U-Pilot & U-Pilot OEM Manual

V 2.02

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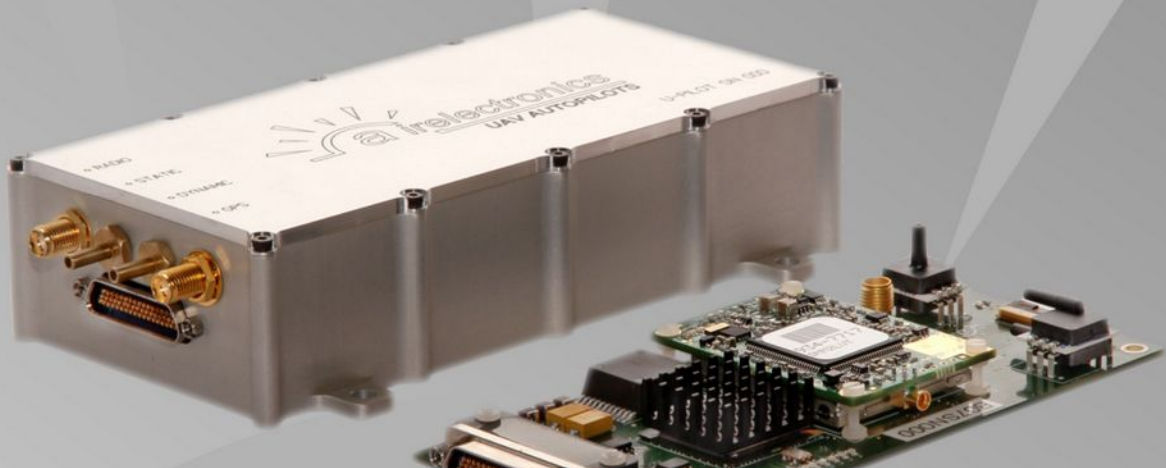


Table of Contents

1 Foreword

This manual applies to autopilots produced from September 1st 2020 and based around the B10 (Board 10).

Please, notice that while the mechanical aspects of the autopilot have been kept equal, the electrical connections are different across hardware version. *Damage to the hardware may occur if these differences are not checked.*

If you don’t know if your autopilot is B10 based check section Identifying B10 based units 4.1.1 on page 10.

Previous versions of this manual are available from Airelectronics. For older autopilots (B09, B08, B07, B04) contact us via email (info@airelectronics.es) to get proper document describing your hardware

2 General System Introduction

Airelectronics has developed a complete solution for both rotary and fixed wing UAVs. The system is mainly composed of:

- U-Pilot or U-Pilot OEM.
- U-Ground or U-Ground OEM.
- U-See Software.

U-Pilot manages and controls the vehicle from Take-off to Landing, being capable of controlling any kind of aircraft including fixed wing, helicopters and multicopters.

U-Pilot is completely capable of following a flight plan with up to 200 real-time editable points. Once the flight plan is loaded on U-Pilot, it is independent of operator instructions, and in case of a communications failure, U-Pilot starts a Return Home, with the possibility of following a predefined path or sequence of actions, and Land manoeuvres which would safely land the UAV on the Runway Point.

Thanks to its versatility, U-Pilot can control any payload on board the UAV such as cameras, parachutes or sensors. These devices can be real time controlled by a computer operator or by U-Pilot automatically.

The FPGA technology used in U-Pilot and U-Ground allows the system to have several logic working in parallel with the main processors. U-Pilot has working in parallel:

- Up to 26 PWM (Pulse-Width Modulation) or GPIO (General Purpose Input / Output).
- 3 ADC inputs (Analogical Digital Converter) to monitor the voltages of 3 batteries on the UAV.
- Up to 8 serial ports RS232 or 4 full duplex RS-485 (configurable), to communicate with payloads, external sensors, specific electronics, etc.
- A radiolink capable of reaching 100 km[1] between receptors. Information sent using this radiolink can be protected using AES-128-CCM encryption.
- GPS with RTK capability[2], dynamic and static pressure sensors, gyroscopes and accelerometers.

U-Pilot is built using a two parallel microprocessor approach:

- One processor handling the state estimation and control of the UAV, using hardware acceleration to calculate high speed algorithms.
- A second processor handles of the mission at high level, communications with U-Ground and the Payload.

The processors do not spend time handling low-level tasks, as these tasks are processed in parallel by dedicated logic of the FPGA.

Due to the fact that those two processors are working in parallel and there is dedicated electronics processing the serial ports, sensors, inputs and outputs, the system is capable of recalculating its position, orientation and closing control loops at 1000 Hz. This control speed provides a great navigation accuracy and control.

On the ground segment, Airelectronics has both U-Ground and U-See.

1 Range may vary with the frequency band used. Default is 900 MHz but legal limitations in some countries may change this.
2 Disabled by default. Contact Airelectronics to acquire this capability.

U-Ground is a ground station that mainly acts as a relay of command and data between U-Pilot and U-See software. Besides acting as data relay, U-Ground provides useful information to U-Pilot such as U-Ground position and pressures. U-Ground hardware is also capable of handling several peripheries, as an Antenna tracking system.

Finally, U-See software is a user friendly program that runs in any personal computer running Windows or Linux. Using U-See, the UAV operator can monitor the current state of the vehicle, control the UAV or modify the vehicle mission in real time.

2.1 Concept of system operation

The system consists of an U-Pilot installed on an aircraft connected to a U-Ground through a radio link. (See figure 1 attached below)

U-Ground and U-Pilot have their own radio links to communicate between them. U-Ground has a RS-232 port to relay the data and command between a PC running U-See and the U-Pilot on-board the vehicle.

Under certain circumstances such as aircraft integration and characterization, a Futaba Emitter is recommended in order to provide manual override of the vehicle.

U-Pilot has up to eight serial ports, providing a wide range of peripherals that could be connected to it: sensors, payloads, additional communication links, designed ad hoc electronics, etc.

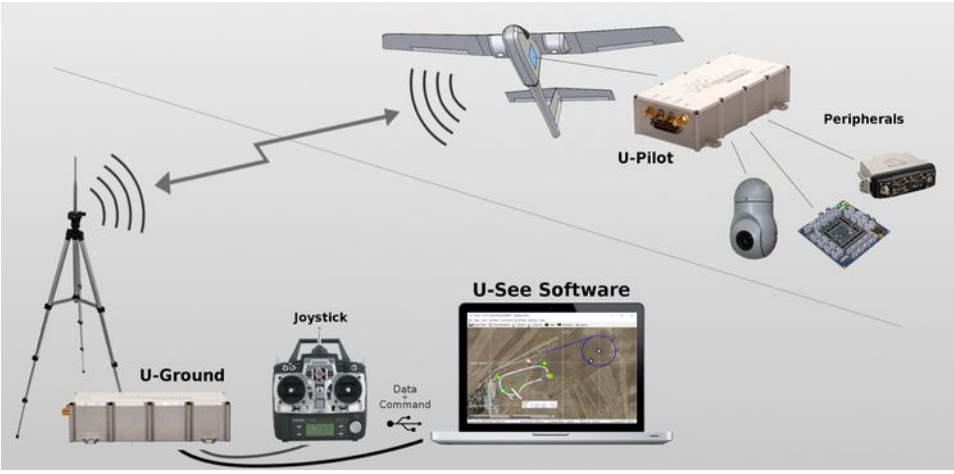


Figure 1: System concept

The mission operation team is usually formed by two persons:

- An external pilot who will handle the Futaba Joystick in case a manual control of the UAV is desired (specially during the development and adjustment phase).
- A U-See operator that will command the mission using a computer.

When using the UAV for surveillance purposes, a camera operator is recommended.

3 Controllable Air vehicles

U-Pilot is able to control Fixed Wing and Rotary Wing vehicles. Each unit is configured for a specific type of vehicle.

3.1 Fixed wing

Fixed wing can take-off automatically on a runway, hand launched, bungee launched or catapulted. The automatic landing can be done using a parachute a net or a runway.

At the time of performing the connections of the servos to the U-Pilot refer to U-Pilot connections.

3.1.1 Conventional configuration fixed wing

Conventional configuration planes are supported with redundant elevator and separated channels for left and right ailerons and flaps.

Other configurations/equipment are supported (spoilers support, parachute deployment for landing, etc.) upon request. Please contact us for this kind of configuration.

3.1.2 Flying wing configuration

Tailless flying wing is supported and aileron control is separated in two channels per wing to improve reliability and enable usage of butterfly air-brake deployment.

3.1.3 V-Tail aircraft configuration

In case of V-Tail aircrafts, the traditional elevator signals changes to a two separate signals for the tail surfaces, while a flaperon channel for each wing is managed. In addition, dedicated flaps signals are maintained.

3.2 Rotary wing

Rotary wing configuration group different vehicles. U-Pilot can be configured for the following type (extra configuration will be added in the future). In addition, each type can be associated to a free rotary wing or to a captive rotary wing.

3.2.1 Helicopter (Swash-plate 4)

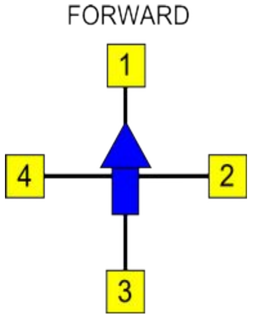


Figure 2: Helicopter servo distribution

The helicopter has a swash-plate driven by four servos. These servos should be connected to U-Pilot following the attached schematic.

- Servo 1 is forward mounted.
- Servo 2 is right mounted.
- Servo 3 is back mounted.
- Servo 4 is left mounted.

The U-Pilot motors connection is detailed in U-Pilot connections.

3.2.2 Helicopter (Swash-plate 3)

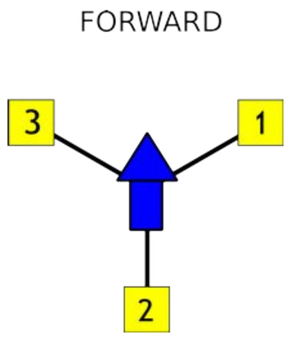


Figure 3: Helicopter (Swash-plate 3) servo distribution

The helicopter configured as swash-plate 3 has a swash-plate driven by three servos. These servos should be connected to U-Pilot following the attached schematic.

- Servo 1 is forward-right mounted.
- Servo 2 is back mounted.
- Servo 3 is forward-left mounted.

The U-Pilot motors connection is detailed in U-Pilot connections.

3.2.3 Helicopter (Direct Drive)

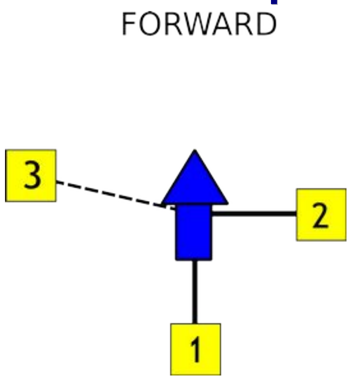


Figure 4: Helicopter (direct swash plate) servo distribution

The helicopter has a swash-plate driven by three servos. These servos should be connected to U-Pilot following the attached schematic.

- Servo 1 drives cyclic pitch
- Servo 2 drives cyclic roll
- Servo 3 drives collective

Note that as every movement of the swash-plate is assigned exclusively to a servo, you don't need to respect the right/left or forward/back indications of the diagram, as you can always check “inverse” in the servos adjustment step.

The U-Pilot motors connection is detailed in U-Pilot connections.

3.2.4 Quadcopter

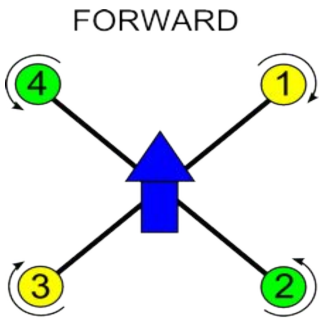


Figure 5: Quadcopter motors distribution

The quadcopter motors distribution and the rotation direction is represented in the attached schematic.

Notice that motors number 1-3 must turn clockwise and motors number 2-4 must turn anticlockwise.

The U-Pilot motors connection is detailed in U-Pilot connections.

3.2.5 Hexacopter config A

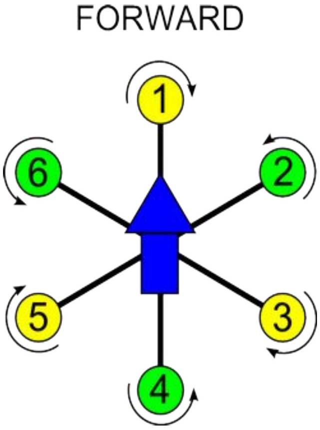


Figure 6: Hexacopter motors distribution config A

The hexacopter motors distribution and the rotation direction is represented in the attached schematic.

Notice that motors number 1-3-5 must turn clockwise and motors number 2-4-6 must turn anticlockwise.

The U-Pilot motors connection is detailed in U-Pilot connections.

Note this manual covers two different possible configurations for a hexacopter. (Config A and config B). They are not interchangable and an autopilot misconfigured (config A on config B et vice versa) WILL lead to a crash and loss of the vehicle. Please, check with Airelectronics which version applies to your vehicle and autopilot if you have any doubt

3.2.6 Hexacopter config B

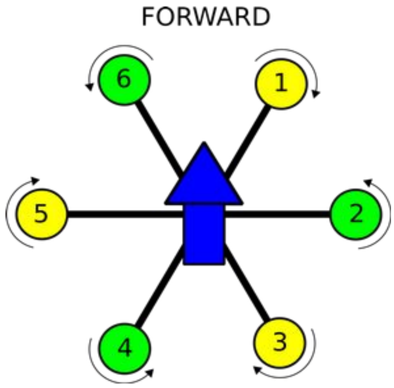


Figure 7: Hexacopter motors distribution config B

The hexacopter motors distribution and the rotation direction is represented in the attached schematic.

Notice that motors number 1-3-5 must turn clockwise and motors number 2-4-6 must turn anticlockwise.

The U-Pilot motors connection is detailed in U-Pilot connections.

Note this manual covers two different possible configurations for a hexacopter. (Config A and config B). They are not interchangable and an autopilot misconfigured (config A on config B et vice versa) WILL lead to a crash and loss of the vehicle. Please, check with Airelectronics which version applies to your vehicle and autopilot if you have any doubt

3.2.7 Octocopter

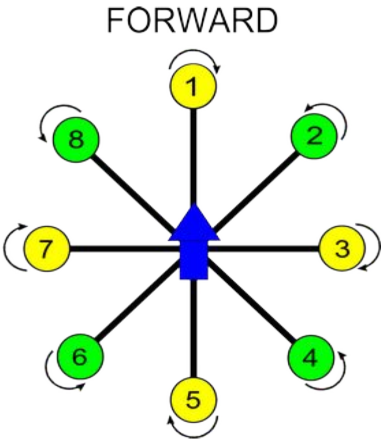


Figure 8: Octopter motors distribution

The octocopter motors distribution and the rotation direction is represented in the attached schematic.

Notice that motors number 1-3-5-7 must turn clockwise and motors number 2-4-6-8 must turn anticlockwise.

The U-Pilot motors connection is detailed in U-Pilot connections.

4 U-Pilot

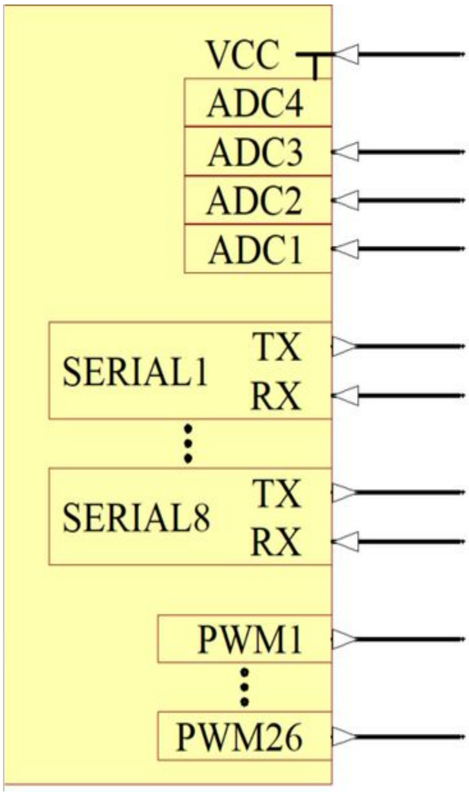


Figure 9: U-Pilot I/O Schematic

The U-Pilot is powered in the range from 6.0V to 24V, view Power Supply. This allows the connection of U-Pilot directly to a 2S LiPo battery without adding possible points of failure in the system.

If the system uses 6V servos, U-Pilot can be connected directly to the servo power and save weight.

The power installation can be done in several different ways described in Power Supply section.

U-Pilot has three ADC available channels to monitor system voltages, and it is possible to connect a Hall-Effect amperometer sensor to control the discharge of battery in electric UAVs.

There are up to 26 PWM outputs signals at 50, 200, 300, 333 or 560Hz frequencies and 1500 or 760 us pulses.

PWM at 50Hz is the most common way to control servos and it will be accepted by almost any servo in the market. This signal pulses every 20 ms (milliseconds), and depending on the length of these pulses the servo will move to different positions.

Digital servos (300Hz) can accept much faster control input and are the recommended choice when controling rotary wing aircraft.

Upon request, all the PWM lines can be reconfigured to output or input any other digital signal.

There are up to 8 serial ports RS232 also available for additional devices use, such as cameras or magnetometers. Serial ports are automatically adapted to the baud rate of the devices connected to it. The voltage levels for the serial ports are the standard +12V/-12V, but they can be configured as serial ports RS485, half or full-duplex, if the user need it, using other voltage levels.

Connector pin configuration is detailed on U-Pilot Connections section.

4.1 U-Pilot and U-Pilot OEM

U-Pilot can be acquired in two versions: the standard, enclosed in an aluminium box, and the OEM version that is not enclosed, ready to be embedded into the customer system.

Unless told otherwise, the explanations provided by this document are valid for both versions. When different explanations are required, this document will state it.

4.1.1 Identifying B10 based units

The autopilot is built around a basic electronics board that change with incremental designs. Current design is based around the B10 (Board 10, 10^{th} iteration of the design) and **the contents of this manual are only applicable to autoplots based on a B10**

The mechanical design of the autopilot has been kept from previous iteration (B09) but the functional and electrical levels of the main connector pinout have been changed so previous designs and current one are not directly interchangeable.

4.1.1.1 OEM

The PCB silkscreen has printed, between the pressure sensors" U-Pilot B10 SNXXX where SN is the serial number of the particular board.

4.1.1.2 Boxed

If the autopilot is B10 based the top left corner of the lid in the autopilolt will have a mechanical notch painted in blue besides de "Radio" text engraving.

4.2 Power supply

U-Pilot power supply accepts voltages in a range from 6.0V to 28V[3]. Main power voltage is directly connected to the ADC channel number 4, thus allowing monitor of AP battery and check for voltage supply stability. This level is displayed as an internal battery 4 on the U-See state window (Consult U-See manual for details)

<u>CAUTION</u>: Power the Autopilot at a voltage OUT of range can cause IRREVERSIBLE DAMAGE to the system. Please read carefully this manual and do not hesitate to contact us (www.airelectronics.es) if needed.

Typical power consumption about 4 Watt, but the power system should be prepared to withstand 7 Watts peaks. This consumption will mean an intensity consumption of 0.8 Amp. at 6V or 0.4 Amp. at 12 V.

4.2.1 Regulated 5V output

For easy integration of external radio-links the autopilot outputs through a main-connector pin a regulated +5V power output (Up to 3A). The comsuption of this output will increase the demand from the autopilot power supply

4.3 Microprocessors structure

The Autopilot has two microprocessors (CPUs).

- **CPU Mission control**. This CPU manages Communications to and from ground segment, the management of payloads and, in general, operations that are not flight related.
- **CPU Flight control**. This CPU produces the surfaces commands and control the attitude of the aircraft. This processor access all its sensors in a non-blocking way and it is always evaluating current position, attitude and control.

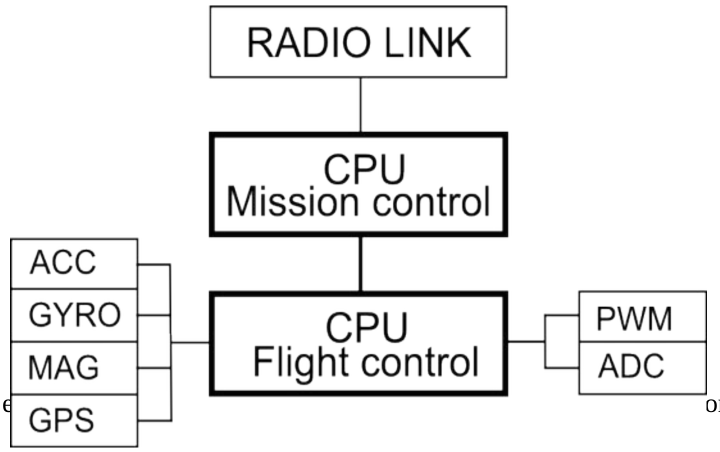


Figure 10: General system architecture.

3 Power supply can be e ... onics for more details

4.4 Sensors

There are several sensors inside U-Pilot and all of them have their own electronics design inside the system taking care of them, this gives the highest reliability and performance to the system. The sensors are:

- Accelerometers
- Gyroscopes
- GPS with Satellite Based Augmentation System and RTK capability.
- Several Static Pressure Sensor to improve accuracy in different altitude ranges.
- Several Dynamic Pressure Sensors for higher accuracy during take-off and landing operations. Different sensors account for different speed segments of the mission. These sensors are only used in Fixed Wing UAVs

Besides these internal sensors, for rotary wing an external magnetometer is used. It is connected to the system through serial port and interfaces with dedicated electronics in U-Pilot. Due to the fact that this sensor is external it can be placed far from any electromagnetic noise inside the UAV. However, it must be connected to the proper main connector on U-Pilot. (See section 4.6 U-Pilot Connections).

If, for some reason, an external dynamic pressure sensor is needed, the system has the provisions to make use of an Airelectronics external I^2C sensor that can be mounted separately from U-Pilot. This sensor is only provided upon request.

Also it is possible to use external dynamic sensors over serial port. Once again, this is provided upon request.

The sensor suite is very flexible and can be modified to reflect a customer requirement on the system.

The on-board GPS has RTK capability allowing precisions around 2 cm.

4.5 Supported peripherals

4.5.1 Payloads and video related systems

Payloads and video related devices are one of the most important systems on board an UAV, and it supposes a critical element for the majority of applications. Airelectronics has prepared the U-Pilot in order to efficiently manage all the main functions of a wide range of payloads and video systems present in market. These functions includes recoding video in real-time, switching on-off, gimbal automatic and manual control, geotracking, camera type switching or calibration.

Related to payload models, the supported cameras and video systems by U-Pilot includes cameras that uses VISCA protocol, CONTROP cameras, Antrica enconders, InPixal ASIO-155 camera or Sightline Applications video processing devices, among others.

Please, contact Airelectronics to check if your payload is supported by the system and, if it is not supported, U-Pilot can be adapted in order to support it.

4.5.2 GPS and navigation systems

Although U-Pilot has its own included GPS, maybe an external GPS is required as a backup navigation source or for differential GPS functionality. Similar to the payloads, U-Pilot supports several GPS devices that can be connected to it externally for these purposes. These GPS devices includes uBlox GPS devices, Septentrio GPS devices or Novatel GPS devices.

Contact Airelectronics to check if your GPS device is supported by the system and, if it is not supported, U-Pilot can be adapted in order to support it.

4.5.3 Other devices

There are some other devices that can be on board an UAV, as communication devices or engine management devices or ECUs. These elements can be essential in some UAVs with specific engines or involved in large distances operations.

Some of the devices supported by the U-Pilot are Moscat ECU devices, Transton AMT ECU devices, MGL RDAC ECU devices, Sagetech transponders or Cobham satcom devices.

Contact Airelectronics to check if your ECU or comms device is supported by the system and, if it is not supported, U-Pilot can be adapted in order to support it.

4.5.4 Custom electronics

We can design and manufacture ad hoc electronics for your specific application. At the moment of writing, these electronics adds to the system the following functions:

- External amperimeter sensor.
- External dynamic pressure.
- External laser altimeter
- External radar altimeter
- External Hall effect sensor, for RPM measuring or WoW functions.
- External magnetometer.
- External pixel flow sensor.
- External engine parameters measurement sensor (temperature, oil and fuel level, etc.)
- Engine kill management electronics.
- Subsystems management electronics (lights, landing gear, activate/deactivate onboard devices, etc.).

If you need a specific function, we can design a new electronics for you.

4.6 U-Pilot Connections

This section provides the required information about U-Pilot connections, including:

- Main connector connections
- Pressure connections
- Radio-Link connections
- GPS antenna connections.
- Magnetometer connections

4.6.1 U-Pilot Main Connector

The aerial part of connector used for the U-Pilot is provided in the Installation Kit. Cables in the aerial connector are colour coded. The following table describes the function of every pin in the main connector in U-Pilot and the corresponding colour coded cable in the supplied aerial connector.

The pin configuration used depending on the UAV vehicle is detailed in the following table and the corresponding connector diagram.

NOTE: Please, take into account than in these tables, Tx and Rx suffix are referred to U-Pilot. This is: a line marked as “Magnetometer Rx” is the pin dedicated to receive data from the magnetometer, and thus, must be connected to the sending pin in the magnetometer connector.

NOTE: This pinout reflects the default configuration for 8 serial ports RS232. For another serial ports option, **pins 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 23, 25 and 35 could change functionality and voltage levels**, so be careful because an error in the connection could cause a permanent damage on the U-Pilot. Information about the configuration associated to these pins can be found in section Error: Reference source not found.Error: Reference source not found.

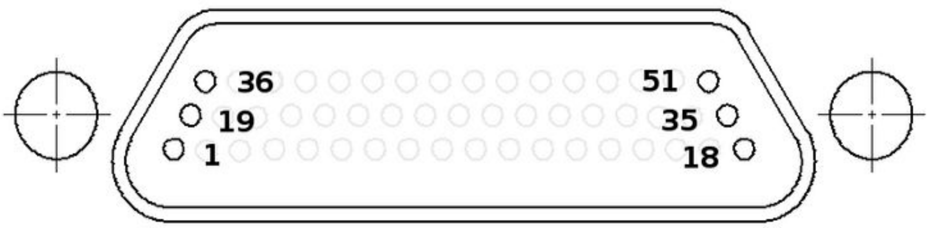


Figure 11: Main connector on U-Pilot as seen from the front.

PIN	I/O	FixedWing	Flying Wing	Helicopter Swash-plate 4	Helicopter Swash-plate 3	Helicopter Direct Swash-plate	Cable Colour
1	In	ADC 2	ADC 2	ADC 2	ADC 2	ADC 2	Black
2	In	ADC 1 / Battery	ADC 1 / Battery	ADC 1 / Battery	ADC 1 / Battery	ADC 1 / Battery	Brown
3	DC in	V_{IN}	V_{IN}	V_{IN}	V_{IN}	V_{IN}	Red
4	GND	**Ground**	**Ground**	**Ground**	**Ground**	**Ground**	Orange
5	In	RS232 Port 3 Rx	RS232 Port 3 Rx	RS232 Port 3 Rx	RS232 Port 3 Rx	RS232 Port 3 Rx	Yellow
6	Out	RS232 Port 3 Tx	RS232 Port 3 Tx	RS232 Port 3 Tx	RS232 Port 3 Tx	RS232 Port 3 Tx	Green
7	Out	RS232 Port 6 Tx	RS232 Port 6 Tx	RS232 Port 6 Tx	RS232 Port 6 Tx	RS232 Port 6 Tx	Blue
8	Out	RS232 Port 7 Tx	RS232 Port 7 Tx	RS232 Port 7 Tx	RS232 Port 7 Tx	RS232 Port 7 Tx	Purple
9	In	RS232 Port 4 Rx	RS232 Port 4 Rx	RS232 Port 4 Rx	RS232 Port 4 Rx	RS232 Port 4 Rx	Grey
10	Out	RS232 Port 4 Tx	RS232 Port 4 Tx	RS232 Port 4 Tx	RS232 Port 4 Tx	RS232 Port 4 Tx	White
11	Out	RS232 Port 5 Tx	RS232 Port 5 Tx	RS232 Port 5 Tx	RS232 Port 5 Tx	RS232 Port 5 Tx	Black
12	In	RS232 Port 5 Rx	RS232 Port 5 Rx	RS232 Port 5 Rx	RS232 Port 5 Rx	RS232 Port 5 Rx	Brown
13	Out	RS232 Port 2 Tx	RS232 Port 2 Tx	RS232 Port 2 Tx	RS232 Port 2 Tx	RS232 Port 2 Tx	Red
14	In	RS232 Port 2 Rx	RS232 Port 2 Rx	RS232 Port 2 Rx	RS232 Port 2 Rx	RS232 Port 2 Rx	Orange
15	In	RS232 Port 7 Rx	RS232 Port 7 Rx	RS232 Port 7 Rx	RS232 Port 7 Rx	RS232 Port 7 Rx	Yellow
16	In	SerialBus In	SerialBus In	SerialBus In	SerialBus In	SerialBus In	Green
17	Out	RS232 Port 1 Tx	RS232 Port 1 Tx	RS232 Port 1 Tx	RS232 Port 1 Tx	RS232 Port 1 Tx	Blue
18	In	RS232 Port 1 Rx	RS232 Port 1 Rx	RS232 Port 1 Rx	RS232 Port 1 Rx	RS232 Port 1 Rx	Purple
19	In	ADC 3 / Amperimeter	ADC 3 / Amperimeter	ADC 3 / Amperimeter	ADC 3 / Amperimeter	ADC 3 / Amperimeter	Grey
20	DC in	V_{IN}	V_{IN}	V_{IN}	V_{IN}	V_{IN}	White
21	Out	Camera Pan	Camera Pan	Camera Pan	Camera Pan	Camera Pan	Black
22	Out	Camera Tilt	Camera Tilt	Camera Tilt	Camera Tilt	Camera Tilt	Brown
23	In	RS232 Port 6 Rx	RS232 Port 6 Rx	RS232 Port 6 Rx	RS232 Port 6 Rx	RS232 Port 6 Rx	Red
24	Out	Camera Shutter	Camera Shutter	Camera Shutter	Camera Shutter	Camera Shutter	Orange
25	Out	RS232 Port 8 Tx	RS232 Port 8 Tx	RS232 Port 8 Tx	RS232 Port 8 Tx	RS232 Port 8 Tx	Yellow
26	Out	DGPS-TTL Correction	DGPS-TTL Correction	DGPS-TTL Correction	DGPS-TTL Correction	DGPS-TTL Correction	Green
27	In	Payload TTL In	Payload TTL In	Payload TTL In	Payload TTL In	Payload TTL In	Blue
28	Out	Payload TTL Out	Payload TTL Out	Payload TTL Out	Payload TTL Out	Payload TTL Out	Purple
29	Out	SerialBus Out	SerialBus Out	SerialBus Out	SerialBus Out	SerialBus Out	Grey
30	Out	Elevator 3	Reserved	Reserved	Reserved	Reserved	White
31	Out	Elevator 4	Reserved	Reserved	Reserved	Reserved	Black
32	Out	Langind Gear	Langind Gear	Langind Gear	Langind Gear	Langind Gear	Brown
33	Out	Left Wheel Brake	Reserved	Reserved	Reserved	Reserved	Red
34	Out	Right Wheel Brake	Reserved	Reserved	Reserved	Reserved	Orange
35	In	RS232 Port 8 Rx	RS232 Port 8 Rx	RS232 Port 8 Rx	RS232 Port 8 Rx	RS232 Port 8 Rx	Yellow
36	GND	**Ground**	**Ground**	**Ground**	**Ground**	**Ground**	Green
37	Out	Throttle	Throttle	Throttle	Throttle	Throttle	Blue
38	Out	Right Aileron	Out Right aileron	Swash-plate 1	Swash-plate 1	Cyclic Pitch	Purple
39	Out	Elevator	In Left aileron	Swash-plate 2	Swash-plate 2	Cyclic Roll	Grey
40	Out	Rudder	Rudder	Tail Servo	Tail Servo	Tail Servo	White
41	Out	Left Aileron	Out Left aileron	Swash-plate 3	Swash-plate 3	Collective	Black
42	Out	Left Flap	Left Flap	Swash-plate 4	Reserved	Reserved	Brown
43	Out	Elevator 2	In Right Aileron	Reserved	Reserved	Reserved	Red
44	Out	Right Flap	Right Flap	Reserved	Reserved	Reserved	Orange
45	Out	Nose Wheel	Nose Wheel	Reserved	Reserved	Reserved	Yellow
46	Out	2nd Aileron Right	Reserved	Reserved	Reserved	Reserved	Green
47	Out	2nd Aileron Left	Reserved	Reserved	Reserved	Reserved	Blue
48	Out	2nd Flap Right	Reserved	Reserved	Reserved	Reserved	Purple
49	Out	2nd Flap Left	Reserved	Reserved	Reserved	Reserved	Grey
50	Out	Parachute	Parachute	Parachute	Parachute	Parachute	White
51	DC Out	+5V regulated Out	+5V regulated Out	+5V regulated Out	+5V regulated Out	+5V regulated Out	Black

PIN	I/O	Quadcopter	Hexacopter (A & B)	Octocopter	Cable Colour
1	In	ADC 2	ADC 2	ADC 2	Black
2	In	ADC 1 / Battery	ADC 1 / Battery	ADC 1 / Battery	Brown
3	DC in	V_{IN}	V_{IN}	V_{IN}	Red
4	GND	**Ground**	**Ground**	**Ground**	Orange
5	In	Magnetometer Rx	Magnetometer Rx	Magnetometer Rx	Yellow
6	Out	Magnetometer Tx	Magnetometer Tx	Magnetometer Tx	Green
7	Out	RS232 Port 6 Tx	RS232 Port 6 Tx	RS232 Port 6 Tx	Blue
8	Out	RS232 Port 7 Tx	RS232 Port 7 Tx	RS232 Port 7 Tx	Purple
9	In	RS232 Port 4 Rx	RS232 Port 4 Rx	RS232 Port 4 Rx	Grey
10	Out	RS232 Port 4 Tx	RS232 Port 4 Tx	RS232 Port 4 Tx	White
11	Out	RS232 Port 5 Tx	RS232 Port 5 Tx	RS232 Port 5 Tx	Black
12	In	RS232 Port 5 Rx	RS232 Port 5 Rx	RS232 Port 5 Rx	Brown
13	Out	RS232 Port 2 Tx	RS232 Port 2 Tx	RS232 Port 2 Tx	Red
14	In	RS232 Port 2 Rx	RS232 Port 2 Rx	RS232 Port 2Rx	Orange
15	In	RS232 Port 7 Rx	RS232 Port 7 Rx	RS232 Port 7 Rx	Yellow
16	In	SerialBus In	SerialBus In	SerialBus In	Green
17	Out	RS232 Port 1 Tx	RS232 Port 1 Tx	RS232 Port 1 Tx	Blue
18	In	RS232 Port 1 Rx	RS232 Port 1 Rx	RS232 Port 1 Rx	Purple
19	In	ADC 3 / Amperimeter In	ADC 3 / Amperimeter In	ADC 3 / Amperimeter In	Grey
20	DC in	V_{IN}	V_{IN}	V_{IN}	White
21	Out	Camera Pan	Camera Pan	Camera Pan	Black
22	Out	Camera Tilt	Camera Tilt	Camera Tilt	Brown
23	In	RS232 Port 6 Rx	RS232 Port 6 Rx	RS232 Port 6 Rx	Red
24	Out	Camera Shutter	Camera Shutter	Camera Shutter	Orange
25	Out	RS232 Port 8 Tx	RS232 Port 8 Tx	RS232 Port 8 Tx	Yellow
26	Out	Reserved	Reserved	Reserved	Green
27	In	Payload TTL In	Payload TTL In	Payload TTL In	Blue
28	Out	Payload TTL Out	Payload TTL Out	Payload TTL Out	Purple
29	Out	SerialBus Out	SerialBus Out	SerialBus Out	Grey
30	Out	Reserved	Reserved	Reserved	White
31	Out	Reserved	Reserved	Reserved	Black
32	Out	Langind Gear	Langind Gear	Langind Gear	Brown
33	Out	Reserved	Reserved	Reserved	Red
34	Out	Reserved	Reserved	Reserved	Orange
35	In	RS232 Port 8 Rx	RS232 Port 8 Rx	RS232 Port 8 Rx	Yellow
36	GND	**Ground**	**Ground**	**Ground**	Green
37	Out	Motor 1	Motor 1	Motor 1	Blue
38	Out	Motor 2	Motor 2	Motor 2	Purple
39	Out	Motor 3	Motor 3	Motor 3	Grey
40	Out	Motor 4	Motor 4	Motor 4	White
41	Out	Reserved	Motor 5	Motor 5	Black
42	Out	Reserved	Motor 6	Motor 6	Brown
43	Out	Reserved	Reserved	Motor 7	Red
44	Out	Reserved	Reserved	Motor 8	Orange
45	Out	Nose Wheel	Nose Wheel	Nose Wheel	Yellow
46	Out	Reserved	Reserved	Reserved	Green
47	Out	Reserved	Reserved	Reserved	Blue
48	Out	Reserved	Reserved	Reserved	Purple
49	Out	Reserved	Reserved	Reserved	Grey
50	Out	Reserved	Reserved	Reserved	White
51	Out	+5V regulated Out	+5V regulated Out	+5V regulated Out	Black

All the output pins with the exception of the RS232/RS485 dedicated pins output 3.3V TTL logic levels.
TTL level UARTs (SerialBus and Payload TTL) expect 0/3.3V TTL signals both for input and output
Depending on configuration of the autopilot the RS232/RS485 logic level may vary, so check with your project documentation for actual values of these pins
ADC Input range is from 0 to 30V, altough it is possible to extend them upon request

4.6.2 Serial ports possible configurations

U-Pilot is capable of managing up to eight RS232 serial ports simultaneously. The function associated to these ports are configurable for each system, depending on the elements to connect to the U-Pilot.

Available configurations are summarized in the following table.

PIN	Config 1 8TX 8RX RS232 (8 serial ports)	Config 2 4TX 4RX RS485 (Full) (4 serial ports)	Config 3 2TX 2RX RS485 (Full) 4TX 4RX RS232	Cable Colour
5	Port 3 Rx	Port 3 RS485 Rx +	Port 3 RS485 Rx +	Yellow
6	Port 3 Tx	Port 3 RS485 Tx +	Port 3 RS485 Tx +	Green
7	Port 6 Tx	Port 5 RS485 Tx -	Port 6 Tx	Blue
8	Port 7 Tx	Port 7 RS485 Tx +	Port 7 RS485 Tx +	Purple
9	Port 4 Rx	Port 3 RS485 Rx -	Port 3 RS485 Rx -	Grey
10	Port 4 Tx	Port 3 RS485 Tx -	Port 3 RS485 Tx -	White
11	Port 5 Tx	Port 5 RS485 Tx +	Port 5 Tx	Black
12	Port 5 Rx	Port 5 RS485 Rx +	Port 5 Rx	Brown
13	Port 2 Tx	Port 1 RS485 Tx -	Port 2 Tx	Red
14	Port 2 Rx	Port 1 RS485 Rx -	Port 2 Rx	Orange
15	Port 7 Rx	Port 7 RS485 Rx +	Port 7 RS485 Rx +	Yellow
17	Port 1 Tx	Port 1 RS485 Tx +	Port 1 Tx	Blue
18	Port 1 Rx	Port 1 RS485 Rx +	Port 1 Rx	Purple
23	Port 6 Rx	Port 5 RS485 Rx -	Port 6 Rx	Red
25	Port 8 Tx	Port 7 RS485 Tx -	Port 7 RS485 Tx -	Yellow
35	Port 8 Rx	Port 7 RS485 Rx -	Port 7 RS485 Rx -	Green

Note that the RS485 lines have +5/-5V voltage levels.

In addition, these ports can be assigned to multiple functions, being possible to separate these functions in TX and RX. Some of these functions are:

- On board payload management.
- External magnetometer management.
- External differential and/or backup GPS management.
- Engine control unit management.
- Other devices management (video processors, transponders, simulators, etc).
- Communication link to ground duplication.

Please, contact Airelectronics if you want to change to one of these configurations.

4.6.3 Pressure sensors connections

U-Pilot has two pressure sensors:

- Static pressure sensor
- Dynamic pressure sensor

For fixed wing vehicles, static and dynamic pressure sensors are required.

For rotary wing vehicles only static pressure sensor is required.

The static pressure tap may be left unconnected if U-Pilot environment is not sealed or pressurized. Otherwise it must be connected to the ambient pressure.

The dynamic pressure must be connected to a pitot tube, installed away from turbulent flows such as propeller down-wash.

The pressure connection installations differ in U-Pilot and U-Pilot OEM. Depending on your U-Ground version, you have to refer to the apropriate subsection

4.6.3.1 U-Pilot (Box) pressure connections

U-Pilot pressure connectors are properly labelled on the front face of the box: “STATIC” for static pressure and “DYNAMIC” for dynamic pressure.

The static pressure sensor can be left unconnected if U-Pilot environment is not pressurized or sealed.

4.6.3.2 U-Pilot OEM pressure connections

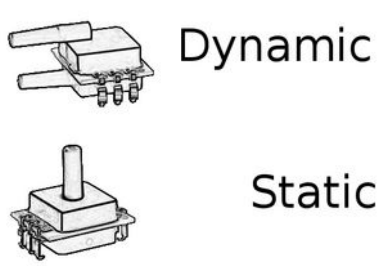


Figure 12: Pressure sensors

The OEM version of U-Pilot exposes directly the pressure sensors. The sensors can be identified with the image.

The static pressure sensor can be left unconnected if U-Pilot environment is not pressurized or sealed.

The dynamic pressure (pitot) must be connected to the lower conduit of the sensor. The upper conduit must be connected to the static tap, and may be left unconnected under the same circumstances as the static sensor.

4.6.4 Radio-link antenna connections

The radio-link antenna connection depends on the version of U-Pilot. Depending on your U-Ground version, please refer to the appropriate subsection.

4.6.4.1 U-Pilot (Box) Radio-link connection

The radio-link antenna must be connected to U-Pilot with an SMA-connector to the connector labelled as “RADIO” in the front face of U-Pilot box.

4.6.4.2 U-Pilot OEM Radio-link connection

The radio-link antenna must be connected to the radio-module using and MMCX connector.

4.6.5 External Radio-link connection

If the U-Pilot doesn't have an internal radio-link module, the U-Pilot box will have a 5-pin connector in order to manage an external radio-link power supply and communications instead of SMA connector. Airelectronics offers a harness for the U-Pilot and U-Radiolink connection using this connector.

The pinout is shown below:

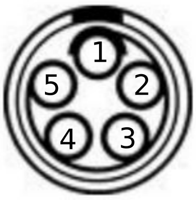


Figure 13: External radiolink connector on U-Pilot as seen from the front if internal radio module is not included

PIN	I/O	Function
1	In	Radio Diagnostics Rx
2	Out	Radio Data Tx
3	In	Radio Data Rx
4	V_{Out}	V_{Out} (5V)
5	**Ground**	**Ground**

NOTE: As it's warned in relation to U-Pilot main connector, take into account than in the table, Tx and Rx suffix are referred to U-Pilot.

In this case, a clearance distance of 45mm is required at the front of the U-Pilot box because of the aerial connector.

4.6.6 GPS antenna connections

The GPS antenna installation depends on the version of U-Pilot. Depending on your U-Ground version, please refer to the apropriate subsection.

4.6.6.1 U-Pilot (Box) GPS connection

The GPS antenna must be connected to U-Pilot with an SMA-connector to the connector labelled as "GPS" in the front face of U-Pilot box.

4.6.6.2 U-Pilot OEM GPS connection

U-Pilot OEM has two GPS connectors:

- UFL connector.
- SMA connector.

The GPS antenna can be connected to any of the two connectors but NOT BOTH at the same time. The location of the UFL and SMA connectors is described in the mechanical drawings for the OEM version.

If the U-Pilot has the RTK capability active, a multiband multi-constelation antenna should be connected. Contact Airelectronics to be supplied with a suitable antenna.

4.6.7 Magnetometer connections

For rotary wing platforms, it is need to connect an external magnetometer to U-Pilot.

It is encased in metal and it interfaces and powers through a DB9 connector. Figure 14 and Table 1 detail the proper wiring to connect the magnetometer to U-Pilot. Note, through, that this magnetometer must be supplied with DC between 6.5V and 15V.

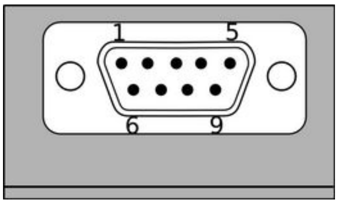


Figure 14: Magnetometer connector viewed from the front.

Magnetometer PIN	Magnetometer Function	Default Connected to
2	TxD	Pin 5 (Magnetometer RX in main connector)
3	RxD	Pin 6 (Magnetometer TX in main connector)
5	GND	Ground
9	Vcc	Magnetometer power supply. (6.5V-15V)

Table 1: Magnetometer connection list

4.6.7.1 Magnetometer mounting on the vehicle

The magnetometer can be rigidly attached to the structure of the aircraft since it should be unresponsive to the normal mechanical vibrations however proximity with magnetic parts must be avoided (permanent magnets, motors, transformers, high current lights, etc)

Orientation of the magnetometer is fully configurable (any orientation is available) but when possible the following orientation should be preferable:

- Serial connector aligned with X axis of the aircraft in the direction of flight
- Top of the magnetometer towards the up direction

Recommended position for the magnetometer in helicopters is on the tail boom.

4.7 Mechanical mounting

The autopilot should be located as close to possible to the center of gravity of the aircraft.

It should have proper vibration insulation for high frequency mechanical noise (> 300Hz)

The autopilot supports mounting in several orientations, however, once an orientation is selected by the client and Airelectronics' technicians it is very important that all subsequent units of the autopilot are installed always in the same way since failing to do so will create a wrong attitude estimation. The available orientations are:

Autopilot Orientation in config	Guide for vehicle positioning
Standard Forward	Connector towards vehicle positive X (towards forward travel direction) and components looking up (Box lid towards up)
Standard Backward	Connector towards vehicle negative X (opposite of travel direction) and components look up (Box lid towards down)
Upsidedown Forward	Connector towards vehicle positive X (towards forward travel direction) and components looking down (Box lid towards down)
Upsidedown backward	Connector towards vehicle negative X (opposite travel direction) and components looking down (Box lid towards down)
Lateral Forward	Connector towards vehicle positive X (towards forward travel direction) and components looking to the Left side of the vehicle (Box lid towards **negative** Y vehicle Axis)
Lateral Backward	Connector towards vehicle negative X (opposite travel direction) and components looking to the Right side of the vehicle (Box lid towards positive Y vehicle Axis)
Sideways up	Connector is installed along Y positive axis (connector is looking to the right of the vehicle) and the components of the autopilot (box lid) are looking up.

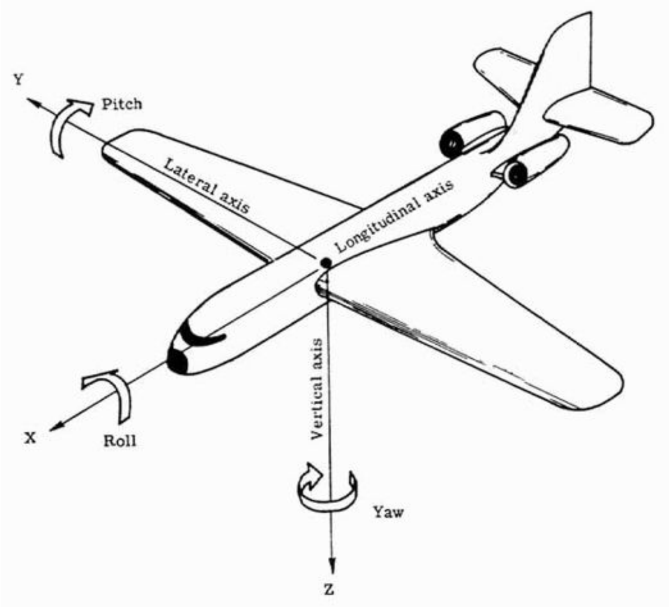


Figure 15: Axis system used in the reference

4.7.1 U-Pilot OEM sensibility to mechanical stress

The U-Pilot OEM board includes three MEM combined gyroscope and accelerometer chips that are sensitive to mechanical stress.

Changes on the board mounting will deviate the 0 of the sensor affecting attitude estimation so every time the OEM board mechanical tension on the mounting holes is changed a full sensor auto-align should be done.

4.8 U-Pilot configurations

4.8.1 Gains configurations

Although U-Pilot can be installed in a huge variety of aircrafts, each one has its own features and characteristics (weight, mass distribution, onboard devices, etc.). In order to adjust perfectly the U-Pilot to the aircraft, there are a number of U-Pilot parameters that have to be set. These parameters have been called ‘gains’.

U-Pilot gains determines how the device will perform the automatic control, how take-off and landing manoeuvres are defined or how the servos mixture will be set, for example, so they are a very critical system configuration. For this, normally Airelectronics technicians will adjust these parameters for the customer in the adjustment phase of the project. However, if you need to configure a specific gain, contact Airelectronics.

4.8.2 Magnetometer configuration

For correct operation with U-Pilot system, the HMR2300 magnetometer must be configured to use:

- Binary output
- Continuous measurement
- Zero offset turned Off
- Averaging Off

- Auto S/R pulses On
- Re-Enter responses On
- 50 samples per
- ID Set to 0

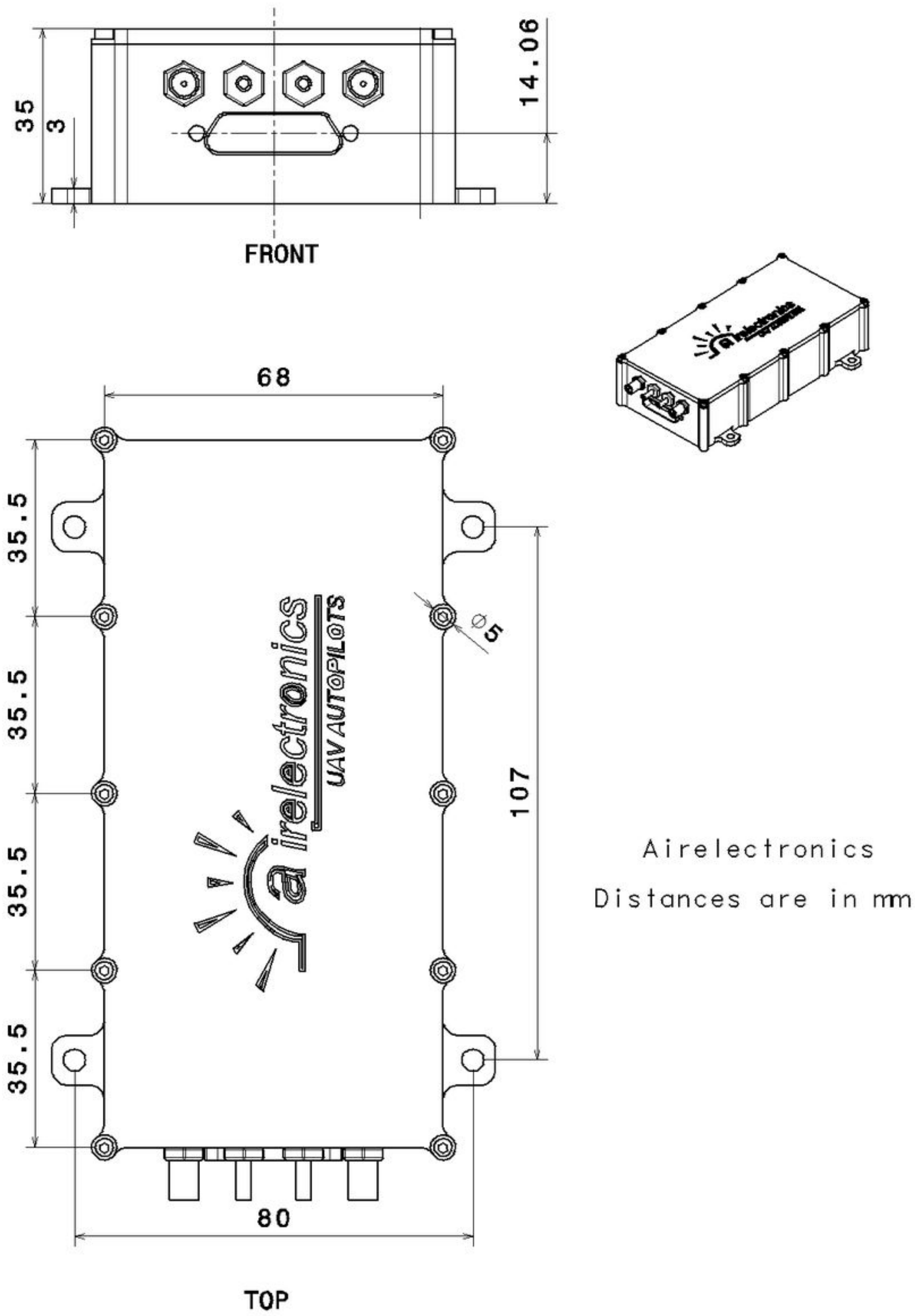
You can check configuration query command answer from the magnetometer against the following response:

```
BINARY, CONTIN, S/R ON, ZERO OFF, AVG OFF, R ON, ID= 00,  50 sps
```

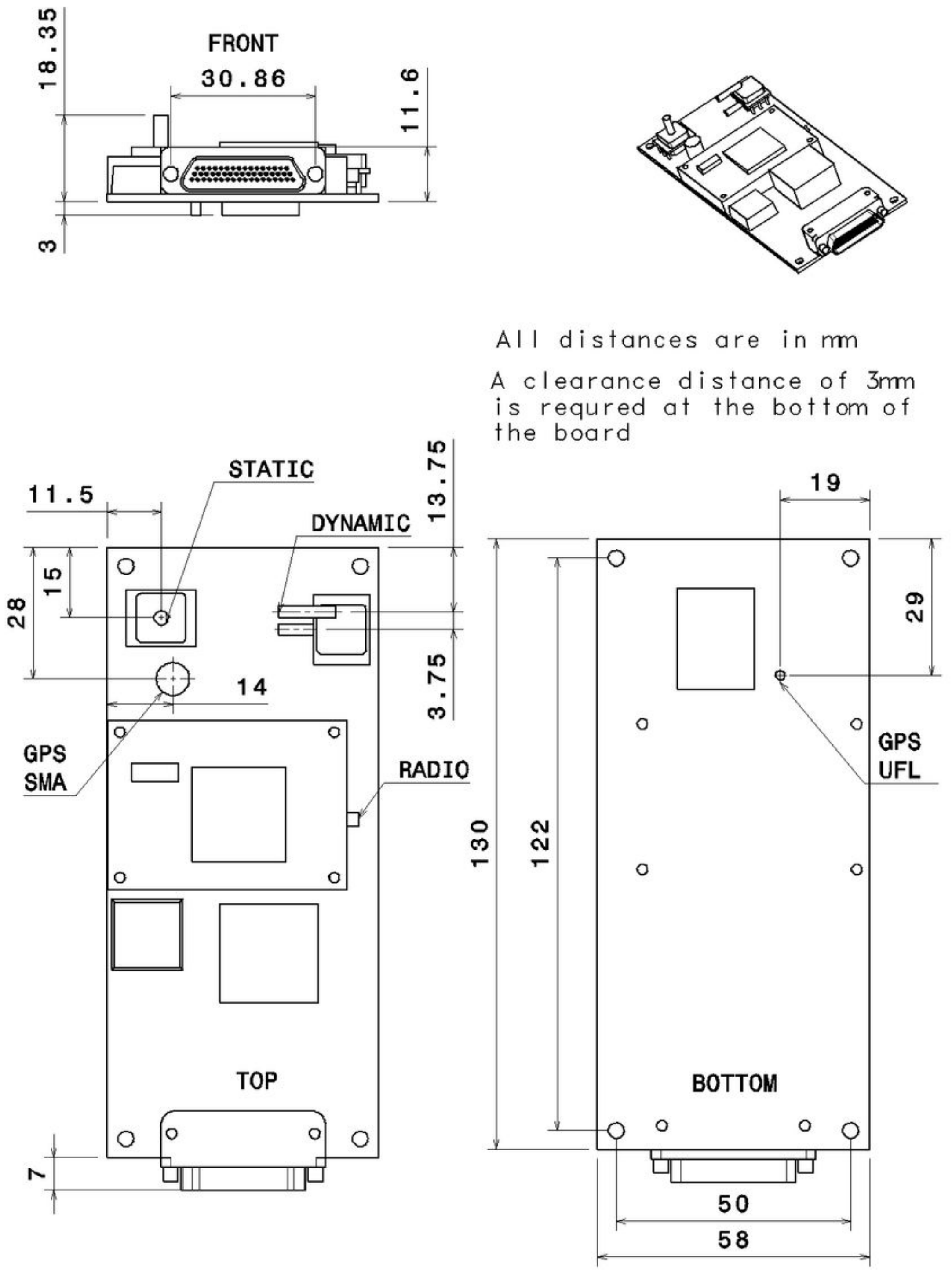
A Correctly configured magnetometer should answer with an identical string.(Configuration can be queried with the command *99Q)

You can check how to enable this configuration in the HMR2300 Magnetometer command sequence on page 29 or in the magnetometer manual.

Appendix A Box Mechanical Drawing



Appendix B OEM Mechanical Drawing



Appendix C Servo adjustment procedure

One of the most important steps in the process of automating an aircraft is adjusting the servos that manage the control surfaces. The objective of this phase is obtaining the PWM range to send to the servo in order to control the surface from its minimum deflection to its maximum deflection.

A diagram of the servo-surface setup is shown below for a clearer explanation.

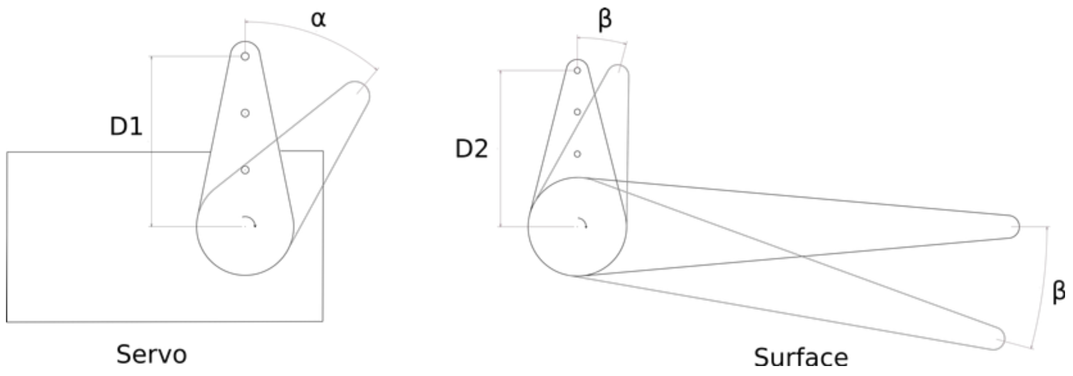


Figure 16: Servo-surface setup with parameters of interest

So, as the main objective is achieving a specific **ß** deflection angle setting a **α** servo angle, the user can use the following equation:

$$D_1 \cdot \sin(\alpha) = D_2 \cdot \sin(ß)$$

Normally, D1 and D2 parameters are selectable by the user in order to adjust the relation between both angles. In addition, the α angle usually has a restricted range determined by the servo manufacturer and is very important for this procedure. Airelectronics recommends to choose a servo with a low range for this angle.

As an example, if we want to achieve ß = 30° as maximum, and we know that the servo can reach a maximum of α = 60°, we have to choose D1 and D2 using the previous equation.

$$D_1 \cdot \sin(60) = D_2 \cdot \sin(20) \Rightarrow D_1 \cdot \frac{\sqrt{3}}{2} = D_2 \cdot \frac{1}{2} \Rightarrow \frac{D_1}{D_2} = \sqrt{3}$$

Selecting D2 = 2cm, D1 ≈ 3,5cm and the problem is solved.

However, although this theoretical procedure is correct and exact, normally D1 and D2 are discrete parameters, i.e., it can be setted in predefined values. As we tried to show in the previous diagram, normally manufacturer servo supplies pre-drilled servo arms in order to introduce transmission between the servo and the surface in them. In addition, reaching maximum values of both angles is not recommended for avoiding a possible servo damaging.

Appendix D Guide for determining servo reverse

When a new vehicle is configured with U-Pilot and U-See it is needed to determine if "Reverse" check-box should be active. Follow the following tables to determine if your servos need reversal.

Fixed Wing servos[4]

Conventional configuration

Servo	Min commanded action	Max Commanded action
Throttle	Carburator closed	Carburator opened
Aileron Right	Right aileron trailing edge up	Right aileron trailing edge down
Elevator	Elevator trailing edge up	Elevator trailing edge down
Rudder	Rudder trailing edge right	Rudder trailing edge left
Aileron Left	Left aileron trailing edge down	Left aileron trailing edge up
Wheel	Steer right	Steer left

Flying Wing

Servo	Min commanded action	Max Commanded action
Throttle	Carburator closed / motor stopped	Carburator opened / motor at max speed
Outward Left aileron	Left aileron trailing edge down	Left aileron trailing edge up
Inward Left Aileron	Left aileron trailing edge down	Left aileron trailing edge up
Rudder	Rudder trailing edge right	Rudder trailing edge left
Outward Right Aileron	Right aileron trailing edge up	Right aileron trailing edge down
Inward Right Aileron	Right aileron trailing edge up	Right aileron trailing edge down
Wheel	Steer right	Steer left

Helicopter Servos

When referring the swash-plate, left/right/front/back will be always referred as watching the swash-plate from above and in the direction of forward movement of the vehicle

Direct Servos

Servo	Min commanded action	Max Commanded action
Throttle	Carburator closed	Carburator opened
Collective	Full Swash-plate down	Full Swash-plate up
Cyclic Roll	Swash-plate tilts right	Swash-plate tilts left
Cyclic Pitch	Swash-plate tilts backwards	Swash-plate tilts forward
Rudder	Tail rotor acts to make tail rotates clockwise	Tail rotor acts to make tail rotates anti-clockwise

4 This section assumes conventional aircraft configuration. Canard configurations require different settings, please contact Airelectronics if that's your case

Swash-plate 4

Servo	Min commanded action	Max Commanded action
Throttle	Carburator closed	Carburator opened
Swash-plate 1	Corresponding swash-plate section moves down	Corresponding swash-plate section moves up
Swash-plate 2	Corresponding swash-plate section moves down	Corresponding swash-plate section moves up
Swash-plate 3	Corresponding swash-plate section moves down	Corresponding swash-plate section moves up
Swash-plate 4	Corresponding swash-plate section moves down	Corresponding swash-plate section moves up
Rudder	Tail rotor acts to make tail rotates clockwise	Tail rotor acts to make tail rotates anti-clockwise

Swash-plate 3

Servo	Min commanded action	Max Commanded action
Throttle	Carburator closed	Carburator opened
Swash-plate 1	Corresponding swash-plate section moves down	Corresponding swash-plate section moves up
Swash-plate 2	Corresponding swash-plate section moves down	Corresponding swash-plate section moves up
Swash-plate 3	Corresponding swash-plate section moves down	Corresponding swash plate section moves up
Rudder	Tail rotor acts to make tail rotates clockwise	Tail rotor acts to make tail rotates anti-clockwise

Quadcopter

Servo	Min commanded action	Max Commanded action
Engine 1	Motor stopped	Motor at max speed
Engine 2	Motor stopped	Motor at max speed
Engine 3	Motor stopped	Motor at max speed
Engine 4	Motor stopped	Motor at max speed

Hexacopter

Servo	Min commanded action	Max Commanded action
Engine 1	Motor stopped	Motor at max speed
Engine 2	Motor stopped	Motor at max speed
Engine 3	Motor stopped	Motor at max speed
Engine 4	Motor stopped	Motor at max speed
Engine 5	Motor stopped	Motor at max speed
Engine 6	Motor stopped	Motor at max speed

Octocopter

Servo	Min commanded action	Max Commanded action
Engine 1	Motor stopped	Motor at max speed
Engine 2	Motor stopped	Motor at max speed
Engine 6	Motor stopped	Motor at max speed
Engine 4	Motor stopped	Motor at max speed
Engine 5	Motor stopped	Motor at max speed
Engine 6	Motor stopped	Motor at max speed
Engine 7	Motor stopped	Motor at max speed
Engine 8	Motor stopped	Motor at max speed

Appendix E HMR2300 Magnetometer command sequence

To configure the magnetometer for use with U-Pilot system you may use the following command sequence. For doing this, you will need to prepare a special DB-9 connector that includes the power for the magnetometer and connect to the magnetometer using a RS-232 terminal program, like putty, windows hyperterminal or minicom.

Default factory setting for HMR2300 is 9600 8N1 while a magnetometer configured for U-Pilot will be at 19200 8N1.

```
*99WE
*99B
*99WE
*99TN
*99WE
*99ZF
*99WE
*99VF
*99WE
*99ID=00
*99WE
*99R=50
*99WE
*99!BR=F (This last command puts magnetometer serial interface into 19200
   bauds, so if you started at 9600 as it is the default, you should
   change your serial terminal settings accordingly)
*99WE
*99C     (This command puts the magnetometer in continous measurement mode,
   so the terminal output will fill with binary data and the following     two
commands may be necessary to input blindly)
*99WE
*99SP
```

After this final step, you should be able to power cycle the magnetometer and check that it starts giving binary output at start-up.

For more detail about the meaning of these commands, please, refer to the Magnetometer user manual.

Appendix F Changelog

This annex describes changes introduced to this document.

Date	Changes
2020/09/01	• Version up to 2.02. • Generalized U-Pilot pinout serial ports. Now, information about serial port functions is on ‘Serial port configuration’ section. • Made corrections.
2020/04/16	• Version 2.01 • Changed system concept image • Changed U-Pilot connections image. • Added information about compatible peripherals. • Added info about how to distinguish new U-Pilot versions and old ones. • Added table about serial ports configurations. • Added V-Tail option to controllable vehicles
2020/01/28	• Version 2.00 • The pinout of the U-Pilot changes drastically; pins
Previous entries have been removed to avoid excessively large changelog.	

If you need a previous version of documentation, please, contact us at info@airelectronics.es