Open Standards & Hardware for Aerial Robotics

ROS Aerial Robotics CWG - November 2023

pixhawk®

✌ whoami

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2016 - Present
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THE LINUX FOUNDATION

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Dronecode Foundation

- Founded in 2014
- Non-profit organization
- Home of open source projects, vital to the industry
- We host the projects **& their communities.**
- We create opportunities for companies in the industry.
- Following on the footsteps of the Linux Kernel

Dronecode FOUNDATION

THE LINUX FOUNDATION

Platinum

Auterion

Gold

Microsoft NXP

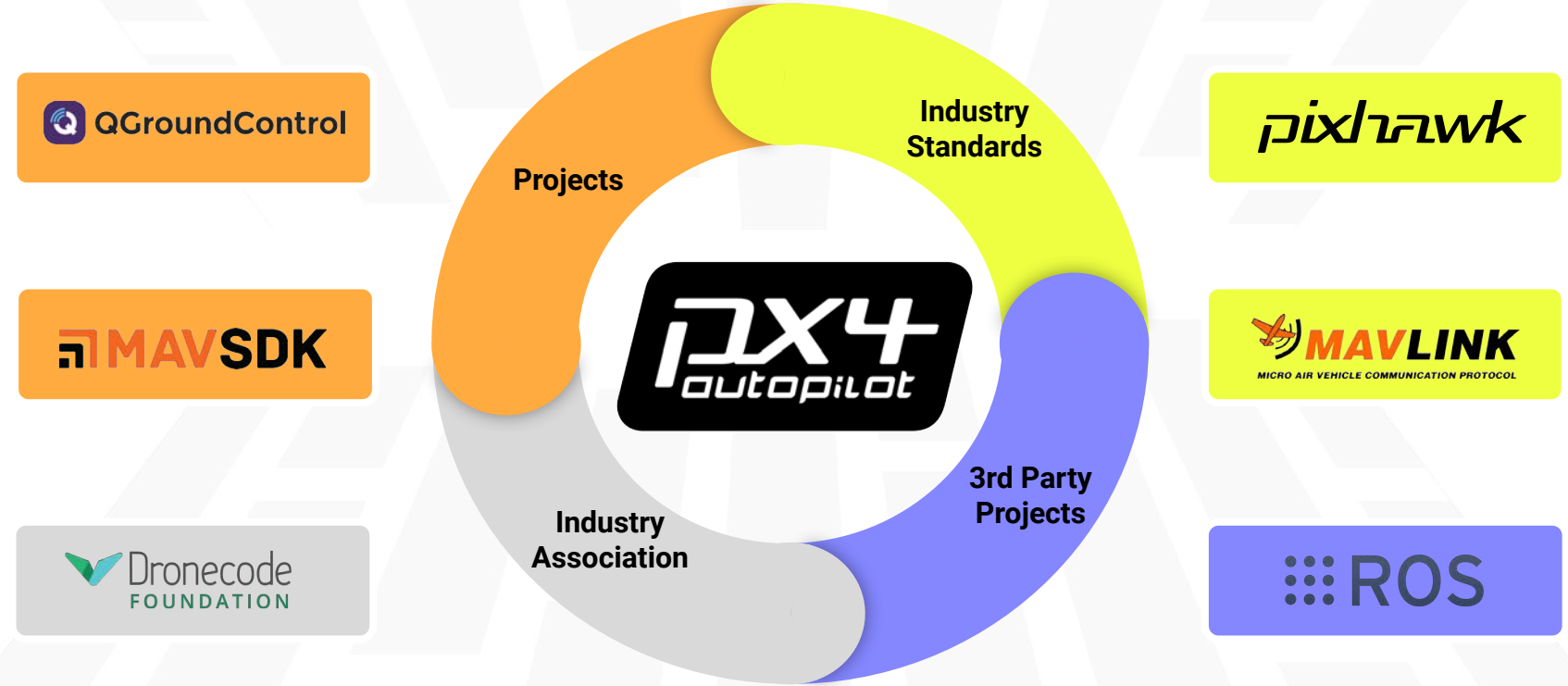
Silver

CUAV DRONEBLOCKS DroneDeploy EpiSci FREEFLY

Holybro mRo MODAL AI MMC UAV Viewpro sunflower labs

TII Technology Innovation Institute UVify wingtra

The home of the PX4/Pixhawk ecosystem



Top level projects

Communication Protocol

Open Source Hardware & Open Standards

Flight Stack

API & SDK for MAVLink

MAVLink-based Ground Station

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PX4 Autopilot

The “linux kernel” of drones

An autopilot with a modern architecture and a highly customizable modular system design made by and for Developers

🚀 PX4 Autopilot

Fully featured project a complete toolkit for drone developers. PX4 runs on top of **Apache NuttX RTOS**, built as a collection of modules talking to each other through a pub/sub middleware (**uORB**) and configurable through a runtime **Parameter** system, with a stable **MAVLink** interface.

The project has experimented exponential growth since creation and has grown to become one of the largest open source communities.

PX4 Supports the following:

- Multicopters
- Fixed-Wing
- VTOL
- Submarines
- Boats
- Rovers (land based)

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Open Hardware & Open Standards

Pixhawk is a project dedicated to advancing the drone industry through standardized hardware.

🚀 Pixhawk

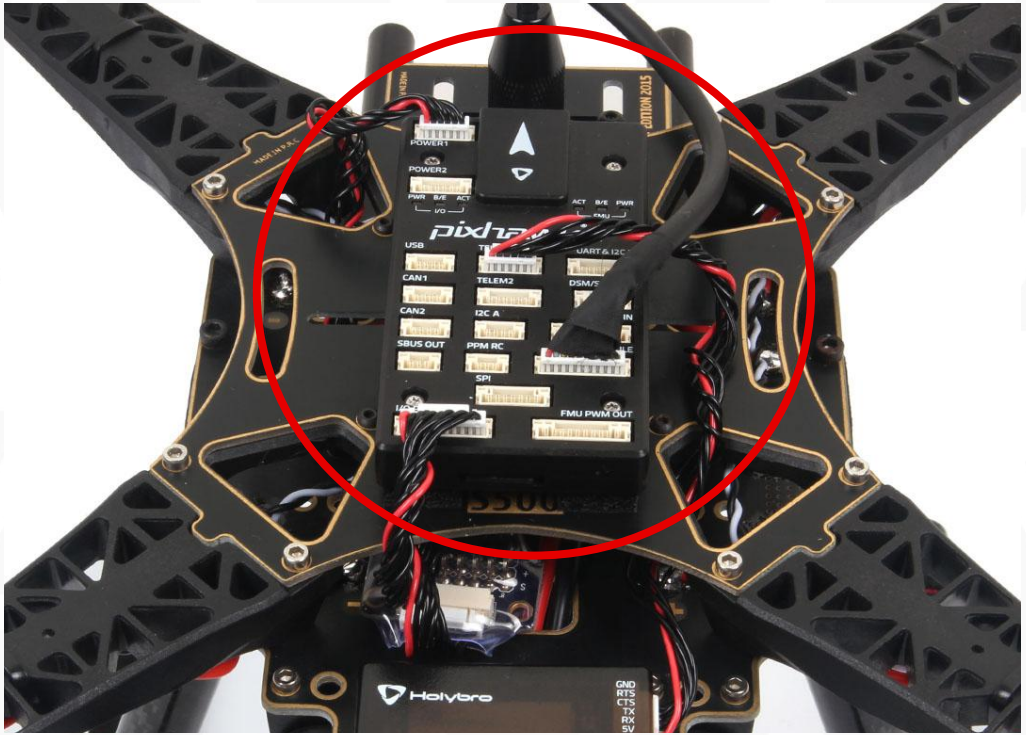
It was created to provide accessible and low-cost flight controllers for researchers under budget constraints.

We estimated around 1,000,000 Pixhawk's being used in the industry

It evolved into the reference implementation of what a flight controller should be.

Hardware is published with an open license on GitHub.

The brain of a Drone, Pixhawk, has a collection of sensors to help position and control it in a given 3D space.


POWER1
POWER2
USB
CAN1
CAN2
SBUS OUT
TELEM2
I2C A
PPM RC
SPI
FMU PWM OUT
Holybro
GND
RTS
CTS
TX
RX
5V

Manufacturing Partners

+ more...

Dozens of Pixhawk Flight Controllers have been built by our manufacturing partners throughout the years

Pixhawk Origins

The 1st generation: pxIMU

Created by Dr. Lorenz Meier when he was working on his Masters at ETH Zurich.

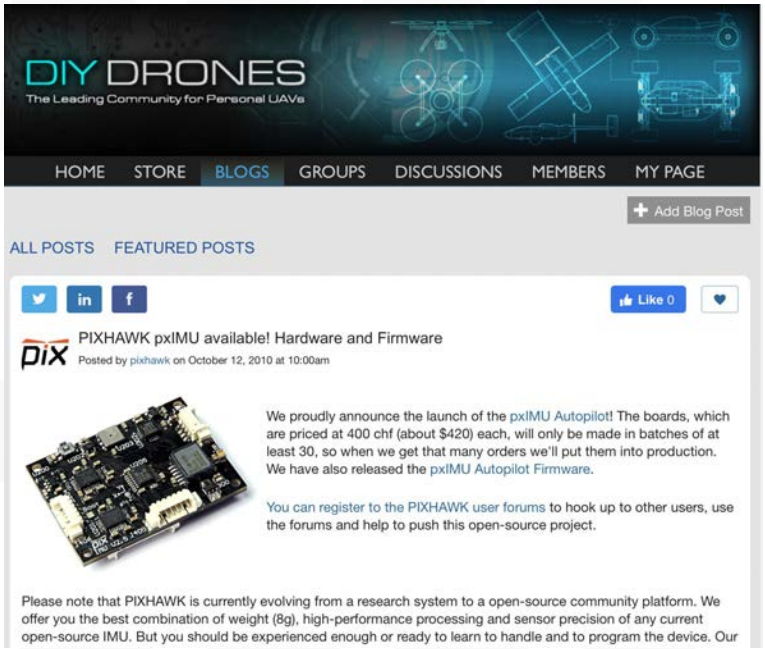
Back then he created the software and hardware.

Dr. Lorenz Meier, ETH Zürich, Switzerland

✨ From a research platform to an OSS project

(2010) After publishing his Master thesis, he introduced the Pixhawk project on the popular blog DIYDrones:

“Please note that PIXHAWK is currently evolving from a research system to an open-source community platform.”



Pixhawk Versions

pxIMU (FMUv1)

Pixhawk Versions

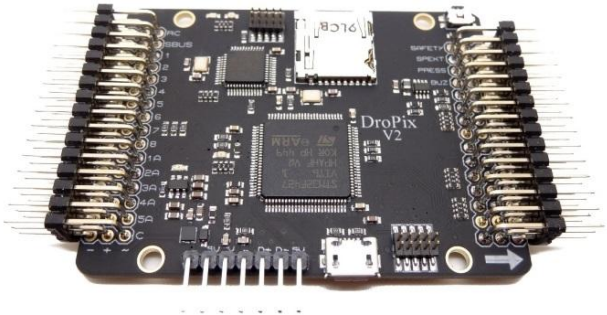
3DR Pixhawk (FMUv2)

HKPilot32 (FMUv2)

3DR Pixhawk Mini (FMUv2)

Pixhawk Versions

Holybro Pixfalcon (FMUv2)



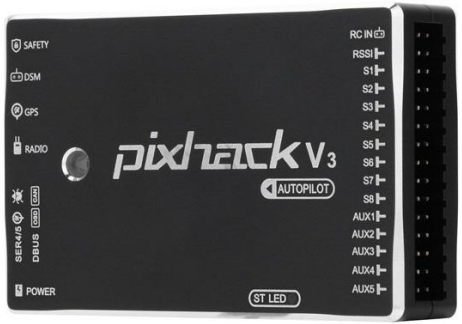
Drotek DroPix (FMUv2)

mRo X2.1 (FMUv2)

Pixhawk Versions

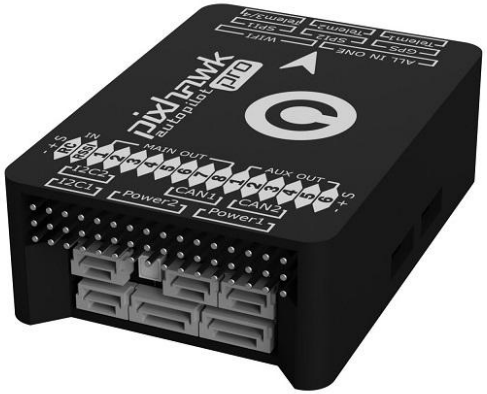
mRo Pixhawk (FMUv3)

Cube Flight Controller (FMUv3)



CUAV Pixhack V3 (FMUv3)

Pixhawk Versions



Drotek Pixhawk 3 Pro
(FMUv4)

Holybro Pixhawk 4
(FMUv5)

Holybro Pixhawk 4
Mini (FMUv5)

Pixhawk Versions

CUAV v5 (FMUv5)

CUAV V5+ (FMUv5)

CUAV V5 Nano (FMUv5)

Open Hardware
↓
Open Standards

It started as a fully open project, and we published CAD, Schematics, and BOM. Still available on GitHub!

It helped us with massive adoption but also brought unintended consequences. We were young and naive.

Pixhawk Open Hardware

In our Open Hardware beginnings, the financing for the project came from the authors; they were in charge of keeping source files up to date, documenting them, and distributing them.

This task required the help of 2-3 FTE supporting manufacturers:

1. Hardware validation, keeping them as close to design as possible
2. Porting firmware (PX4)
3. Maintaining their firmware build targets for their users

The high cost of maintenance for the Pixhawk and PX4 teams forced them to change the way they worked.

You won't read about the duality of open hardware projects in books

PROS

- Massive adoption thanks to multiple options available for customers
- You can create an ecosystem around your designs
- Volume and options mean low cost for end users
- Gain the trust of manufacturing partners

CONS

- Even if you publish schematics, manufacturers will change the design, only sometimes for the better.
- When a change is introduced downstream on hardware, the firmware stops working upstream.
- Some manufacturers will work with you, but most will just download, make changes, print, and start selling without validating.
- Users lose credibility in the project when things don’t work.
- There’s no financial incentive for the authors and no sustainability plans for the project

📌 From Open Hardware to Open Standards

Midway between open and closed, we found Open Standards

- We captured the core components of the hardware.
  - List of components, including the location of each interface (pinout), and document the project. Kept the firmware open (PX4).
- Dronecode is in charge of maintaining the standards.
- Using foundation resources, we can keep it up to date and with good documentation
- We can also offer standards validation.

We formed the Pixhawk SIG, and Dronecode is helping with:

- Create and maintain work groups to foster collaboration between manufacturers
- Focus the WG on creating new standards
- Create, support, and distribute a reference design
- Validate the hardware built using the reference design
- Safeguard the Pixhawk Trademark.

You fix some and create some more

PROS

- Access to the core project is still open
- Finer control over who has access to the source files.
- Shared maintenance cost of firmware and hardware
- To participate, you need to be part of the Foundation
  - The membership cost offsets some of the costs of the project.
- Validation and conformity are built into the project.
  - Initially, it was only offered to members.

CONS

- The pinout gives you the direction, but you must still walk the path and invest a few thousand hours of engineering time.
- You need a membership to access the source files. Paywall.
- While you can participate in public meetings, only members have voting rights over the final decisions.
- Initially, only a few hardware options will be available.

😱 Community Impact?

Before we made the switch to open standards, we made sure to talk to key stakeholders and our partners.

- Manufacturers
- PX4 Developers
- Members of our community, Pixhawk users.

We had an extended research process, and we were apprehensive about losing the community's trust and credibility.

What did we find?

- The end users were impacted the most by unreliable hardware with no quality control from specific manufacturers (mostly clone hardware)
- Manufacturers require handholding to implement the designs.
- What we thought was a very good process turned out to be hard to understand and follow for our partners. Top-down direction with manufacturers on the bottom.
- The PX4 team was on the receiving end of most of the complaints of the community and manufacturing partners.

🥰 Community Impact!

The solution was to form a Special Interest Group to maintain the Pixhawk project, hosted under Dronecode.

- Formed by Dronecode members, the Pixhawk team, and PX4 devs.
- We put together recurring coordination calls (publicly available)
- Anyone can join and share their opinion. We will listen.
- "Members only" voting for any significant conflict resolution.
- The group watches over the creation, maintenance, and validation of the open standards.
- Dronecode and its members are footing the bill for all expenses.

What results did we achieve?

- 200% increase in participation in the development of new standards
- Increased sense of ownership from all parties involved
- A clear and neutral path for the funding of the project

Pixhawk SIG

The Special Interests Group is formed by some of Dronecode's members.

The SIG members have identified a few areas of development where open standards can help the industry and formed focused work groups to tackle those problems.

- FMU Work Group
- Payload Work Group
- BMS Work Group
- Radio Interface Work Group

Dronecode FOUNDATION

Auterion NXP ARK ELECTRONICS

Holybro CUAV MODAL AI ROBOTIC PERCEPTION

TII Technology Innovation Institute gumstix mRo MAXWELL INNOVATIONS

Current Generation: Open Standards

Thanks to the Open Standards, we are helping avoid fragmentation in the industry by providing a single point of reference for the most common of hardware components, by providing everything needed for basic functionality, and a framework for collaboration.

Both generations and many other open hardware standards are freely available on GitHub

https://github.com/pixhawk/Pixhawk-Standards

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👀 Current Pixhawk based products

Auterion Skynode

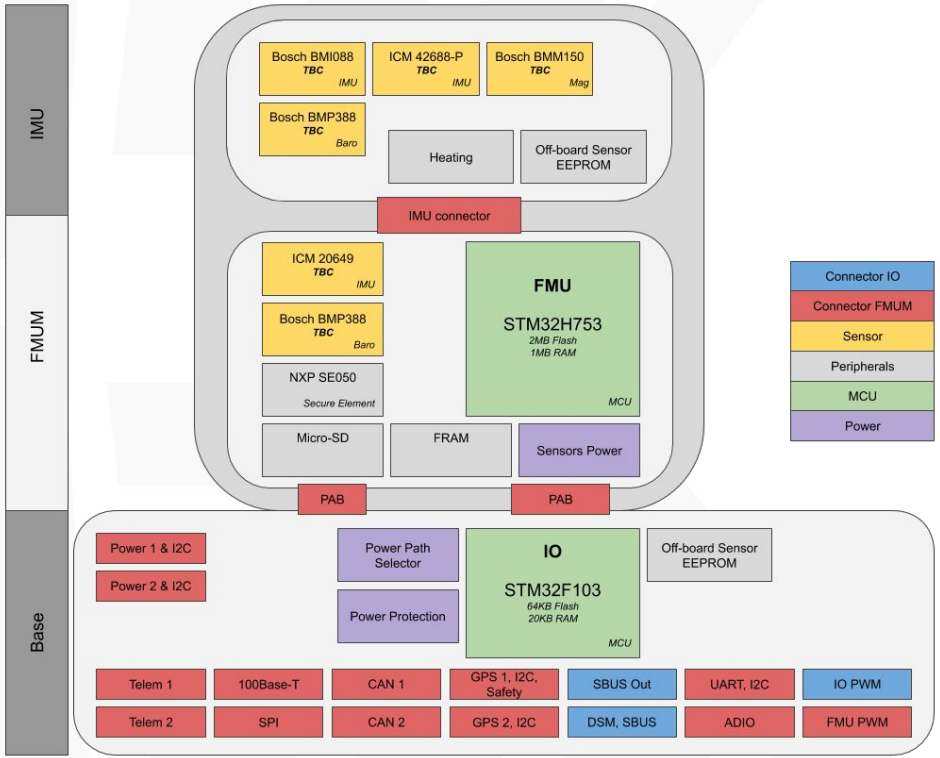
Holybro Pixhawk

Note: I only picked two out of many options

Current Generation: FMUv6X

STM32H7 based modular flight controller suitable for the most demanding applications

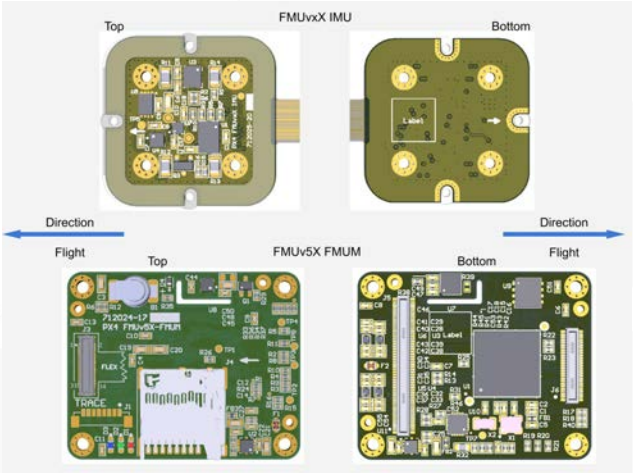
- Secure authentication capable
- Ethernet for high-speed mission computer integration
- Three redundancy domains: Completely isolated sensor domains with separate buses and separate power control
- Allows parallel and continuous operation even in the event of a hardware failure.

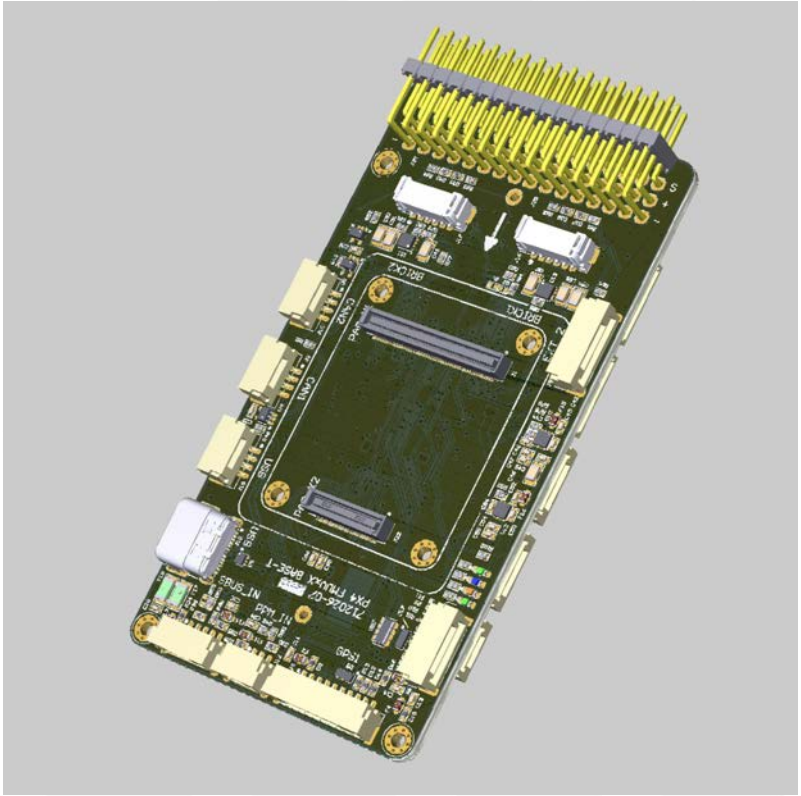


Current Generation: Modular design

There are four sensor sets currently available from multiple manufacturers.

The modular design allows manufacturers to differentiate by adding value on top of the design.





📸 Pixhawk: Payload Interface (DS-014)

The standard defines the capabilities of a current payload, from electronics to mechanical design and software, and guarantees “plug-n-play” interoperability.

Made for OEM drone vendors, Gimbal and Camera providers.

Interfaces defined by the standard:

- 100Base-T Ethernet
- USB 2.0
- CAN FD
- UART
- TRIG
- CAPTURE
- GNSS_PPS
- VCC_BAT

Example:

Payload gimbals by Freefly Systems based in Seattle, USA.

🔋 Pixhawk: Smart Battery System (DS-013)

A standard for developing smart battery management systems, it allows for total control of a battery, including access to reliable telemetry.

Pinout

- Pin 1: Battery ID
- Pin 2: Boot
- Pin 3 - 4: Battery Return (Pack -)
- Pin 5 - 8: Battery Return (Pack +)
- Pin 9 - 10: Battery Return (Pack -)
- Pin 11: CAN H
- Pin 12: CAN L

Example:

Smart battery by Freefly Systems based in Seattle, USA.

Quick Example


ASTRO
@ WORK

Interested in building Pixhawk’s?

How to get involved

As you have already guessed the best way to get involved is by getting a Dronecode membership

- Access to schematics
  - Saves you hundreds of engineering hours by following a validated reference design
- Helps sustain the ongoing project efforts

But what if we want more...

- Pixhawk Standards Validation
  - For a flat fee $2.5k we will validate the design
  - Guaranteeing cross vendor compatibility
- Pixhawk Design Services
  - Want a sensor set we don't yet support?
  - For a flat fee of $2.5k we can help you choose the right path
- Pixhawk Trademark Access
  - Want to sell your new shiny flight controller using the Pixhawk brand?
  - For a flat fee of $5k Dronecode can give you permission to do so.
  - Requirements
    - Fee payment
    - No dual use hardware
    - Needs to pass validation first
      - Guaranteed Pixhawk!

Preguntas?

@mrpollo | @dronecode

Gracias!

@mrpollo