_ID_BROADCAST_WIFI_BEACON | 0 | 1 | 1 | Enable Wifi Standard Beacon broadcast |
| DRONE_ID_BROADCAST_WIFI_NAN_BEACON | 0 | 1 | 1 | Enable WiFi NaN Beacon broadcast |
| DRONE_ID_DRONE_CATEGORY_CLASS | 0 | 7 | 0 | Drone category class:<br>0 – None<br>1 – C0<br>2 – C1<br>3 – C2<br>4 – C3<br>5 – C4<br>6 – C5<br>7 – C6 |
| DRONE_ID_HEIGHT_TYPE | 0 | 1 | 0 | Height type:<br>0 – Relative to take-off location<br>1 – Relative to ground |
| DRONE_ID_LOCALIZATION_BROADCAST_PERIOD | 100 | 1000 | 500 | Localization frame broadcast period in [ms] |
| DRONE_ID_MAVLINK_CONNECTION_TIMEOUT | 2 | 30 | 5 | Mavlink timeout in [s] |
| DRONE_ID_MODE | 0 | 1 | 1 | Determines Mavlink reception:<br>0 - Full mavlink support<br>1 - Ignore all mavlink messages<br>2 - Ignore only location messages |
| DRONE_ID_OPERATIONAL_STATUS | 0 | 2 | 0 | Operational status:<br>0 – Undeclared<br>1 – Ground<br>2 – Airborne |

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Table 34 – continued from previous page

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| DRONE_ID_OPERATION_CATEGORY | 0 | 3 | 0 | Operation category:<br>0 – None<br>1 – Open<br>2 – Specific<br>3 - Certified |
| DRONE_ID_OPERATOR_ID | – | – | – | Operator message payload |
| DRONE_ID_OPERATOR_ID_TYPE | 0 | 255 | 0 | Operator ID type:<br>0 - Operator ID<br>1 – 200 Reserved<br>201 – 255 Available for private use |
| DRONE_ID_SELF_ID | – | – | – | Self message payload |
| DRONE_ID_SELF_ID_TYPE | 0 | 255 | 0 | Self ID type:<br>0 - Text description<br>1 – 200 Reserved<br>201 – 255 Available for private use |
| DRONE_ID_TYPE | 0 | 3 | 0 | UAS ID type: 0 – None<br>1 - Serial Number<br>2 - CAA Assigned Registration ID<br>3 - UTM Assigned UUID |
| DRONE_ID_UAS_TYPE | 0 | 15 | 0 | Specification of the type of UAS:<br>0 – None<br>1 – Aeroplane<br>2 - Helicopter or Multirotor<br>3 – Gyroplane<br>4 - Hybrid Lif<br>5 - Ornithopter<br>6 – Glider<br>7 – Kite<br>8 - Free Balloon<br>9 - Captive Balloon<br>10 – Airship<br>11 - Free Fall<br>12 – Rocket<br>13 - Tethered Powered Aircraft<br>14 - Ground Obstacle<br>15 – Other |

# 12 RemoteID receiver subsystem

Aerobits devices with **RemoteID IN** functionality capture Remote ID using Bluetooth and WiFi interfaces, following ASTM/ASD-STAN standard.

**Important:**

This part of documentation is relevant only for devices which have **RemoteID IN** functionality

**Note:**

trkMe+ device receives UAVs in range of 1 km.

## 12.1 Settings

Table 35: Descriptions of RemoteID settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| DRONE_ID_SCAN_ENABLE_BT | 0 | 1 | 1 | Scan enable Bluetooth |
| DRONE_ID_SCAN_ENABLE_WIFI | 0 | 1 | 1 | Scan enable Wi-Fi |

## 12.2 Protocols

### 12.2.1 RemoteID CSV protocol

This message describes state vector of aircraft determined from remoteID messages. The message format is as follows:

```
#RB\B4\B5\WN\WB :UAS_ID,ID_TYPE,UAS_TYPE,LAT,LON,HEIGHT,ALT_BARO,ALT_GEO,TRACK,
VELH,VELV,STATUS_FLAG,OPERATOR_ID,OPERATOR_ID_TYPE,OPERATOR_LAT,OPERATOR_LON,
OPERATOR_LOC_TYPE,TIMES,RSSI,CRC\r\n
```

Table 36: Descriptions of RemoteID fields.

| #B4-B5-WN-WB | Aircraft message start indicator | Example value |
|---|---|---|
| UAS_ID | aircraft ID | 18099300000132 |
| ID_TYPE | Flags bitfield riditype | 1 |
| UAS_TYPE | Callsign of aircraft riduastype | 2 |
| LAT | Latitude, in degrees, accuracy 0.6 degree | 57.57634 |
| LON | Longitude, in degrees, accuracy 0.6 degree | 17.59554 |
| HEIGHT | Height based on start up altitude, in meters | 0.5 |
| ALT_BARO | Barometric altitude, in meters | 50 |
| ALT_GEO | Geometric altitude, in meters | 50 |
| TRACK | Track of aircraft, in degrees [0,360) | 35 |
| VELH | Horizontal velocity of aircraft, in m/s, accuracy 0.1 m/s | 464 |
| VELV | Vertical velocity of aircraft, in m/s, accuracy 0.1 m/s | -1344 |
| STATUS_FLAG | Operation status | 0 |
| OPERATOR_ID | The operator number from local FAA department | AAABBBBBBBBBBBC-DDD |
| OPERATOR_ID_TYPE | Specific type of Operator ID | 5 |

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Table 36 – continued from previous page

| #B4-B5-WN-WB | Aircraft message start indicator | Example value |
|---|---|---|
| OPERATOR_LAT | The operator latitude in degrees, accuracy 0.6 degree | 57.52614 |
| OPERATOR_LON | The operator longitude in degrees, accuracy 0.6 degree | 17.60154 |
| OPERATOR_LOC_TYPE | The operator location type | 0 |
| TIMES | Timestamp of the sent frame expressed in seconds since current hour, accuracy 0.1 s-1.5 s | 408.5 |
| RSSI | Signal strength, in dBm | 0 |
| SELF_ID_TYPE | Self id type ridselfidtype | 0 |
| SELF_ID | Self id | |
| FTYPE_TYPE | Frame type ridframetype | 15 |
| MAC | MAC address | df:a5:c3:84:78:66 |
| CRC | CRC16 (described in CRC section) | 2D3E |

Whereby the following prefixes mean:

- #B4 - Bluetooth 4.0(Legacy) frame
- #B5 - Bluetooth 5.0 frame
- #WN - Wi-Fi NaN frame
- #WB - Wi-Fi beacon frame
- #RB - Own RemoteID data

Table 37: Descriptions of RemoteID ID Type field.

| ID Type value | Description |
|---|---|
| 0 | None. |
| 1 | Serial Number. |
| 2 | CAA Assigned Registration ID. |
| 3 | UTM Assigned UUID. |

Below is a list of emitter category values returned in UAS_TYPE value field.

Table 38: Descriptions of RemoteID UAS_TYPE field.

| UAS_TYPE value | Description |
|---|---|
| 0 | None. |
| 1 | Aeroplane. |
| 2 | Helicopter or Multirotor. |
| 3 | Gyroplane. |
| 4 | Hybrid Lift. |
| 5 | Ornithopter. |
| 6 | Glider. |
| 7 | Kite. |
| 8 | Free Balloon. |
| 9 | Captive Balloon. |
| 10 | Airship. |
| 11 | Free Fall. |
| 12 | Rocket. |

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Table 38 – continued from previous page

| UAS_TYPE value | Description |
|---|---|
| 13 | Tethered Powered Aircraft. |
| 14 | Ground Obstacle. |
| 15 | Other. |

Table 39: Descriptions of RemoteID SELF_ID_TYPE field.

| Self Id Type value | Description |
|---|---|
| 0 | Text Description. |
| 1 | Emergency Description. |
| 2 | Extended Status Description. |
| 3–200 | Reserved. |
| 201–255 | Available for private use. |

Table 40: Descriptions of RemoteID FTYPE_TYPE field.

| Frame Type value | Description |
|---|---|
| 0 | Basic ID. |
| 1 | Location. |
| 3 | Self ID. |
| 4 | System. |
| 5 | Operator ID. |
| 15 | Packed all in one. |

**Note:**

Referring to the ASD-STAN prEN 4709-002 standard, our product displays all the required information (ASD-STAN prEN 4709-002 Table 1 - Data Dictionary), optional data is only available upon special request.

If data of any field of frame is not available, then it is transmitted as empty. For example:

```
#B5:18099300000170,1,0,53.3960175,14.6283543,-0.5,58.0,86.5,0,0.0,0.0,0,,0,0.
0000000,0.0000000,0,103.7,-46,0,,15,84:f7:03:28:e3:1a,420C\r\n
```

**Note:**

RSSI is measured based on analog RF signal.

# 13 Network communication system

## 13.1 Network communication modes MQTT

The trkME communicates through the **LTE** network using **MQTT** 3.1 protocol. Connection can be configured to use username and password authentication, as well as **TLS** encryption. All data are transmitted into specific **MQTT** topic.

## 13.2 Settings

### 13.2.1 LTE

Table 41: Descriptions of LTE settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| APN_NAME | – | – | – | LTE APN name |
| APN_PASSWORD | – | – | – | LTE APN user password |
| APN_TYPE | 0 | 5 | 0 | Type of APN:<br>0 – auto<br>1 – GSM<br>2 – CDMA<br>3 – WCDMA<br>4 – EVDO<br>5 – LTE |
| APN_USER | – | – | – | LTE APN user name |
| LTE_LOG | 0 | 1 | 0 | Show LTE log:<br>0 – disable<br>1 – enable |

### 13.2.2 MQTT

Table 42: Descriptions of MQTT settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| MQTT_BROKER_ADDRESS | – | – | – | MQTT broker address (IP, URL) |
| MQTT_BROKER_PORT | – | – | – | MQTT broker port (0-65535) |
| MQTT_CLIENT_ID | – | – | – | MQTT client ID, leave blank to use '{user}_{imsi}_{rand}' |
| MQTT_KEEPALIVE | 0 | 3600 | 0 | MQTT keepalive interval in seconds |
| MQTT_LOG | 0 | 1 | 0 | Debug log of MQTT module:<br>0 – disable<br>1 – enable |
| MQTT_PASS | – | – | – | MQTT broker password |
| MQTT_TLS | 0 | 1 | 0 | Enables TLS in MQTT:<br>0 – disable<br>1 – enable |
| MQTT_USER | – | – | – | MQTT broker user name |

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Table 42 – continued from previous page

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| MQTT_WEBSOCKET | 0 | 1 | 0 | Use websocket when connecting to broker:<br>0 – disable<br>1 – enable |
| REMOTE_ID_TOPIC | – | – | – | OpenDroneID MQTT topic |
| RID_RX_PROTOCOL_DECODED | – | – | CSV | Remote ID decoded protocol:<br>None<br>CSV<br>JSON |

For devices **TrkMe+ and TrkMe PRO** available are additional settings:

Table 43: Descriptions of MQTT settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| ADSB_PROTOCOL_MQTT | – | – | JSON | Format of mqtt messages:<br>JSON<br>ASTERIX |
| ADSB_TOPIC | – | – | – | ADS-B plot MQTT topic |
| AUX_DATA_TOPIC | – | – | – | Topic for transmitting data received by aux port |
| CSV_TOPIC | – | – | – | CSV plot MQTT topic |
| FLARM_TOPIC | – | – | – | FLARM plot MQTT topic |
| MLAT_TOPIC | – | – | – | MLAT plot MQTT topic |
| TELEMETRY_TOPIC | – | – | – | JSON Telemetry plot MQTT topic |

## 13.3 Protocols

Remote ID data transmitted to REMOTE_ID_TOPIC are in JSON format described below. Example of JSON data:


```
{
    "remoteid": {
        "uasid": "18099440000001",
        "id_type": 1,
        "uas_type": 0,
        "uas_latitude": 53.39689,
        "uas_longitude": 14.628,
        "height": 0.06,
        "altitudeBaro": -15.04,
        "altitudeGeo": 1775.59,
        "direction": 0,
        "speedH": 0,
        "speedV": 0.2,
        "status": 0,
        "operator_id": "POL7f4b6c87bbd5w",
        "operator_id_type": 0,
        "operator_latitude": 53.38649,
        "operator_longitude": 14.63821,
        "operator_location_type": 0,
        "timestamp": 83.3,
        "self_id_type": 0,
```


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```
        "self_id": "TEST1",
        "pressure": 1015.06,
        "temperature": 47.88
    }
}
```

Table 44: Description of JSON fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| uasid | – | 18099440000001 | string value representing UAV ID |
| id_type | – | 1 | Type of ID |
| uas_type | – | 0 | Type of UAV |
| uas_latitude | degrees | 53.39689 | Latitude of UAV position in degrees |
| uas_longitude | degrees | 14.62835 | Longitude of UAV position in degrees |
| height | m | 0.06 | Height based on start up altitude, in meters |
| altitudeBaro | m | 200 | Altitude based on Pressure sensor |
| altitudeGeo | m | 1775.59 | Altitude based on GNSS |
| direction | degrees | 120 | Direction angle |
| speedH | m/s | 14 | Horizontal speed |
| speedV | m/s | 2 | Vertical speed |
| status | – | 0 | Status of UAV |
| operator_id | – | POL7f4b6c87bbd5w | The operator number from local FAA department |
| operator_id_type | – | 0 | Type of operator id |
| operator_latitude | degrees | 53.39689 | The operator latitude in degrees |
| operator_longitude | degrees | 14.62843 | The operator longitude in degrees |
| operator_location_type | – | 0 | Type od operator location |
| timestamp | milliseconds | 69061337 | Timestamp in milliseconds, relative to last UTC midnight |
| self_id_type | – | 0 | Type of Self ID string |
| self_id | – | TEST1 | Self ID string |
| pressure | hPa | 1015.06 | Pressure measured by onboard sensor |
| temperature | Celsius | 32.21 | Temperature measured by onboard sensor |

**Note:**

The order of JSON object fields in any part of message may vary between firmware revisions and messages.

# 14 Sensors receiver subsystem

## 14.1 Settings

Table 45: Descriptions of Sensors settings.

| Setting | Min | Max | Def | Comment |
|---|---|---|---|---|
| SENSORS_RX_PROTOCOL_RAW | – | – | None | Sensors decoded protocol:<br>None<br>CSV<br>JSON |

## 14.2 Protocols

### 14.2.1 Pressure CSV protocol

This message describes state vector of sensor determined from SENSORS messages and is sent once per second. The message format is as follows:

```
#SP:CALIB,PRESS,TEMP,CRC
```

Table 46: Descriptions of SENSORS fields.

| #SP | Sensors message start indicator | Example value |
|---|---|---|
| CALIB | Pressure sensor calibration value | 1 |
| PRESS | Current pressure value | 1002.213742 |
| TEMP | Current temperature value | 56.420123 |
| CRC | CRC16 (described in CRC section) | 2D3E |

### 14.2.2 Sensor JSON protocol

The *sensor* section contains values acquired from miscellaneous sensors present in Aerobits device hardware and consists of fields shown below. This message is sent once per second. All fields are optional - they are sent only if appropriate sensor is enabled.

```
{
    "ver": 1,
    "sensor": {
        "pressure": 1006.87,
        "temp": 39.8
        },
    "HumiditySensor": {
        "Temperature": 36.9,
        "Humidity": 19,
        }
    }
}
```

Table 47: Descriptions of JSON Sensor section fields.

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| ver | – | 1 | See table *Description of main JSON fields.* (page 20). |
| sensor | – | type of sensor | |

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Table 47 – continued from previous page

| JSON Field | Unit | Example | Description |
|---|---|---|---|
| pressure | hPa | 1006.87 | Current pressure sensor value in hPa. |
| temp | °C | 39.8 | Current temprerature sensor value in °C. |
| HumiditySensor | – | type of sensor | |
| Temperature | °C | 36.9 | Current temperature sensor value in °C. |
| Humidity | % | 19 | Current humidity sensor value in %. |

# 15 Quick start

This section will describe how to start up with **trkME** devices.

**Note:**

Details could vary between **trkME**, **trkME+** and **trkME-PRO** devices.

## 15.1 Dismantling aluminium housing

This step is neccessary for inserting your SIM card inside trkMe device.

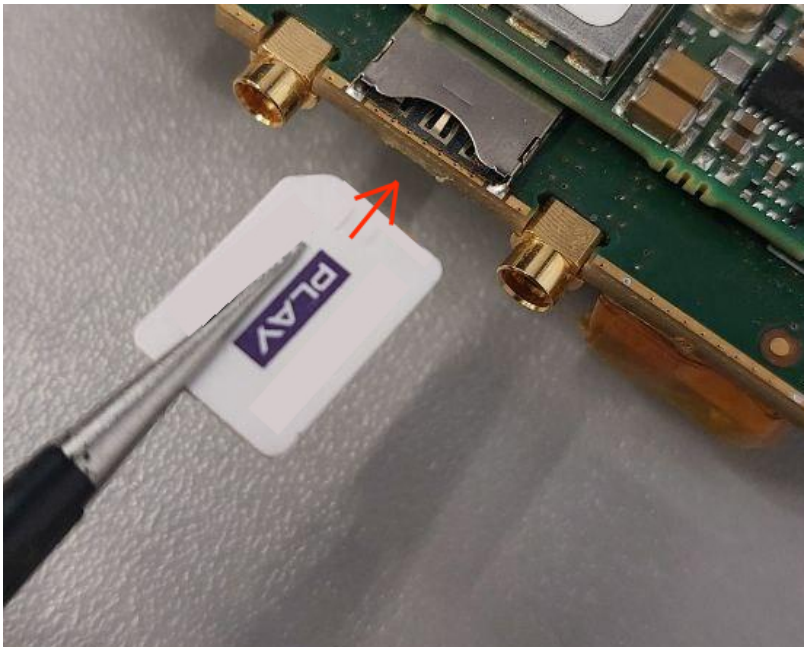
Unscrew four screws and open the aluminium lid.

Gently take out PCB from the housing.

## 15.2 Inserting SIM card

Insert valid nano SIM card from your local operator.

In case of connectivity issues please check if SIM card is working. You can do that with other LTE modem, for example mobile phone.



## 15.3 Powering up

Connect USB C cable to **trkMe** device. Use **USB-C Device** connector, like on below picture.


## 15.4 Setting the correct APN name in device settings

Connect trkME to your PC. Open serial connection and write commands:

```
AT+CONFIG=1
AT+APN_NAME=<apn_name_from_your_lte_provider>
AT+CONFIG=0
```

## 15.5 Setting mqtt parameters

For collecting data from trkME to your mqtt broker you should use commands:

```
AT+CONFIG=1
AT+REMOTE_ID_TOPIC=<topic_where_remote_data_will_be_Send>
AT+MQTT_BROKER_PORT=1883
AT+MQTT_BROKER_ADDRESS=<address_of_your_broker>
AT+CONFIG=0
```

## 15.6 Example minimal setup

```
AT+CONFIG=1
AT+APN_NAME=internet
AT+REMOTE_ID_TOPIC=TEST_TOPIC_REMOTE
AT+MQTT_BROKER_PORT=1883
AT+MQTT_BROKER_ADDRESS=test.mosquitto.org
AT+CONFIG=0
```

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