Document Status

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☐ Canceled	☐ Public

Version Control

Ver.	Date	Summary of changes
1.0	2022-11-18	Initial release
1.01	2022-12-05	Include Horizon XC 1.01 release notes
1.02	2023-03-21	Include Horizon XC 1.02 release notes
1.03	2023-04-06	Include Horizon XC 1.03 release notes, add description of FNZ command
1.04	2023-05-16	Include Horizon XC 1.04 release notes
1.05	2023-10-08	Include Horizon XC 1.05 release notes, add description on FNT and FAP commands
1.06	2023-10-24	Include Horizon XC 1.06 release notes

Scope and Summary

This document describes the hardware and software integration of Horizon XC.

Table of Contents

1 Introduction

Horizon XC is a miniature radio modem with FANET and FLARM connectivity for integration in instruments for hang- and paragliding. By combining the two protocols, Horizon XC combines the best of both worlds: Very long radio range for tracking and buddy flying through FANET's LoRa technology; visibility and safety through FLARM's huge installation base in General Aviation.

It works in the 868 MHz and the 915 MHz frequency bands, suitable for the European or North American markets. FANET and FLARM are continuously transmitted at nominal rates with the aid of a single antenna. For reception, FANET is prioritized in normal operation to maximize connectivity. The reception priority of FLARM is reduced, resulting in a higher latency and an update rate comparable to FANET traffic data.

2 Specifications

Dimensions	8.5 x 9.3 x 1.8 mm	
Mass	1.3 g	
Mounting	SMD	
Platform	FLARM Atom System-on-Chip	
Interfaces	Data interface Antenna Optional FLASH	UART (up to 3.3 V TTL) RF 50 Ω SPI
Protocols	Host communication Firmware upgrades Optional obstacle upload	line-based, ASCII bootloader protocol binary communication protocol
Power Supply	1.8 V	
Current Consumption	20 mA (typ.), 30mA (max)	
RF	Frequency (FLARM) Frequency (FANET) Power	868.2-868.4 MHz (Europe, Africa) 869.2 MHz (New Zealand) 902-928 MHz (North America) 916.2 MHz (Israel) 917-926.6 MHz (Australia, South America) 868.2 MHz (Europe) 920.8 MHz (North America, Australia) 866.2 MHz (India) 923.2 MHz (Korea, Asia) 918.5 MHz (India) 13.5 dBm

3 Operation

The radio chip on Horizon XC is run in a shared mode between FANET and FLARM. A Radio Manager component optimizes the dual use of the single radio chip for both protocols in the following way:

FANET:

- Whenever possible the radio chip is in FANET reception mode.
- Messages are sent on demand if the radio chip is available for sending.

FLARM:

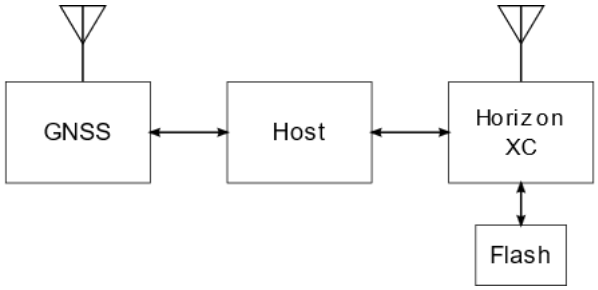
- At least one frame per second is sent. A maximum of two is possible.
- Every 5 seconds a FLARM reception-only phase is enforced, independent of traffic density.

4 Hardware Integration

Horizon XC is based on the miromico FMLR Maxim SX1261 module. The integration is based on the information provided by miromico[1]. In particular, the document 'Development_Board_fmlr_maxim_sx1261_Schema_PCB_V7.0.pdf', dated 12/05/2022, page 5 has the relevant components: Power Supply, U500A and U500B.

4.1 Standalone Integration

To integrate with a host controller, the module must be connected to a host that feeds the state (position and time) from a GNSS receiver, as well as an accurate time pulse (pulse per second, PPS) from the GNSS receiver directly. As an alternative to an electrical time pulse, the time pulse can also be supplied via UART command (see description below). However, for better timing accuracy, an electrical time pulse is recommended.



Horizon XC provides FANET and FLARM targets, as well as optionally obstacle warnings. The firmware update is driven by the host via UART. For the update process to start, Horizon must be put into bootloader by pulling the reset pin, and then the firmware be copied to the module via the binarycomm protocol (see next section).

The following pins must be connected:

External	Function	Pin Name	Pin Number
1.8 V LDO	VCC (1.8 V)	VCC1V8	19
3.3 V host supply	UART TTL (1.8V to 3.3V)	VCC	20
GND	GND	GND	4, 45
Host TX	UART RX (TX on host)	P0.0	38
Host RX	UART TX (RX on host)	P0.1	39

[1] https://docs.miromico.ch/datasheets/modules.html#_fmlr_maxim_sx1261

Host RESET output	RESET	RSTN	43
GNSS receiver PPS	PPS	P1.3	34
GND	GND	GND	1
RF connector	Antenna	ANT	2
GND	GND	GND	3

Make sure to connect pins 1-3 with a design of an RF transmission line with 50 Ω characteristic impedance.

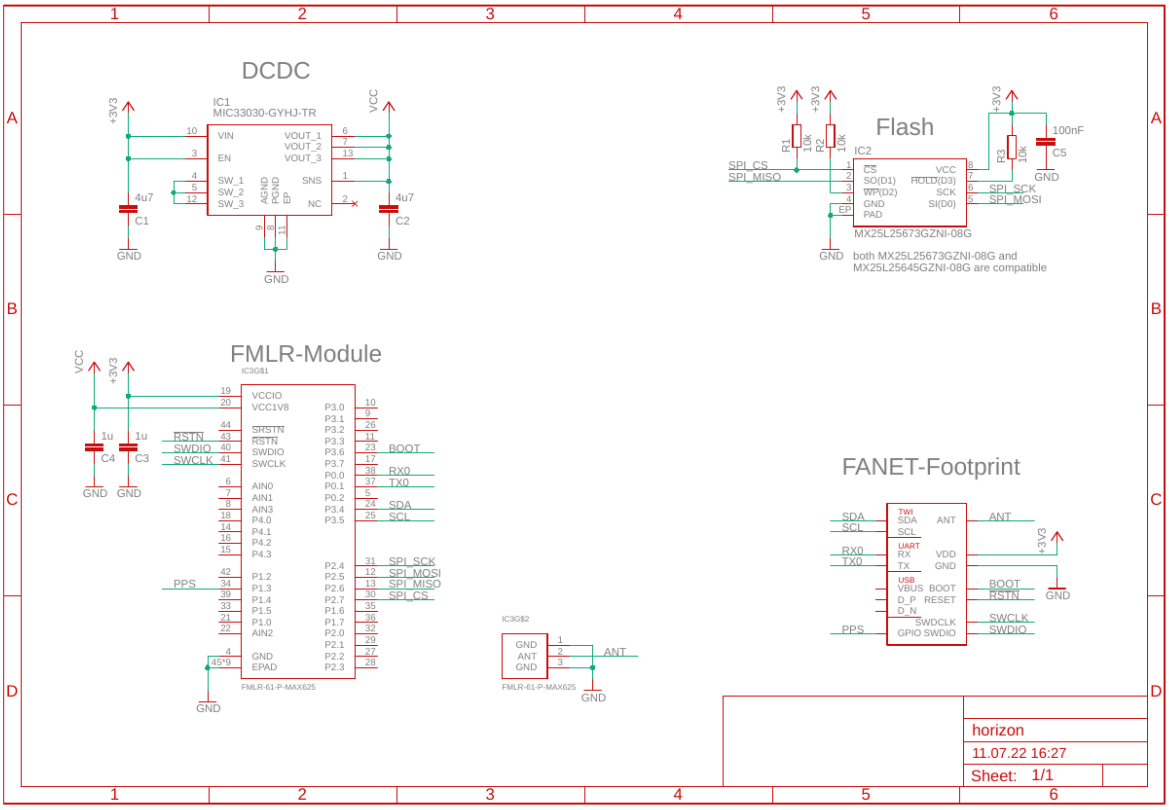
The following pins are optional for FLASH functionality. This is required for the obstacle database.

Function	**Pin Name**	**Pin Number**
SPI_SCK	P2.4	31
SPI_MOSI	P2.5	12
SPI_MISO	P2.6	13
SPI_CS	P2.7	30

Use Macronix MX25L25673GZNI-08G or MX25L25645GZNI-08G.

4.2 FANET+ compatible

For an integration with a FANET+ module-compatible pinout, use the schematics below.



Due to the difference in the bootloader, connecting to SDA, SCL, SWCLK, SWDIO and BOOT is not required.

A reference design is available upon request.

4.3 Antenna Integration

FLARM operates in the (low-power) SRD band with a relatively low emitted power. Therefore, good antenna selection and integration is crucial to achieving a satisfactory range.

While it is appreciated that for antennas mounted in small handheld devices, some performance penalties must be accepted, it is nevertheless encouraged to give the antenna selection appropriate attention.

All FLARM installation have the monopole or dipole antennas installed vertically, leading to vertically polarized RF signals. For the integration of Horizon XC, the intention is to be visible in all directions. Therefore, the antenna should have an omnidirectional antenna pattern along the horizontal plane with vertical polarization in the intended frequency range. A gain of at least 0 dBi in all directions when mounted on the device is desired.

Note: Some performance degradation will occur if the device is worn close to the human body. In severe cases, this can be up to 20 dB lower gain towards the rear, leading to a reduction of the achievable range by a factor of 10.

5 Software Integration

5.1 API

The text-based serial interface is based on the FANET+ specifications[2].

5.1.1 Startup Sequence

For a usual bootup sequence, please check Section 4.4 in the FANET+ specifications. The main difference is that Horizon uses a FLARM-specific bootloader. Therefore, the jump to boot-loader command (`#DGJ`) will simply reset the microcontroller.

The startup sequence of the module is as follows:

First, the bootloader communicates with 57'600 baud. During this phase, the firmware can be uploaded. Typical output:

```
FLARM Bootloader v1.22
Checking Application Memory: OK
```

Second, the bootloader launches the application. The baud rate switches to 115'200 baud for the duration of the application runtime. Typical output:

```
FLARM Horizon XC firmware
(c) 2022-2022 FLARM Technology Ltd
Build 0.11, "ed32e740f", Date "2022-07-04T09:08:25+00:00"
FLARM Expiry 01.01.2023
Serial Number FLAHORXCW-000482
Base System OK
Serial API OK
RF Driver OK
PubSub OK
FLARM OK
FANET OK
Radio Manager OK
#FNR MSG,1,initialized
```

[2] https://raw.githubusercontent.com/3s1d/fanet-stm32/master/fanet_module.pdf

5.1.2 Differences to FANET+ protocol specifications

The serial API was changed in the following way:

#FAO: This is a new unsolicited message providing Traffic information about Targets received via FLARM.

Syntax:

```
#FAO <source 0 = FLARM>,<id [6 digit hex]>,<id type [0 = random, 1 = icao, 2 = flarm]>,<aircraft type [according to the FTD-012 Aircraft type definition]>,<latitude>,<longitude>,<altitude>,<groundspeed>,<climbrate>,[<track>]
```

Example:

```
#FAO 0,DF2029,2,8,47.182989,8.521088,429.0,0.0,-0.1,127.0
```

This message indicates that a FLARM target has arrived with ID DF2029. The ID is of type FLARM, and the device is a powered aircraft. The position is at latitude 47.182989° and longitude 8.521088°. The altitude is at 429 m WSG84 with a groundspeed of 0 m/s. The climb rate is -0.1m/s and the track (heading) is 127°. The track is given in degrees from north, positive values are clockwise.

#FAT: This is a new input command allowing the user to signal PPS (time-pulse) events via serial API instead of the physical GPIO.

Syntax:

```
#FAT <delay in milliseconds [0 – 100]>
```

Example:

```
#FAT 42
```

The message provides a time-pulse event. Since the preparation and sending of the event can cause delays to the real GNSS (GPS) second the command allows to define the delay to the real PPS signal in milliseconds.

#DGJ will ignore additional input data after the BL prefix and reset Horizon. This allows the user to step into the bootloader during startup.

Example:

```
#DGJ BL
```

#DGL is not operational anymore. The frequency is implicitly selected based on the current supplied position in the #FNS message.

#DGP: FANET power command responds according to the API specification but have no effect on power consumption. The module is always up and running.

#FAP: FLARM power command allows to inhibit transmission of FLARM packets. Simultaneously stops transmission and reception. Responds with `#FAR OK` (identical to FANET+ module, but not according to FANET+ protocol specification).

Note: The #FNS (state) message must contain a valid timestamp and undulation value (`sep`) for FANET and FLARM to work correctly.

#DBG: Debug output can be activated via the #DBG interface. This defines the debug output level (ERROR, WARNING, INFO, DEBUG, TRACE).

Example:

```
#DGB LEVEL,INFO
```

Only very limited debug output is available.

#FNZ: This command (with no arguments) returns the currently active zone for FANET.

Syntax:

```
#FNZ <zone>,<zone description>
```

Examples:

```
#FNZ -1,UNSET
```

No zone is currently set

```
#FNZ 6,EU868
```

The current region is Europe, with a carrier frequency of 868 MHz.

5.2 Compliance Test

The correct implementation must be validated using a compliance test. Please refer to the associated documentation[3] and contact FLARM to obtain the required hardware. This step is particularly important when the time-pulse is fed via the FAT message.

[3] See "FTD-069 FLARM Compliance Test Manual" for more information.

5.3 Updates

5.3.1 Firmware Updates

The firmware binary is provided as a FLARM fw container.

To install a new firmware, use the bootloader communication channel. Horizon XC requires a recovery update. Please refer to FTD-027 for further details.

Briefly, the procedure is as follows:

1. Preparation: The host opens and inspects the fw container file per Section 2 of FTD-027. Containers for Horizon XC contain one entry only, and the type is always 2 (“extended”). For this entry, the host reads out the meta information:
   a. `Platform Descriptor`: Must be be `flarm2` for a valid entry.
   b. `Version Descriptor`: Horizon XC software version contained in the entry, e.g. `1.0.4`. This the host can compare to the version installed currently.
   c. `Extended Info`: This must be set to `PlatformFamily=Horizon;` for a valid entry.

   The host then computes the CRC value over the whole entry (entry header + data) and match to the `Crc` entry in the entry description. If a mismatch is detected, the entry is to be discarded.
2. Next, the host resets Horizon XC by pulling the reset pin and immediately synchronizes and handshakes with the bootloader (Sections 3.1 & 3.2 in FTD-027).
3. If the handshake succeeds, the bootloader immediately sends the device information in the form `K`*`xxxxx`*`PlatformFamily=Horizon`. This must match the `PlatformFamily` entry of the fw container from Step 1. The `K` corresponds to the `flarm2` platform from Step 1 while the `xxxxx` are the 5 reserved bytes and can be ignored. See Section 3.3 in FTD-027 for more information.

The `Offset` entry in the extended entry corresponds to the start address of the firmware in the microcontroller flash storage. The `Page size` is 0x100 (256 bytes). For Horizon XC the `UseIV` flag is set. Therefore, the first page of the data blob contains the Initial Vector and needs to be written at page address 0xFFFF. Furthermore, the `Offset` is 0x6000 bytes or 0x60 pages. The second and consecutive pages in the fw container must therefore be written at page address starting from 0x60 according to Section 3.4 in FTD-027.

5.3.2 Obstacle Database Upload

For uploading the database, the binary communication protocol is used. Please refer to FTD-026 and code snippets for more details.

6 Radio Compliance Testing

The application firmware exposes several radio test modes specifically for testing compliance with applicable regulations. These functions are to be used during the product engineering, i.e. validation in a lab, and not intended for end users.

Caution: Using transmit tests may interfere with other FLARM devices operating normally. Local radio regulations may not permit this. Do not use near flying operations. Only use for as brief periods as possible (seconds, not minutes).

Please note that these test commands are available on the application firmware image, not the factory test firmware.

6.1 Unmodulated Carrier

Test emitting an unmodulated carrier signal (i.e. a plain sine wave)

6.1.1 RF Transmit Carrier

Transmit an unmodulated (sine wave) carrier on the given frequency with the given power. Useful for antenna optimization in the lab or verification of the antenna installation in the field.

Command:

```
#TST carrier,<Frequency>,<Power>
```

Parameters

`<Frequency>`	Defines the frequency in MHz. Must be a multiple of 200kHz.
`<Power>`	Power output in dBm from -3 to 14 dBm.

Output: The module starts transmitting the unmodulated carrier.

Note: To exit the test, send `#TST`.

6.1.2 RF Detect Carrier

Detects incoming, unmodulated radio energy and reports the signal strength. This can be used e.g., as the opposite part of 6.1.1

Command:

```
#TST pin,<Frequency>
```

Parameters

`<Frequency>`	Defines the frequency in MHz. Must be a multiple of 200kHz.

Output: The test continuously reports the received signal strength indicator (RSSI) measurements in dBm.

```
rx_pwr_dbm:-100
```

Note: To exit the test, send `#TST`.

6.2 Modulated Packets

This test allows to send or receive modulated RF packets. The send and receive tests work as counterparts, sending, receiving, and displaying modulated data in distinct packets. The packet payload is purely for testing purposes and not compatible with FLARM/FANET traffic. Interference with the FLARM/FANET networks is minimized by using different sync words, but interference due to frequency usage (with short delays) persists.

The test allows to send/receive both FLARM signals modulated via FSK and FANET signals modulated via LORA.

The FSK modulated packets can also be tested with existing FLARM device using the corresponding RF Compliance Test Mode.

6.2.1 RF Transmit Packets

This test sends modulated RF test frames. These test frames are used for RF compliance tests. The payload contains diagnostics data used by its reception counterpart in the next section.

Command:

```
#TST send,<Modulation>,<Frequency>,<Power>,<Interval>
```

Parameters:

`<Modulation>`	Defines the modulation as either `FSK` or `LORA`.
`<Frequency>`	Defines the frequency in MHz. Must be a multiple of 200kHz.
`<Power>`	Power output in dBm from -3 to 14 dBm.

`<Interval>`	Interval in milliseconds between packages.

Output: The test outputs the sent frames with their metadata continuously:

```
time:3647880, id:A002A, tx_pwr_dbm:14, sequence:284, (0 retries)
time:3648881, id:A002A, tx_pwr_dbm:14, sequence:285, (0 retries)
```

Note: To exit the test, send `#TST`.

6.2.2 RF Receive Packets

This test receives the sent RF frames issued by the send command at 6.2.1. It ignores all other frames.

Command:

```
#TST receive,<Modulation>,<Frequency>
```

Parameters:

`<Modulation>`	Defines the modulation as either `FSK` or `LORA`.
`<Frequency>`	Defines the frequency in MHz. Must be a multiple of 200kHz.

Output: The test outputs the received frames with their metadata continuously, indicating a potential package loss and RSSI values:

```
time:311661, id:16002A, sequence:284, tx_pwr_dbm:14, rx_pwr_dbm:-52,
loss:0.0%
time:312662, id:16002A, sequence:285, tx_pwr_dbm:14, rx_pwr_dbm:-52,
loss:0.0%
```

Note: To exit the test, send `#TST`.

7 Current Limitations

Missing features:

- Power optimizations not implemented
- Obstacle data upload and processing not available

8 Release Notes

8.1 Release v1.06 (1722e538e)

Expiration: 01.03.2025

Fixes:

- FANET reception sporadically stopped in the vicinity of many FANET transmitters

8.2 Release v1.05 (a7ef19b9b)

Expiration: 01.03.2025

Enhancements:

- Implement FAP command

Fixes:

- FNT command accepts empty pilot string
- Watchdog period set to ~6 seconds

8.3 Release v1.04 (050d97247)

Expiration: 01.11.2024

Fixes:

- Received aircraft positions not decoded correctly on the southern hemisphere after March 2024.

8.4 Release v1.03 (3bba887b7)

Expiration: 01.07.2024

Enhancements:

- Include command to retrieve currently used FANET zone (#FNZ command)

8.5 Release v1.02 (bdd5722af)

Expiration: 01.07.2024

Enhancements:

- Include international frequency band settings for FANET
- Enable debug output (#DBG command)

8.6 Release v1.01 (e34934ba5)

Expiration: 01.03.2024

Fixes:

- Correct field values in #FAO sentences
- Correct timing of FLARM transmissions

8.7 Release v1.00 (21ae52092)

Expiration: 01.02.2024

Initial firmware release.

Appendix – End User License Agreement (EULA)

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2. **Terms of use of FLARM**
   - 2.1. Every FLARM installation must be approved by licensed Part-66 certifying staff or the national equivalent. A FLARM installation requires an EASA Minor Change Approval or the national equivalent.
   - 2.2. FLARM must be installed according to the Installation Instructions and the EASA Minor Change Approval, or the national equivalent.
   - 2.3. FLARM cannot warn in all situations. In particular warnings may be incorrect, late, missing, not being issued at all, show other threats than the most dangerous or distract the pilot's attention. FLARM does not issue resolution advisories. FLARM can only warn of aircraft that are equipped with FLARM, SSR transponders (in specific FLARM devices), or of up-to-date obstacles stored in its database. The use of FLARM does not allow a change of flight tactics or pilot behavior. It is the sole responsibility of the pilot in command to decide upon the use of FLARM.
   - 2.4. FLARM may not be used for navigation, separation, or under IMC.
   - 2.5. FLARM does not work if GPS is inoperative, degraded, or unavailable for any reason.
   - 2.6. The most recent Operating Manual must be read, understood and followed at all times.
   - 2.7. The firmware must be replaced once per year (every 12 months). The firmware must also be replaced earlier if a Service Bulletin or other information is published with such instruction. Failure to replace the firmware may render the device inoperable or incompatible with other devices, with or without warning or notice thereof.
   - 2.8. Service Bulletins are published as a Newsletter by FLARM Technology. You are required to sign up for the Newsletter on www.flarm.com to ensure that you are informed of published Service Bulletins. If you are entering into this agreement in a form where your email address is available (e.g. online shop) you may be automatically signed up for the Newsletter.
   - 2.9. After power-up, FLARM performs a self-test which must be monitored by the pilots. If a malfunction or defect is observed or suspected, FLARM must be disconnected from the aircraft by maintenance before the next flight and the device inspected and repaired, as applicable.
   - 2.10. The pilot in command is solely responsible to operate FLARM according to applicable national regulations. Regulations might include, but are not limited to, airborne usage of radio frequencies, aircraft installation, safety regulations, or regulations for sports competitions.
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7. **General terms**

7.1. **Governing Law**. This Agreement shall be governed by and construed in accordance with the internal law of Switzerland (to the exclusion of Swiss Private International Law and of international treaties, in particular the Vienna Convention on the International Sale of Goods dated April 11, 1980).

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Governing Language. Any translation of this Agreement is done for local requirements and in the event of a dispute between the English and any non-English versions, the English version of this Agreement shall govern