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Space-Friendly™

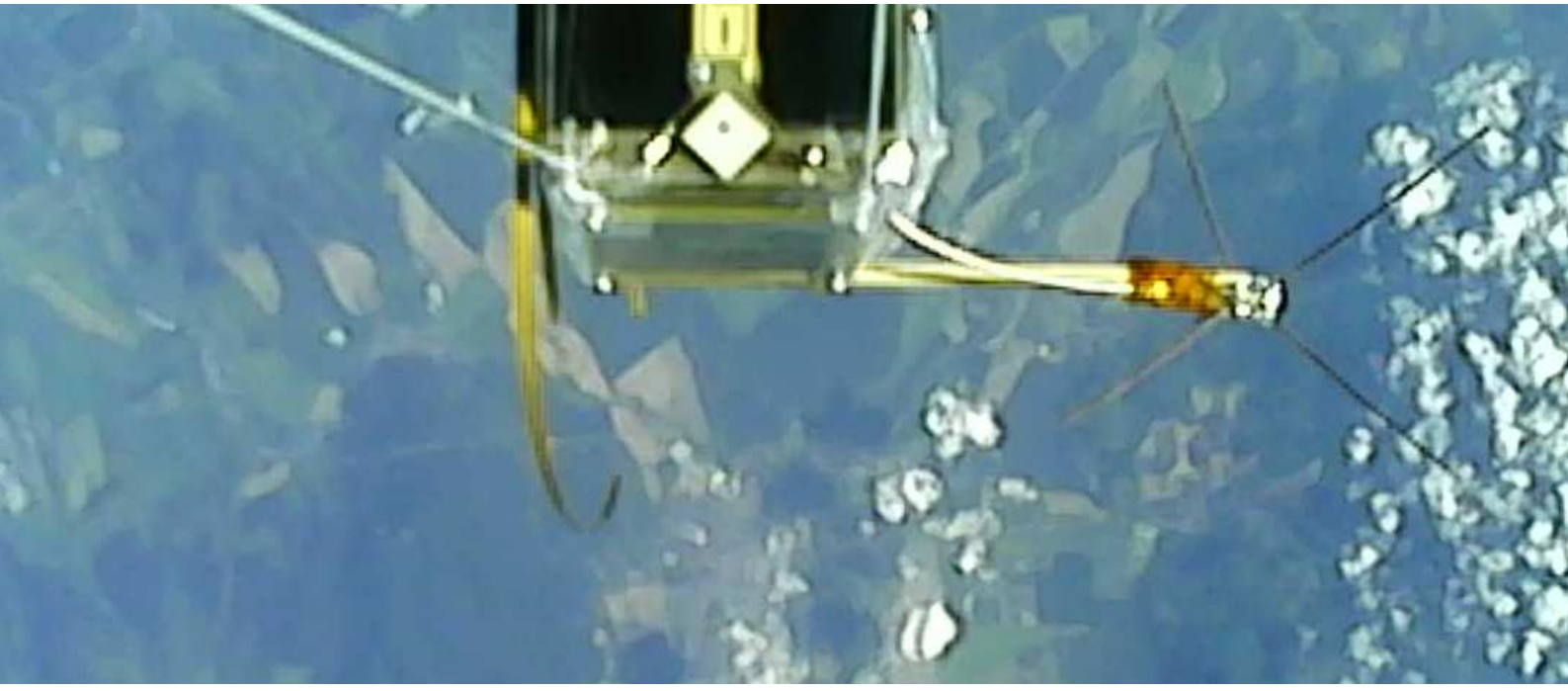
## PC/104+ CubeSat Compatible

# piNAV-NG/**Evaluation Kit**

## Quick Start Guide

**Rev. C/2017**

Intended to cover all **CubeSat Project** needs.



*Made in Czech Republic, a country with space heritage since 1978.*

# Quick Start Guide — piNAV-NG / Evaluation Kit

## GENERAL DESCRIPTION

To make the first meet with the Space-Friendly™ Ultra Low Power CubeSat GPS Receiver piNAV-NG comfortable and effective, the PC/104+ Evaluation Kit has been designed and is provided with each piNAV-NG/EM (Engineering Model) and piNAV-NG/FM (Flight Model).

The Evaluation Kit package contains the main PCB with indicating LEDs, test pins to be used with scope probe hooks, low voltage linear regulator (3.3 V), current sensing pins, header for the external USB-to-TTL serial cable connector (included) and the connector for the piNAV-NG main interface. The module is powered directly from the USB port and can be operated simply from portable PC.

The Kit provides excellent opportunity to study the recommended mechanical mounting layout using footprint library (CadSoft EAGLE) as well. Four 15mm long standoffs are delivered to demonstrate the available space below or above the piNAV-NG receiver when mounted onto the Evaluation Kit PCB.

Since the current consumption of the receiver connected to the Evaluation Kit is far below typical USB current driving capability (500 mA @ 5V), the piNAV-NG interfaced to the Evaluation kit can be left running without any external power source. However, it is strongly recommended to check the current consumption especially after connecting the unknown Active (or passive) GPS antenna, as this may rise up the power consumption and could cause the damage of the USB port.


**Fig. 1 The piNAV-NG / Evaluation Kit**, PC/104+ CubeSat Kit Compatible. Note, piNAV-NG receiver is not a part of the Evaluation Kit.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## TABLE OF CONTENTS



## ABSOLUTE MAXIMUM RATINGS

$V_{DD}$ (TP1) to GND (TP2) ……..……..-0.3 V to (≤ 4.2 V max)
DC Input Voltage: $V_I$ ..... -0.3 V to $V_{DD}$ + 0.3 V (≤ 4.2 V max.)
DC Output Voltage: $V_O$ ....-0.3 V to $V_{DD}$ + 0.3 V (≤ 4.2 V max.)
DC Input Current: $I_I$ at $V_I$ < 0 V or $V_I$ > $V_{DD}$ .....±20 mA
DC Output Current: $I_O$ at $V_O$ < 0 V or $V_O$ > $V_{DD}$.....±20 mA

Other Pins to GND:..... -0.3 V to +($V_{DD}$ +0.3) V

Maximum Output Current to the Active Antenna:.....100 mA
Operating Temperature Range:……..……0°C to +70°C
Storage Temperature Range:……...0°C to +70°C

**NOTE:**

**1)** Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under specification conditions is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability. Voltage values are with respect to system ground terminal. The manufacturer reserves all rights to decline the responsibility for any damage caused by improper using of the piNAV-NG / Evaluation Kit.

**2) The VDD test pin TP1 together with GND test pin TP2 are for voltage sensing purpose only! Never connect any external voltage source to these pins !!!**

**CAUTION:** *Because the central pin of the MCX coaxial connector mounted on the piNAV-NG receiver is under DC bias when the receiver is powered on, the special care has to be taken when handling with the coaxial cable, connector and antenna as well. Never connect the GPS antenna element designed as a closed dipole antenna, closed loop antenna, closed helical type, etc. to the receiver input to prevent the short circuit of the DC bias feed. Keep in mind, the central tap of the conventional patch antenna is galvanically connected to the DC bias feed. Prevent the tap against short circuit with the ground plane or GND potential when the receiver is turned On. Always disconnect the power before start to change the receiver electrical/mechanical setup. Short circuit of the DC bias feeding or its overloading over the Absolute maximum ratings may affect device reliability, damage the device and void the product warranty.*

## BOARD DESCRIPTION

Two sided PCB with outer dimensions of 90.2×95.9 mm contains five indicating LEDs, test pins and connectors required to properly interface the piNAV-NG with the PC via USB.

**Green** LED shows the presence of 3.3V voltage at the output of the regulator. It indicates the proper powering from the USB port. It shines permanently, when the kit is powered On.

**Red** LED is connected to monitor the data output stream from the piNAV-NG. The LED driver is not inverting and thus the normal condition on the serial bus (the idle state, no data output) is indicated by constant shine. However, immediately after initialization of the receiver it starts to blink with respect to data stream. Since the transmitted logical zero (each start bit for example) at the TXD output pin changes the "duty cycle" of the LED power, it starts to fade. After the data packet is sent, the red LED is shining in full power again (for approx. 300 miliseconds). This cycle is repeating each second and thus the 1 Hz shining and fading can be observed in nominal operation.

**Yellow** LED is present to complete the bidirectional indicator of data stream. This LED is not used in nominal operation, since the piNAV-NG ignores incoming data at the RXD pin.

**Two blue** LEDs are used to indicate the Valid Position Pulse and Position Fix signals. Since the log. 1 of the Valid Position Pulse is very fast (~500 µs), the VPP LED is only weakly flashing, each 1 second. The raising edge at this line indicates the time to which the position provided by the piNAV was actual. This pin can be utilized for synchronization of the other (satellite) systems to the GPS or UTC time.

The second, Position Fix LED, indicates the actual status of the piNAV-NG. Log. 0 indicates no GPS satellites are being tracked resulting in no position data provided. Pulses with 0.5 Hz frequency (1000 ms log. 1, 1000 ms log. 0) indicates tracking of at least one GPS satellite, however no position data can be provided (not


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enough satellites processed or visible to calculate the position). Permanent log. 1 (shining) indicates the piNAV-NG GPS position fix and provision of navigation data. Navigation data are valid and based on at least four GPS satellites in view.

The piNAV-NG receiver is connected to the Evaluation Kit via the System Interface dual row 2×10 pin connector header (2 mm pitch). Each pin, its function and direction or manner of use is indicated in the Tab.: below. The system is powered via the FTDI USB to TTL serial cable via connector labeled as "FTDI".

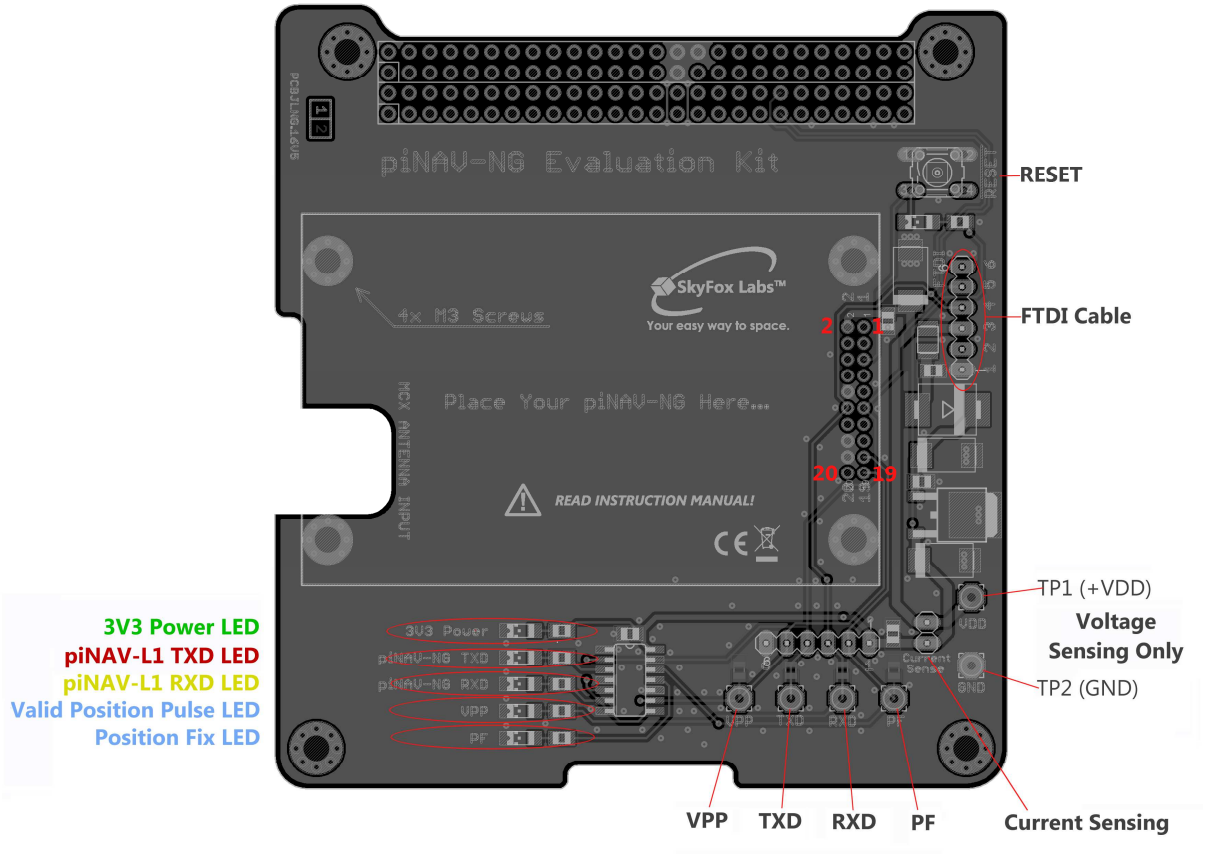


**Fig. 2 Test pins, indicating LEDs and connectors of the piNAV-NG Evaluation Kit.**

Tab.: 1 **The piNAV-NG Pin Description**, NOTE: Minimum required interface pins are highlighted.

| Pin | Name | I/O, Power or Do Not Connect | Description |
|---|---|---|---|
| 1 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| **2** | **VDD** | **Power** | **Positive system power input.** Positive power supply input, connect to +3.3 V with respect to GND system ground pin. |
| 3 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| 4 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| **5** | **/RESET** | **I** | **Reset Input.** Active in log. 0. No reset pulse needed. May be used to force Cold Start. |
| 6 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| 7 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| 8 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| 9 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| **10** | **GND** | **Power** | **System ground.** Must be connected to ground potential. This pin is internally connected (equal) to pin 13, 16 and 18. |
| **11** | **TXD** | **O** | **GPS Receiver Serial Data Output.** NMEA and piNAV sentences are present on this pin. Data is provided by standard UART serial transfer at a rate of 9600 bps, no parity, 8 databits, 1 stop bit. New set of sentences are provided with update frequency of 1 Hz. LVCMOS compatible. |
| 12 | RXD | I | GPS Receiver serial data input. Not used in normal operation. Data received on this pin has no effect. For future use. LVCMOS compatible. |
| **13** | **GND** | **Power** | **System ground.** Must be connected to ground potential. This pin is internally connected (equal) to pin 10, 16 and 18. |
| 14 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| 15 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |
| **16** | **GND** | **Power** | **System ground.** Must be connected to ground potential. This pin is internally connected (equal) to pin 10, 13 and 18. |


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| | | | |
|---|---|---|---|
| 17 | PF | O | Position Fix. This pin indicates the actual status of the piNAV-L1. Log. 0 indicates no GPS satellites are being tracked, no position data will be provided. Pulses with 0.5 Hz frequency (1000 ms log. 1, 1000 ms log. 0) indicates tracking of at least one GPS satellite, however no position data can be provided (not enough satellites). Permanent log. 1 indicates the piNAV-L1 GPS position fix and provision of navigation data. Navigation data are valid and based on at least four GPS satellites in view. |
| **18** | **GND** | **Power** | **System ground.** Must be connected to ground potential. This pin is internally connected (equal) to pin 10, 13 and 16. |
| 19 | VPP | O | Valid Position Pulse. Raising edge on this pin indicates time to which the position provided by the piNAV was actual. This pin can be utilized for synchronization of the other satellite systems to the GPS or UTC time. LVCMOS compatible. |
| 20 | NC | DNC | Do not connect. Keep left floating. For factory purpose only. |

Tab.: 2 **The piNAV-NG/Evaluation Kit PC/104+ Pin Description**, NOTE: Minimum required interface pins are highlighted.

| Pin | Name | I/O, Power or Do Not Connect | Description |
|---|---|---|---|
| **H1.39** | **TXD_MHX** | **O** | **GPS Receiver Serial Data Output.** NMEA and piNAV sentences are present on this pin. Data is provided by standard UART serial transfer at a rate of 9600 bps, no parity, 8 databits, 1 stop bit. New set of sentences are provided with update frequency of 1 Hz. LVCMOS compatible. |
| H1.40 | RXD_MHX | I | GPS Receiver serial data input. Not used in normal operation. Data received on this pin has no effect. For future use. LVCMOS compatible. |
| H2.29 | GND1 | Power | **System ground.** This pin is internally connected (equal) to pin 10, 13, 16 and 18. |
| H2.30 | GND2 | Power | **System ground.** This pin is internally connected (equal) to pin 10, 13, 16 and 18. |
| H2.32 | GND3 | Power | **System ground.** This pin is internally connected (equal) to pin 10, 13, 16 and 18. |

The piNAV-NG receiver is equipped with the female MCX straight RF connector (located on the piNAV-NG module, no antenna connector on Evaluation Kit). The male right angle MCX connector is recommended.


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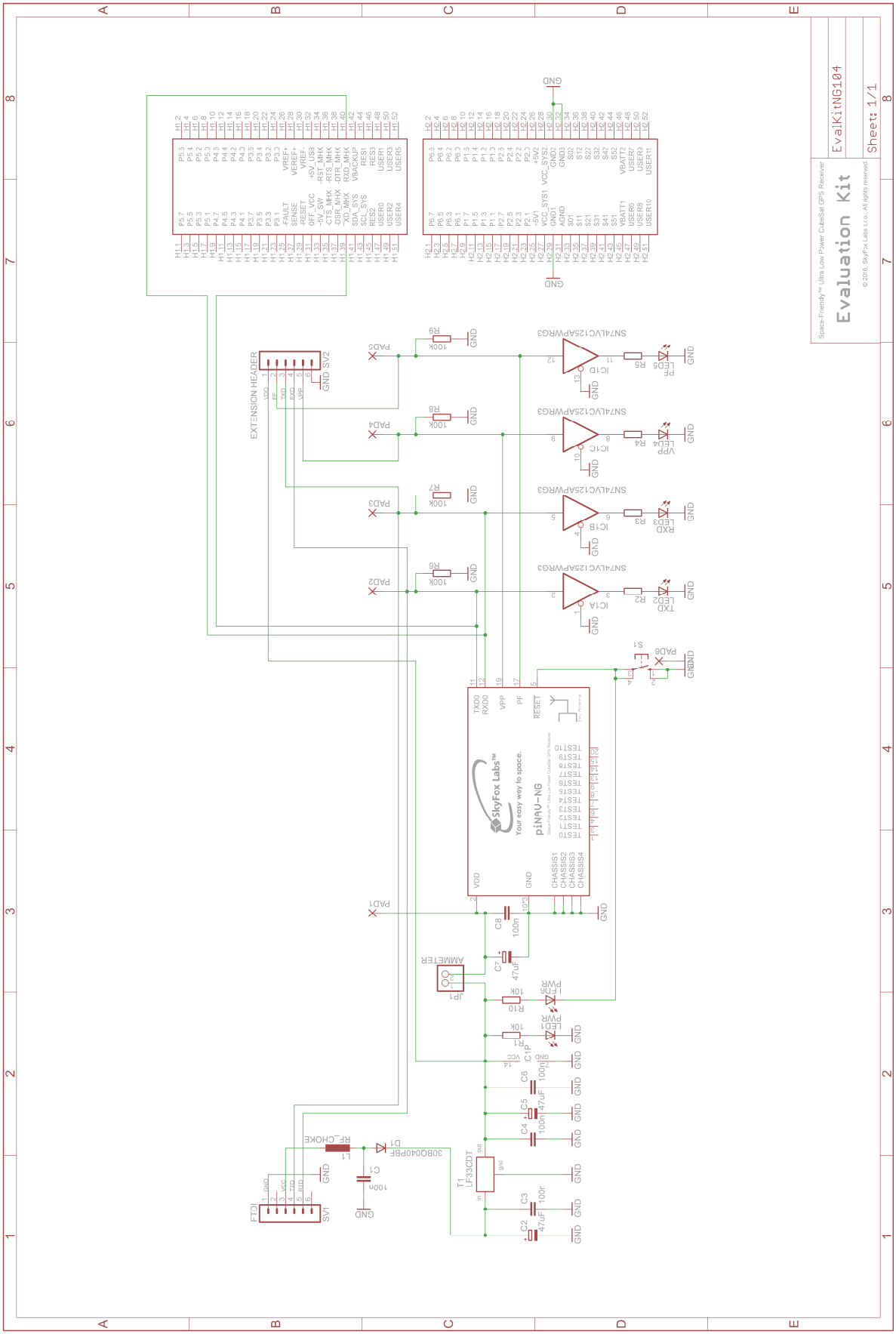
## SCHEMATIC DIAGRAM





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## THEORY OF OPERATION

The Evaluation Kit uses connection to the PC via delivered USB cable, running as a virtual com port (also known as VCP). The FTDI TTL-232R-3V3 cable with LVCMOS compatible signalling is used. Software drivers for VCP are available online at http://www.ftdichip.com/Drivers/VCP.htm supporting Windows, Linux, Mac OS X, Windows CE with various release versions. After successful driver installation, keep the USB cable connected and identify the newly added (virtual) COM port number installed in your system especially for the FTDI cable. Note that the VCP COM port number can vary within one PC, when the cable is connected to the PC via different USB ports. If the user software or terminal is not able to "open" the COM port, please check the proper drivers installation, installed COM port number or FTDI cable connection to the USB. Note that once opened COM port cannot be opened more times.

The communication setup have to be set to 9600 bits per second, no parity, 1 stop bit and 8 data bits. No other configuration will work properly. Use conventional serial communication terminal software to display the data provided by the piNAV-NG.

The Evaluation kit can be used to feed the dedicated microcontroller system. For such case, the 2.54 mm pitch pin header footprint is allocated for soldering of dedicated 6 pin extension interface connector header (SV2 in Fig. 3, not soldered).

Conventional ammeter can be used to determine the current consumption. For this purpose two-way header with 2.54 mm pitch is available on the Evaluation Kit. Disconnect the USB from PC first to terminate the input power. Remove the jumper (shorted current sensing) and connect the measurement device with the current rating of at least 200 mA. Then turn On the whole setup again and determine the input current. The current is measured directly before the piNAV-NG receiver at the 3.3V power source. In cooperation with voltage sensing measurement, the total input power can be calculated as $P_{IN} = I_{SENSE} \cdot V_{DD}$.

## ANTENNA

The piNAV-NG receiver has been tested with various GPS antennas including passive and active (including/excluding local Low Noise Amplifier), helical, loop, GP and patch antennas to find the best setup providing maximum receiver performance, sensitivity and position fix capability onboard the CubeSat structure. The best results were observed with the patch antenna (20×20 mm) and local LNA (gain $P_{LNA} \geq +13$ dBm, noise figure NF approx. 1 dB) and Z-axis CubeSat panel serving as the Patch Antenna ground plane (copper PCB with square shape, outer dimensions 100×100 mm and milled corners fitting the standard CubeSat Structure Z-axis footprint). It is recommended to keep the antenna facing the Zenith with suitable ADCS (Attitude Determination and Control Subsystem). Recommended deviation from the Zenith allowing the piNAV-NG to fix the position within the $t_{TTFF}$ time is determined as a cone of ± 45° along the Z-axis as described in Fig. 4.

**NOTE:** *The blocking of the satellite reception by the target satellite construction or improper orientation of the antenna deteriorates the piNAV-NG receiver performance and prolongs the Time-to-First-Fix ($t_{TTFF}$) parameter (mentioned in the piNAV-NG Product Datasheet). The receiver disposes by sufficient tracking and acquisition margins and can be operated even if the part of the sky is blocked by the obstacle. However, the performance of the receiver cannot be guaranteed then. Note that the acquired satellite should be tracked at last 30 seconds with $C/N_0 > 35$ dBc-Hz to be able to receive ephemeris data and then the $C/N_0$ could not fall below 25 dBc-Hz permanently, otherwise the satellite tracking is not possible (typical Zenith GPS satellites are tracked on ground at approx. 43 to 48 dBc-Hz with passive antenna).*

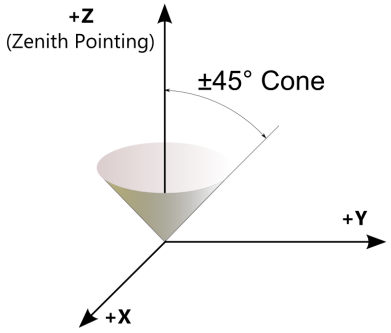


**Fig. 4 The conical area borders of the vector perpendicular to recommended GPS patch antenna's ground plane.**


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After the position fix the antenna can be swapped or rotated or periodically rotated in attitude to Nadir position and back to Zenith, whilst the tracking of the satellites is kept. However, when the signal to noise ratio $C/N_0$ of at least four visible GPS satellites fall below the 35 dB level at the $RF_{IN}$ input of the receiver, the position calculation will not be available to avoid providing with too inaccurate position data. When the $C/N_0$ of the latest four satellites serving for navigation reception falls below the minimum $P_{RF\_IN\text{-}Trck}$ the receiver will be trying to maintain the tracking of the satellites while actively perform the seeking for the new satellites. The total loss of all satellite signals results in no position data output. To recover the position information output the receiver need to spend the cold start time again.

The antenna quality can be analysed by the SNR parameters in GSV navigation sentences. The SNR of the satellite signal with the active antenna in the place with clear view to the whole sky shall be at least 48 dBc-Hz for Zenith GPS satellites and at least 43 dBc-Hz for satellites with elevation higher than 30˚.

Special care should be taken to the installation of the GPS Patch Antenna. The antenna shall be installed on the sufficiently large ground plane. The shape of the ground plane, near objects and antenna matching affects the patch resonant frequency and radiation pattern. SkyFox Labs™ as industry's first manufacturer is ready to offer to end users the recommended and proved GPS antenna mounted, glued and combined with the **+Z**-axis panel as the only one compact product on the small satellite market. The photo of the whole set of the GPS Active Patch Antenna with LNA is displayed in Fig. 5. For more details please see manufacturer's website at http://www.skyfoxlabs.com .

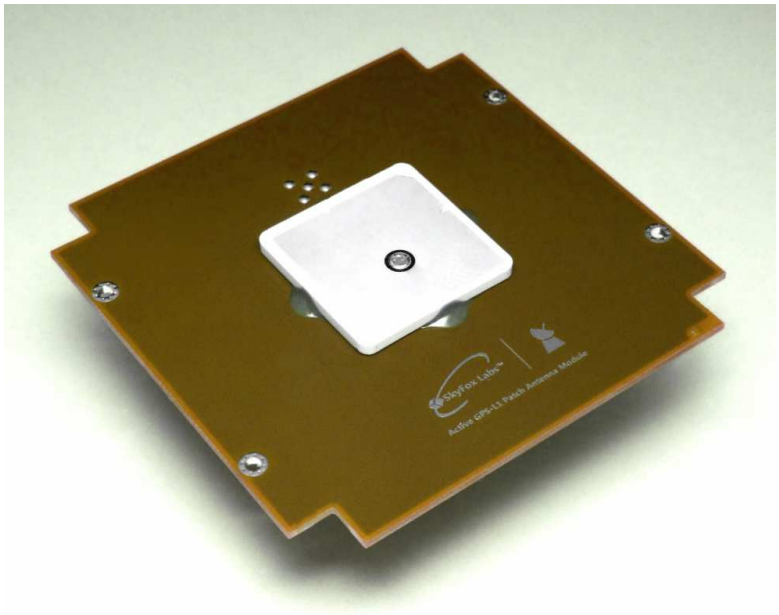

**Fig. 5 The GPS Patch Antenna – Flight Model.**

## PROTOCOLS

The physical communication is realized via the standard UART data interface. The baud rate is set to 9600 bps, no parity, 8 data bits, 1 stop bit. Logical levels are equal to LVCMOS levels as defined in JEDEC JESD8C.01 standard.

The piNAV-NG receiver provides navigation data in standard NMEA 0183 format. The standard NMEA sentences GGA, GSA, GLL, RCM, VTG and GSV were augmented by the manufacturers's defined sentences (piNAV) LSP and LSV in the NMEA format. It provides position and velocity vector in the Cartesian coordinates in the reference frame WGS-84 and GPS time instead of UTC.

As the receiver does not store the navigation data in the non-volatile memory, the UTC time in NMEA sentences is available after reception of the ionospheric and UTC data from the satellites. The coarse GPS time in piNAV sentences is available immediately after reception of any sub-frame. The receiver time is corrected immediately after the position fix. The piNAV-NG provides position information immediately after it is calculated. For more info please refer to the piNAV-NG Product Datasheet.


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# APPLICATION NOTES & RECOMMENDATIONS

## EMC CONSIDERATIONS

As the size of the small satellites imply the high level of integration of different electronic devices (switch mode power supplies, high speed digital electronics, pulse-width modulated electromagnetic actuators, etc.) into a limited satellite structure volume containing potential sources of disturbing signals, the electromagnetic susceptibility and compatibility is critical for implementation of any subsystems sensitive to electromagnetic radiation.

Proper ground planes and PCB design rules minimizing the radiated and conducted emissions shall be applied within the whole small satellite structure, including custom payloads, conventional (Communication and Data Handling, Power Supply and Power Distribution, Onboard Computer, Attitude Determination and Control) and third party electronic subsystems. The small satellite electronics should be properly designed to not disturb the GPS receiver input with harmonic frequencies falling to the GPS L1 frequency band.

The $C/N_0$ parameter provided in GSV sentences can be exploited as a diagnosis tool if the EMC issues affect the piNAV-NG reception capability. Observe the $C/N_0$ levels and switch On/Off each electronic subsystem to identify the potential source of the disturbance, if needed.

## ANTENNA LOCATION

Special care should be taken to the interference with the small satellite communication subsystem, as an active electronic device radiating the high power electromagnetic waves. The manufacturer recommends installing the GPS antenna as far from the (transmitting) communication antennas as possible.

Be sure to test the target small satellite subsystems against affecting the performance of the piNAV-NG receiver under all satellite operation conditions. Keep in mind the receiver may be sensitive to harmonics of the downlink (transmitter) frequency (i.e. 1575 MHz /9, /8, /7, /6, /5 /4, /3,/2, etc.).

The piNAV-NG receiver has been successfully tested onboard the 1U CubeSat with omnidirectional antenna and FM modulated transmitter with 500 $mW_{EIRP}$ output power at the UHF band (435 MHz) with no functional degradation of the receiver performance.

## RECYCLING

Below mentioned logo given on the goods, its packaging or inside the user guide or other related documentation means that used electrical or electronic devices, or products should not be disposed with household waste. To ensure proper disposal of the product hand it to designated collection points, where they will be accepted free of charge. Eco disposal of our products is maintained by collective system RETELA. Please recycle product packaging in proper way. The piNAV-NG/ Evaluation Kit is RoHS Compliant.


## PRODUCT SAFETY

According to use of the product in line with this Quick Start Guide, the product is safe under normal use The CE mark (Conformité Européenne) has been issued on this family of products. Related EC Declaration of Conformity is issued with each supply and is available online at manufacturer's website http://www.skyfoxlabs.com .

CE


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