Pixhawk FMU hardware overview

Presented by:

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Pixhawk Hardware overview

- Different version of Pixhawk hardware
- Overview of selected FMU schematic
- Overview of selected FMU PCB layout
- Become familiar with installed sensors & chips
- Peripheral hardwares
- Compatible modules list
- Useful compatible Companion Computers (CC)
- 3rd party compatible code hardwares
- Ready made vehicles based on Pixhawk

Different version of Pixhawk hardware

- Different versions from different manufacturers!

- Open-source Hardware! Download from github!

Different version of Pixhawk hardware

- mRo Pixhawk

- A hardware compatible version of the original Pixhawk 1
- Runs PX4 on the NuttXOS

Different version of Pixhawk hardware

- **mRo-X2.1**

- based on the Pixhawk®-project **FMUv2** open hardware design
- Runs PX4 on the NuttX OS.

Different version of Pixhawk hardware

- **HKPilot32**

- based on the Pixhawk®-project **FMUv2** open hardware design
- Runs PX4 on the NuttX OS.

Different version of Pixhawk hardware

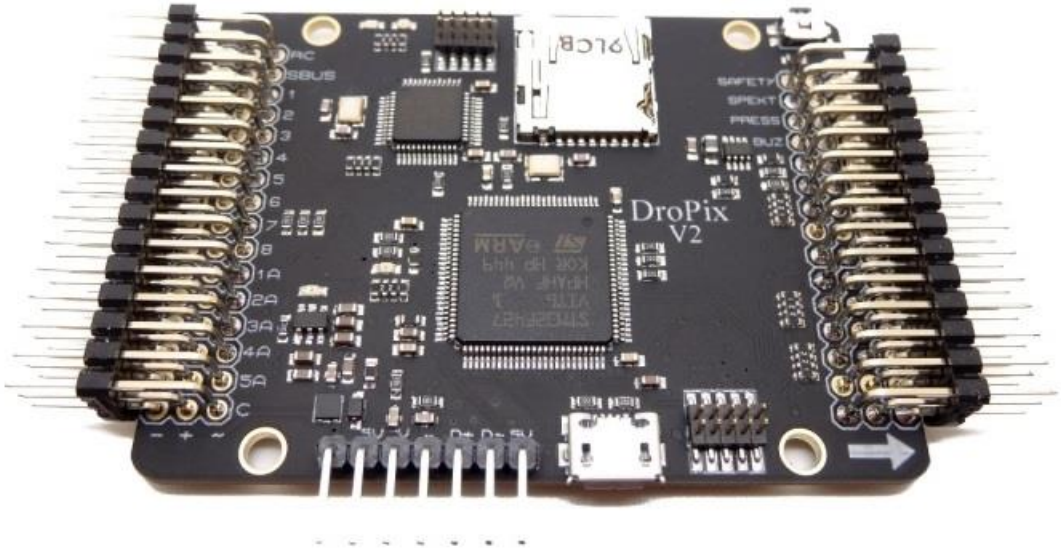
- **Pixfalcon**

- binary-compatible (FMUv2) derivative of the Pixhawk 1Runs PX4 on the NuttX OS.
- optimized for space-constrained applications such as FPV racers
- less IO to allow for the reduction in size

Different version of Pixhawk hardware

- **DroPix**

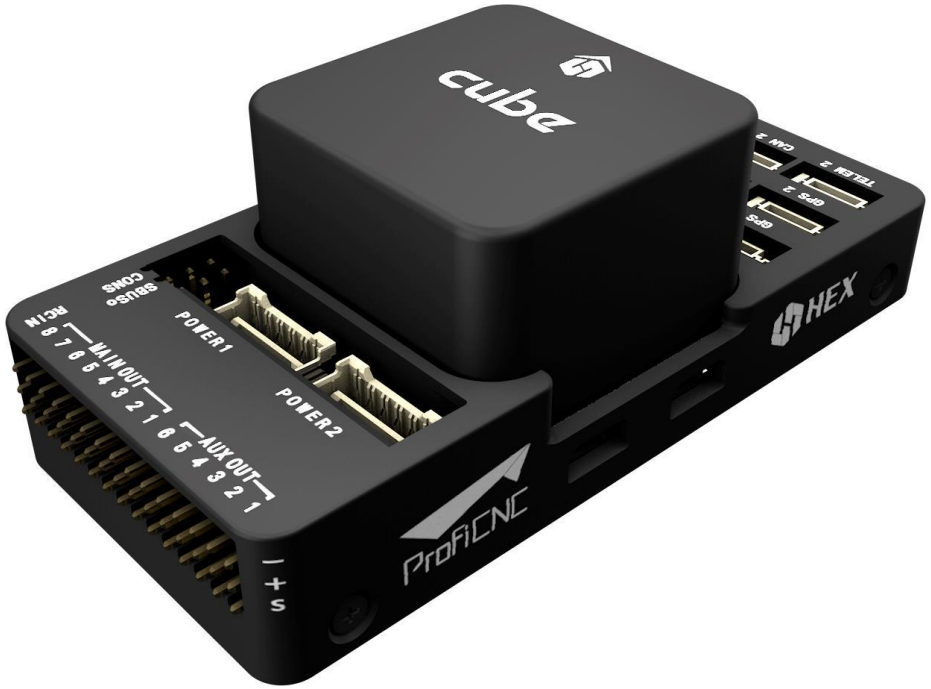
- based on the Pixhawk®-project **FMUv2** open hardware design
- Runs PX4 on the NuttX OS.



Different version of Pixhawk hardware

- **Cube**

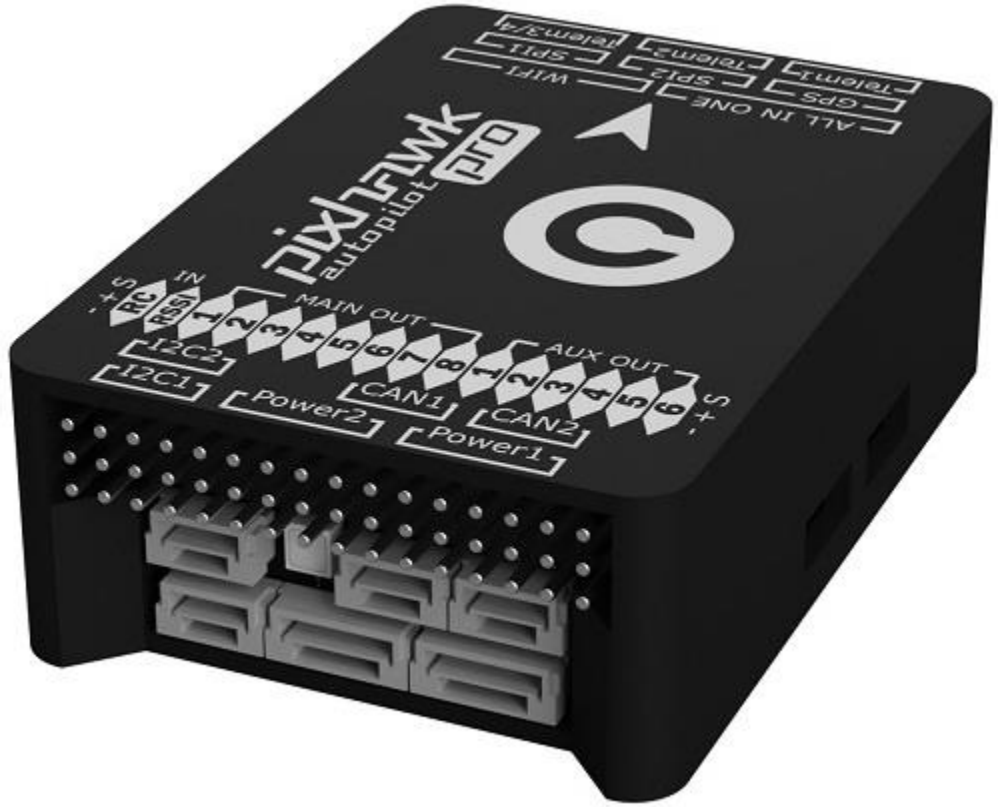
- intended primarily for manufacturers of commercial systems
- previously known as Pixhawk 2.1
- based on the Pixhawk-project **FMUv3** open hardware design
- runs PX4 on the NuttX OS.



Different version of Pixhawk hardware

- **Pixhawk 3 Pro**

- based on the FMUv4 hardware design (Pixracer)previously known as Pixhawk 2.1
- some upgrades and additional features



Different version of Pixhawk hardware

- **Pixhack V3**

- intended primarily for manufacturers of commercial systemssome upgrades and additional features
- A variant of the SOLO Pixhawk® 2 (PH2)
- based on the Pixhawk-project **FMUv3** open hardware design
- runs PX4 on the NuttX OS
- fully compatible with both PX4 or ArduPilot® (APM) firmware

Different version of Pixhawk hardware

- **Pixhawk 4**

- optimized to run PX4 version 1.7
- suitable for academic and commercial developers
- based on the Pixhawk-project **FMUv5** open hardware design
- runs PX4 on the NuttX OS

Different version of Pixhawk hardware

- **Pixhawk 4 Mini**

- working with smaller drones
- based on the Pixhawk **FMUv5** design standard
- optimized to run PX4 flight control software

Different version of Pixhawk hardware

- **Pixhack V5**

- based on the Pixhawk-project **FMUv5** open hardware design
- runs PX4 on the NuttX OS
- fully compatible with PX4 firmware
- intended primarily for academic and commercial developers

Different version of Pixhawk hardware

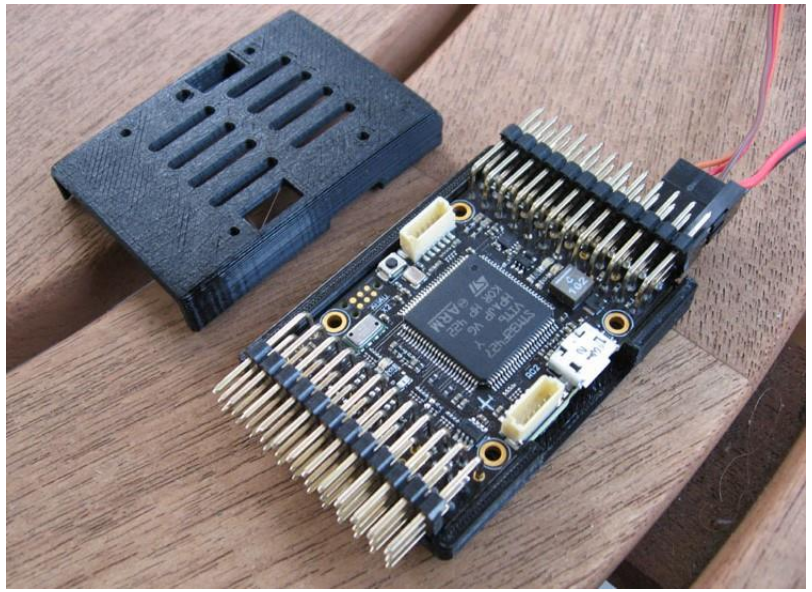
- **Pixhawk Mini (Discontinued)**

- 1/3rd the size of the original Pixhawk
- more powerful processors and sensors
- based on the PX4 open-hardware project

Different version of Pixhawk hardware

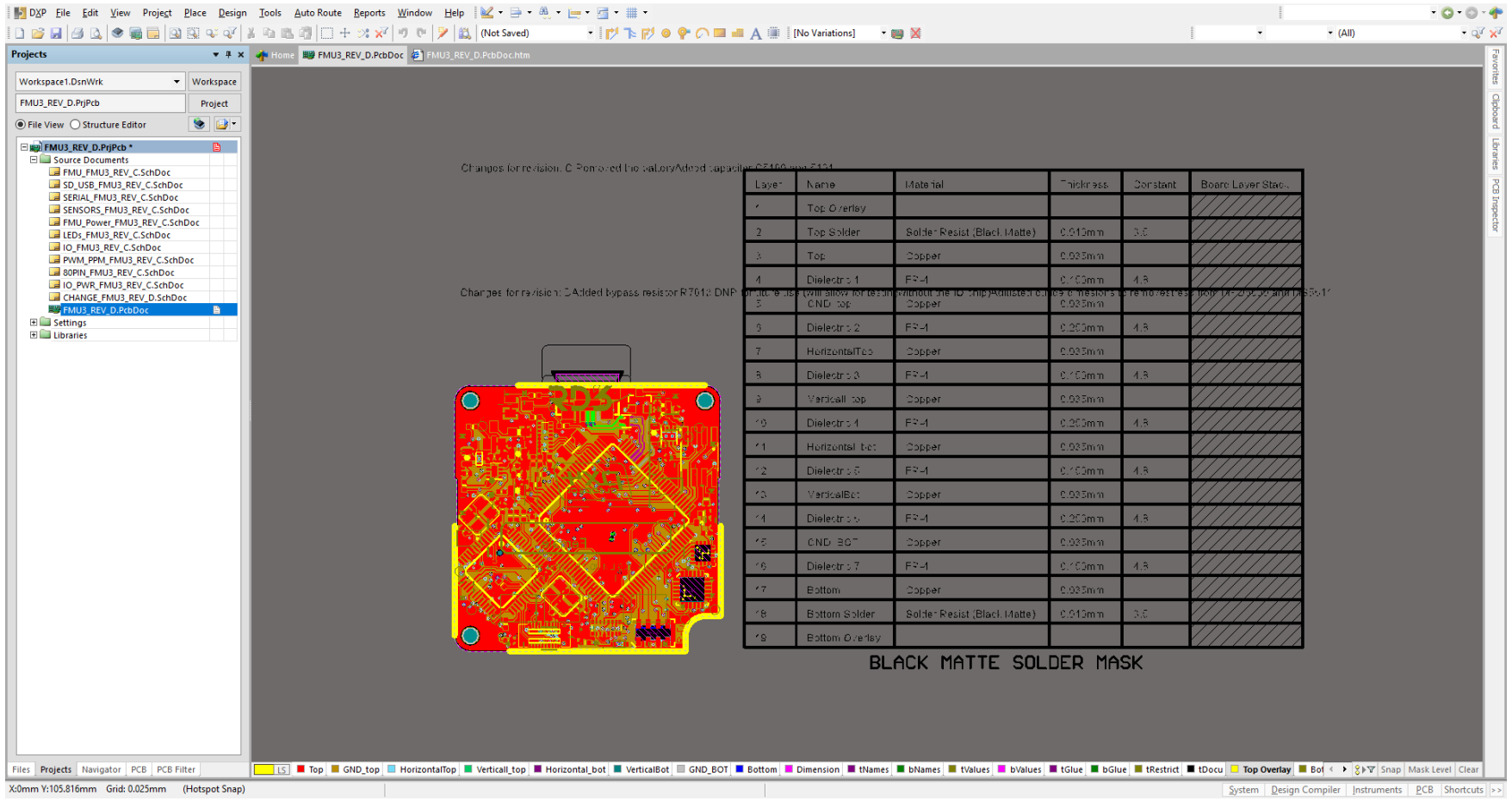
- **AUAV-X2 Autopilot (Discontinued)**

- based on the Pixhawk®-project **FMUv2** open hardware design
- runs PX4 on the NuttX OS



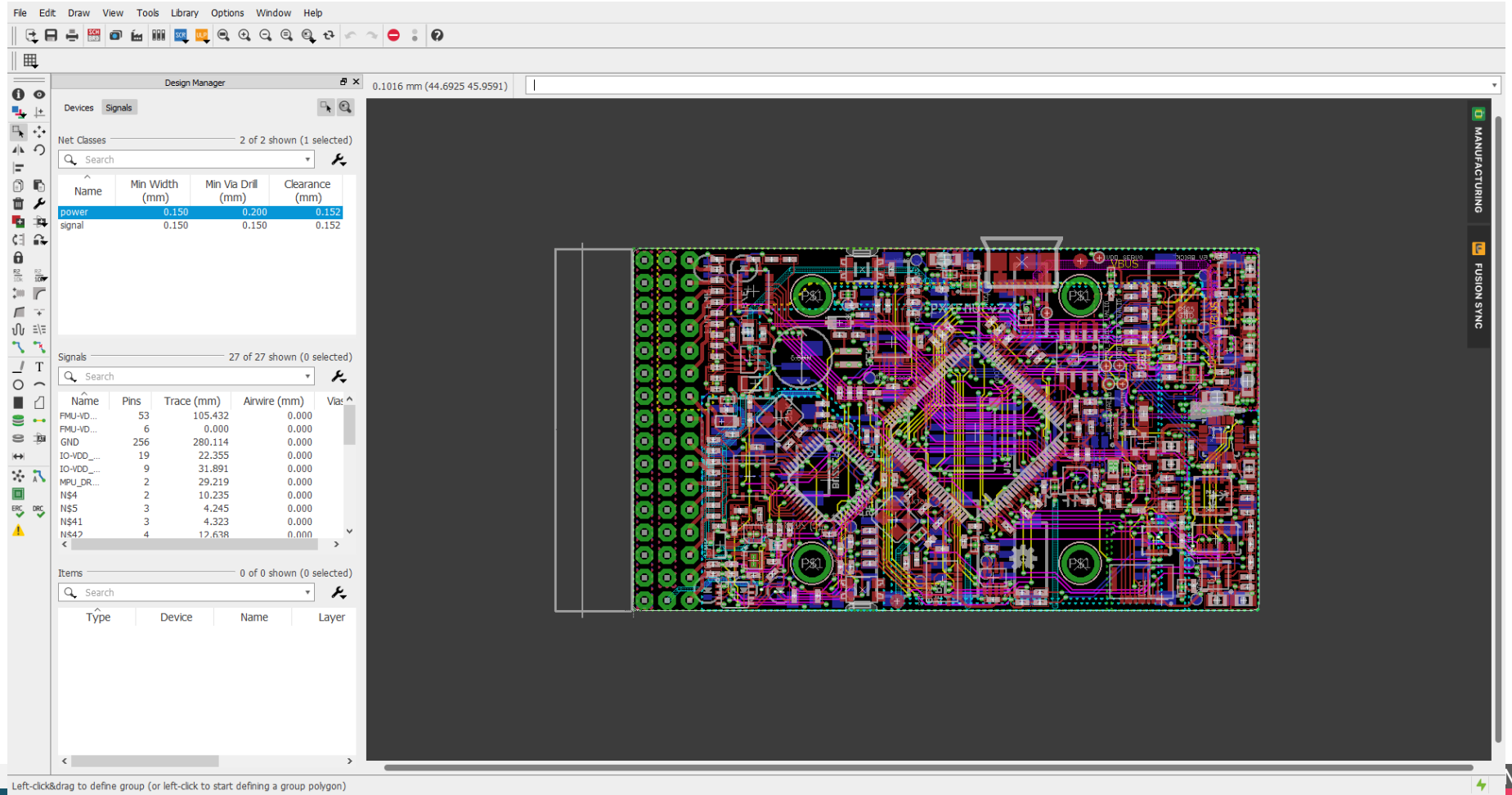
Design by different software

- Altium



Design by different software

- Eagle



Different version of Pixhawk hardware

- Pixhawk 2 vs 1
  - **SAME** or **DIFFERENT**?

Different version of Pixhawk hardware

- Pixhawk 2 vs 1
  - Same Processor
  - Equivalent sensors
  - **Different** mechanical design and the connectors
  - Pixhawk 1
    - Everthing on the Main Board
  - Pixhawk 2
    - One Main Board, Connected to Expansion Boards
    - price is around 5 times of Pixhawk 1
    - Provide good vibration damping needed for the sensors best performance
    - Temperature control IMU

versions of Pixhawk hardware

- FMU Main board sensors
  - MPU9250 (or ICM 20xxx) integrated accelerometer / gyro
  - MS5611 Baro
- IMU Board Sensors
  - LSM303D integrated accelerometer / magnetometer.
  - L3GD20 gyro.
  - MPU9250 (or ICM 20xxx) Gyro / Accel
  - MS5611 Baro

- ST Micro L3GD20H 16 bit gyroscope
- ST Micro LSM303D 14 bit accelerometer / magnetometer
- Invensense MPU 6000 3-axis accelerometer/gyroscope
- MEAS MS5611 barometer

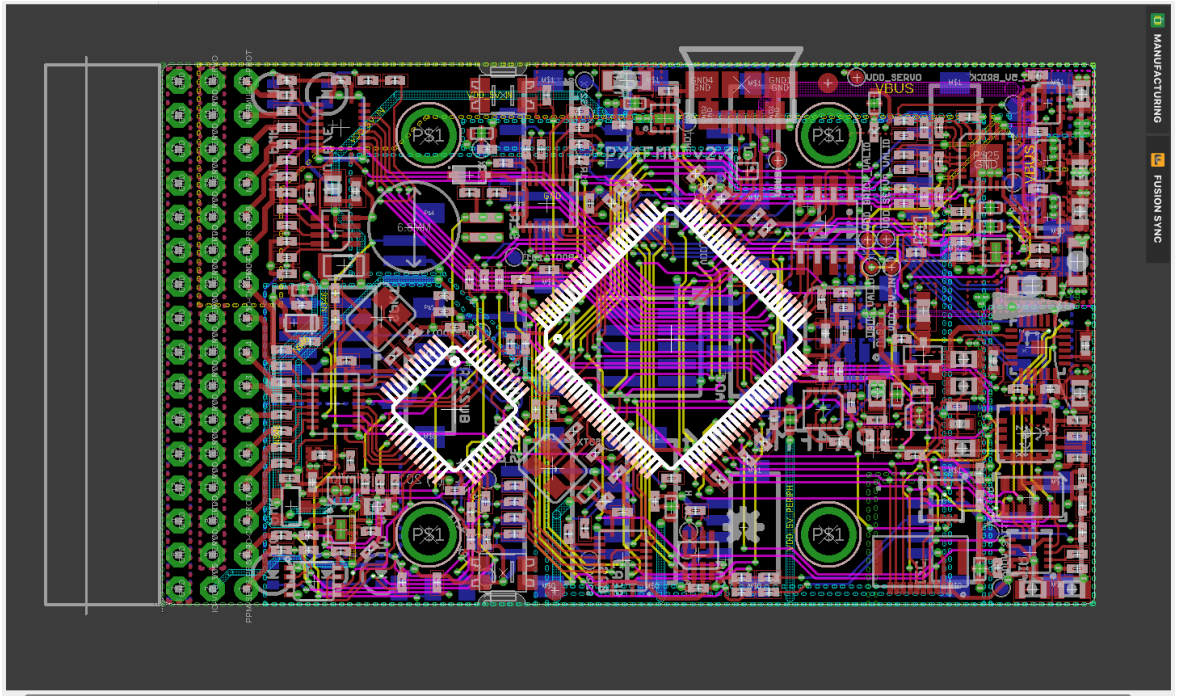
- Accelerometers (3): LS303D, MPU6000, MPU9250/hmc5983
- Gyroscopes (3): L3GD20, MPU6000, MPU9250
- Compass (2): LS303D, MPU9250
- Barometer (2): MS5611 X2

Overview of selected FMU PCB layout

- FMUv2.4.5
  - Number of layers
  - How to position Components
  - Connectors
  - Input/Outputs
  - Alarming Components
  - Safety

Overview of selected FMU PCB layout

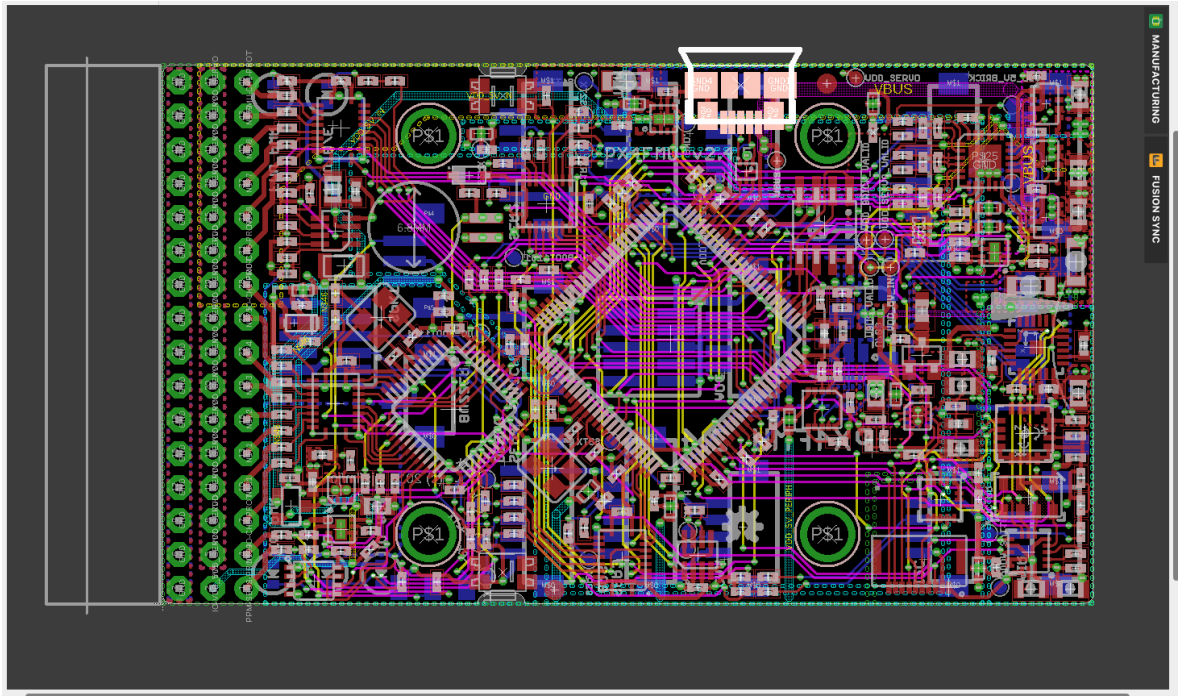
- Core Processors
  - Main Processors
  - Fly by Wire



Overview of selected FMU PCB layout

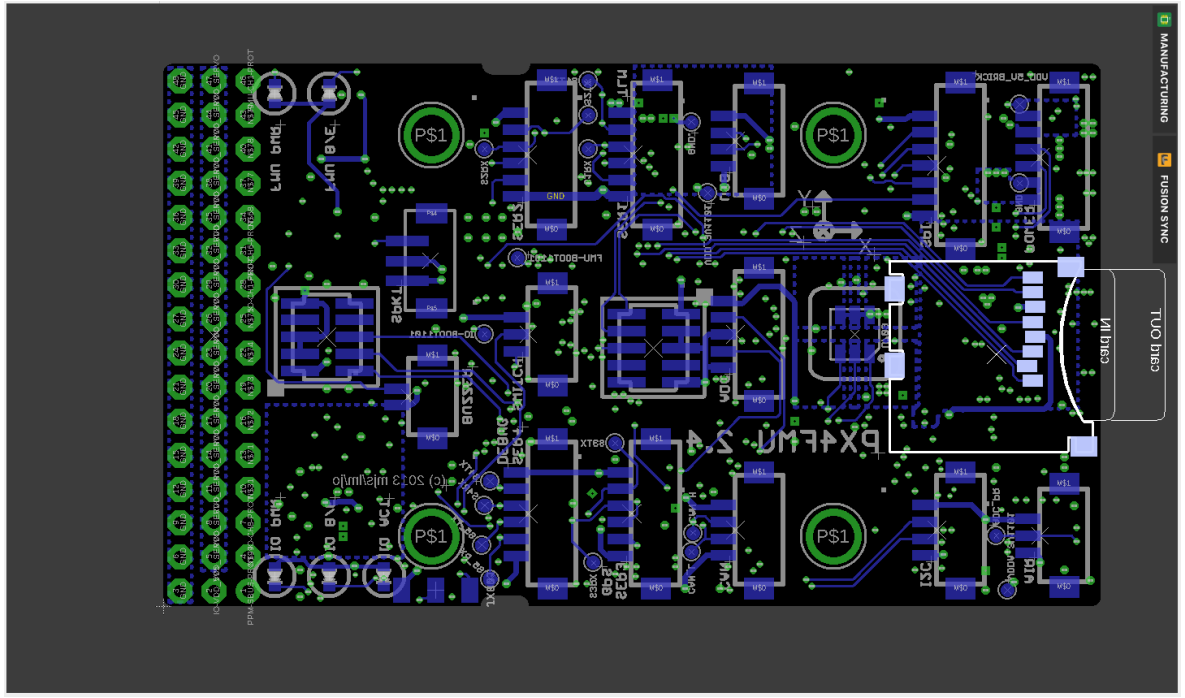
- USB
  - Firmware Upgrade
  - Firmware Version

    (Airplane, Quadrotor, etc)
  - Telemetry Port



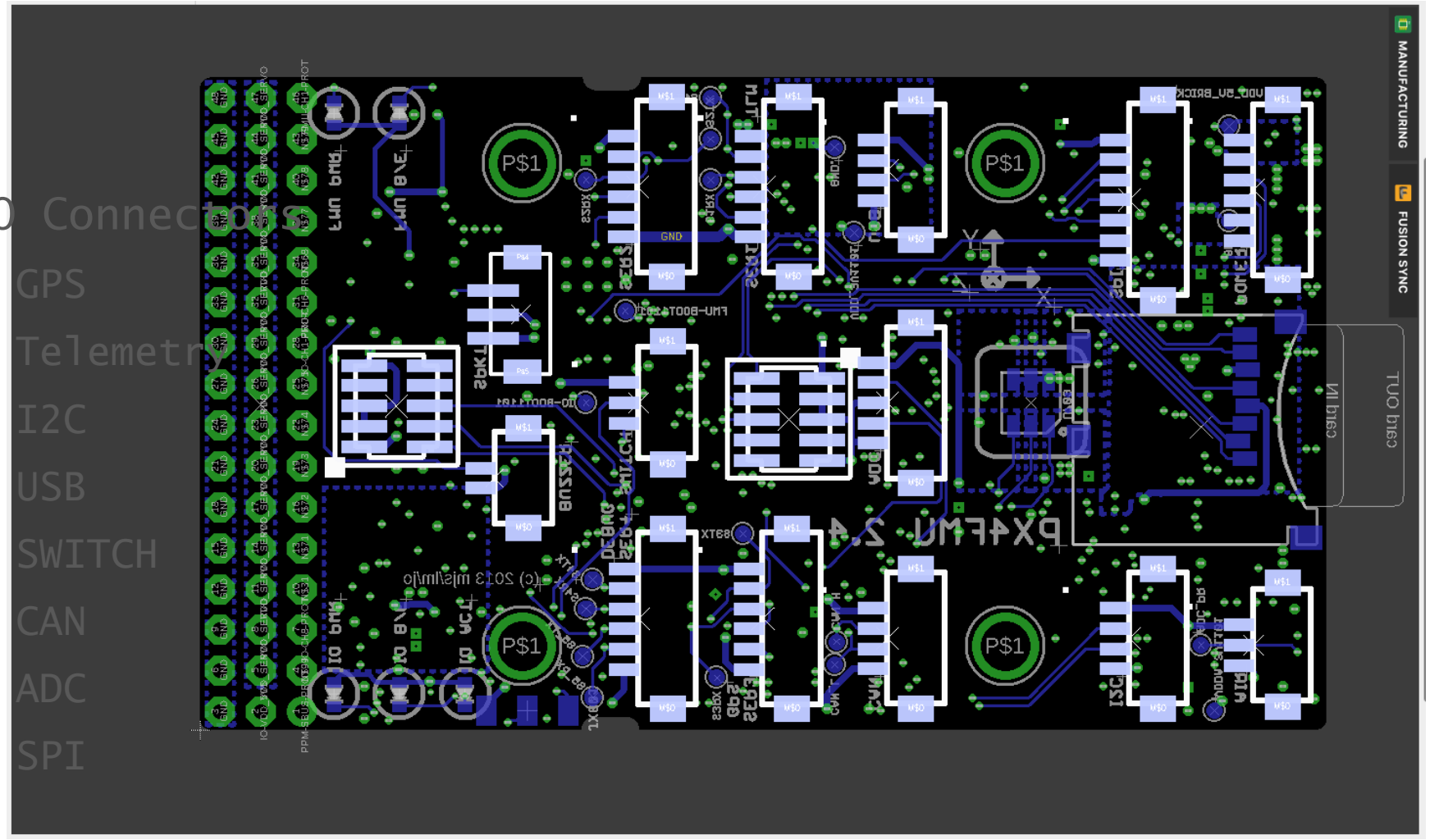
Overview of selected FMU PCB layout

- MicroSD
  - LOG Data
  - Run RTOS



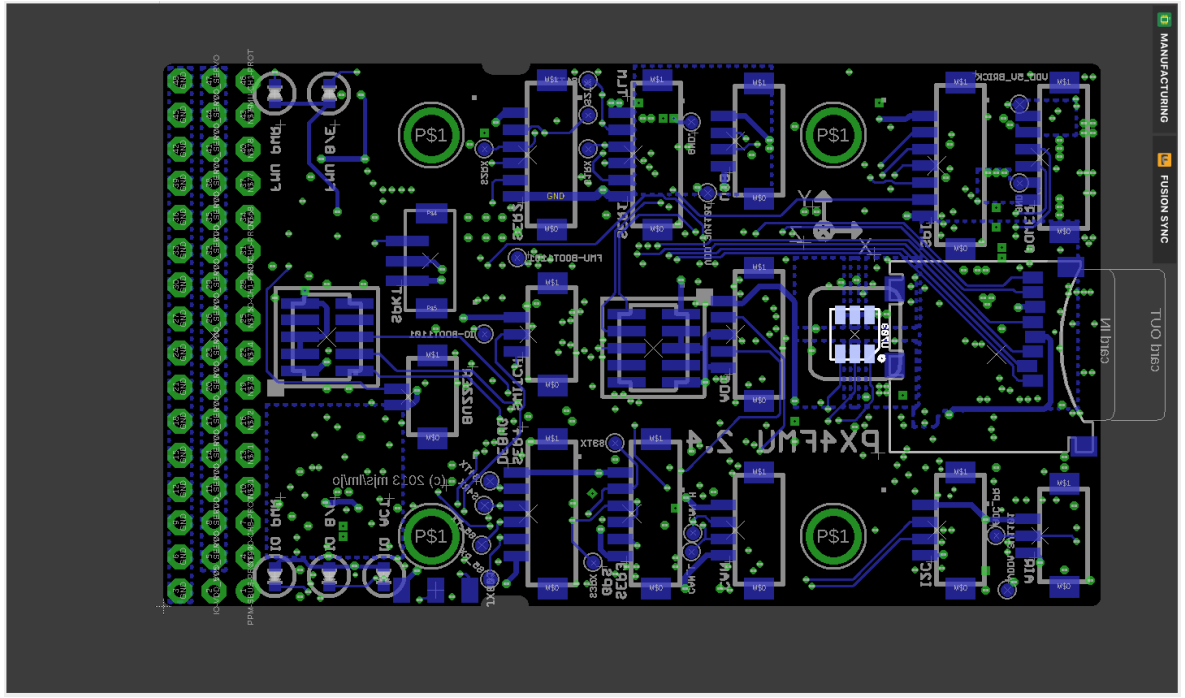
Overview of selected FMU PCB layout

- I/O Connectors
  - GPS
  - Telemetry
  - I2C
  - USB
  - SWITCH
  - CAN
  - ADC
  - SPI



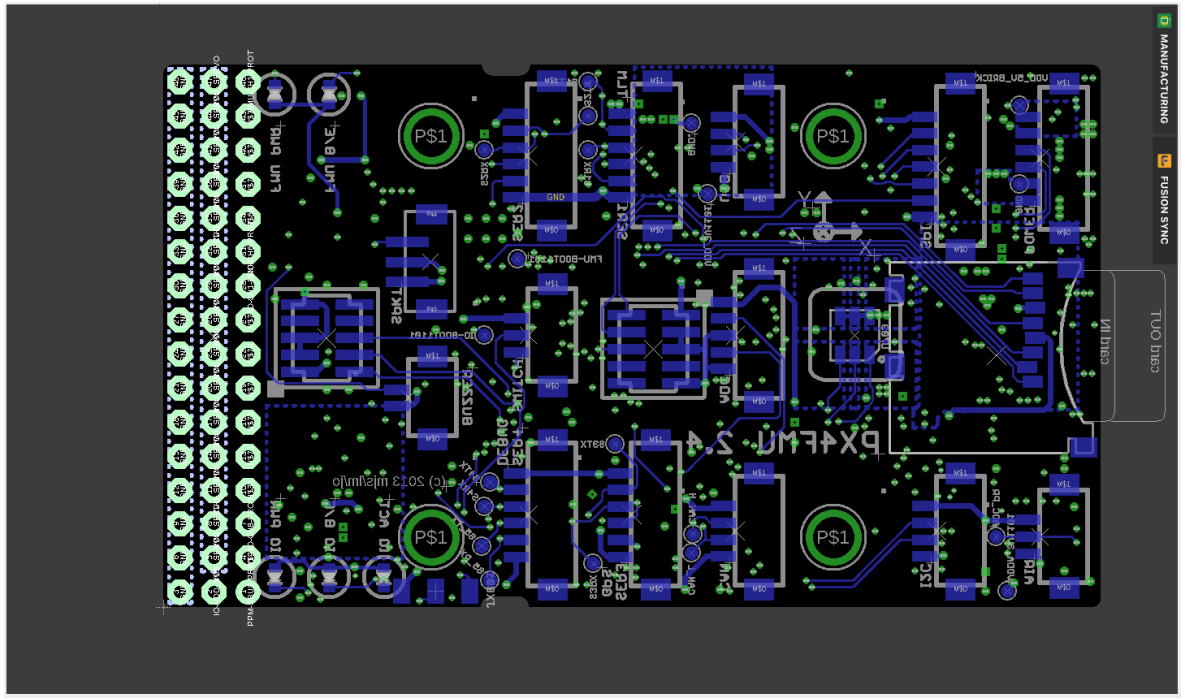
Overview of selected FMU PCB layout

- MultiColor LED



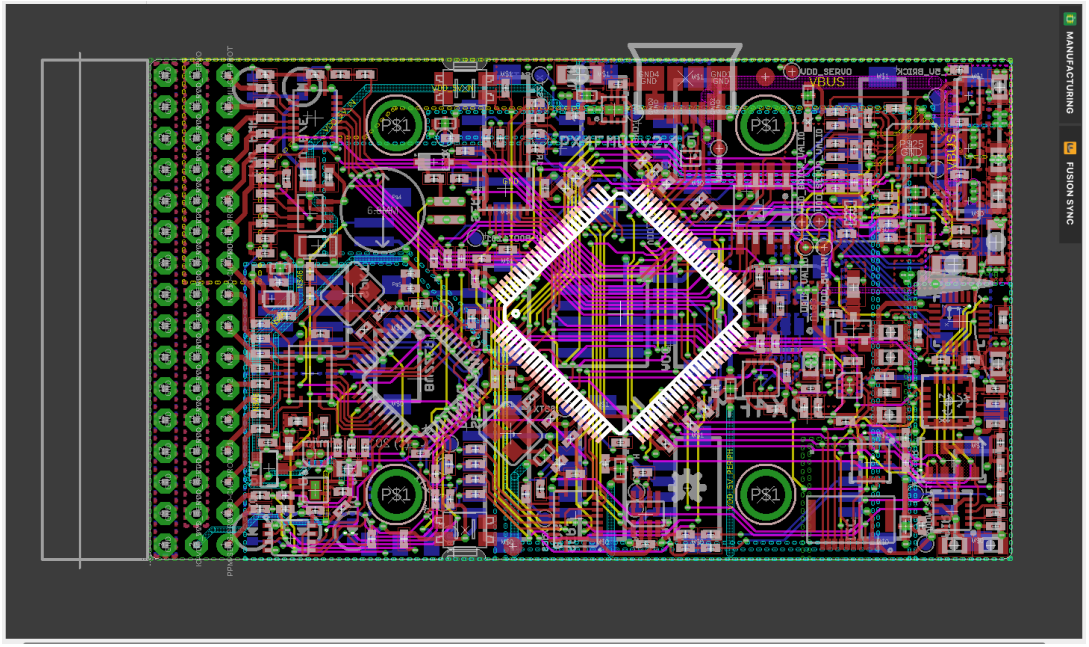
Overview of selected FMU PCB layout

- Output pin-headers
  - Servo output
  - AUX output
  - RC Input
  - SBUS



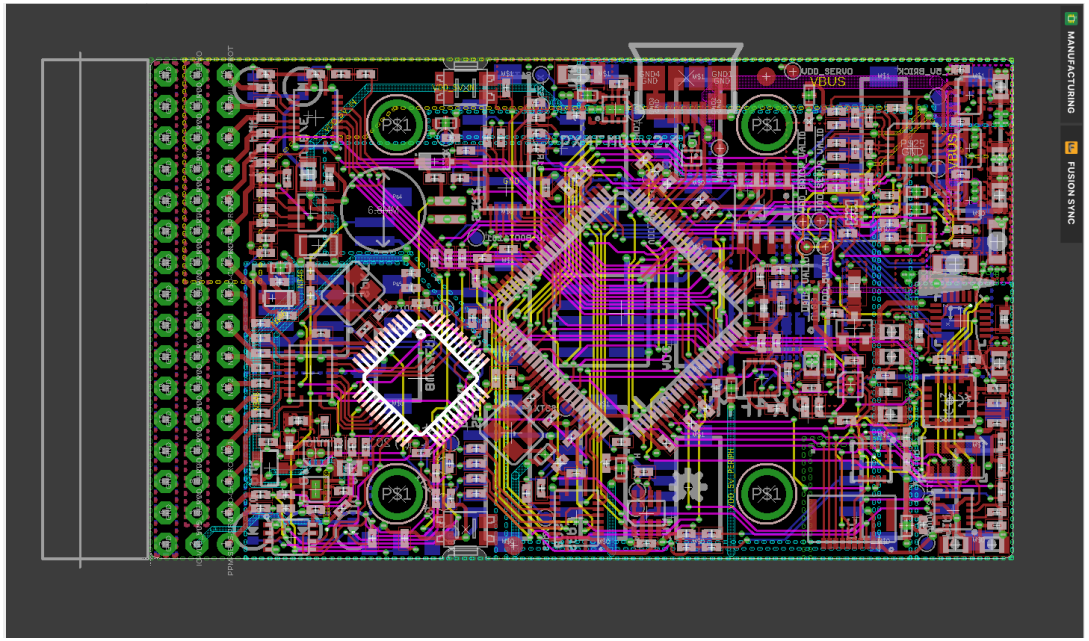
Become familiar with installed sensors & chips

- Main System-on-Chip: STM32F427
- CPU: 180 MHz ARM® Cortex® M4 with single-precision FPU
- RAM: 256 KB SRAM (L1)



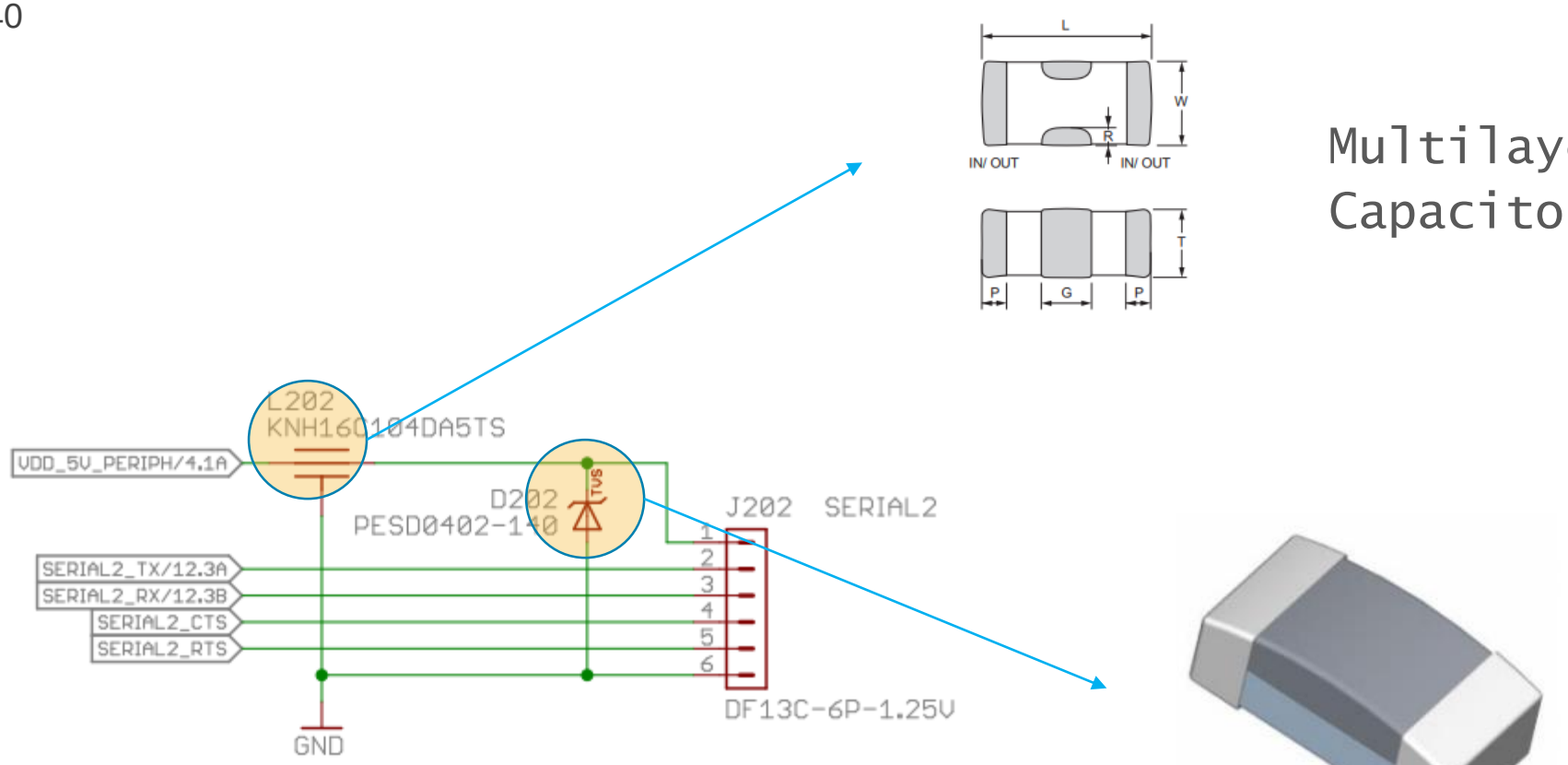
Become familiar with installed sensors & chips

- Failsafe System-on-Chip: STM32F100CPU: 24 MHz ARM Cortex M3
- RAM: 8 KB SRAM



Become familiar with installed sensors & chips

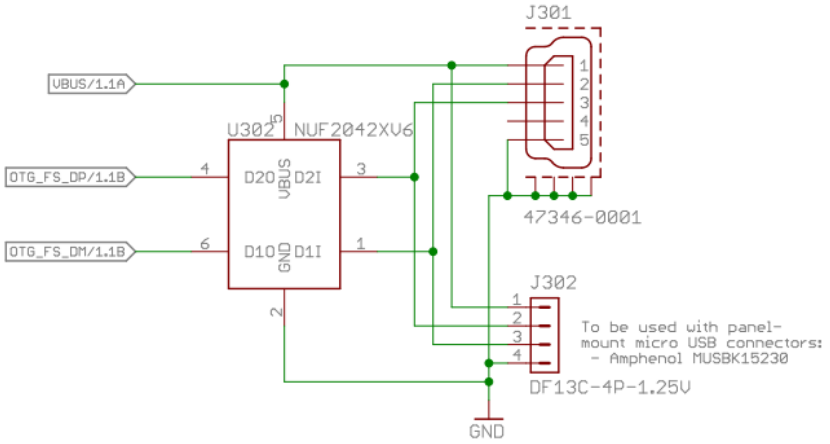
- ESD Protection
  - TVS Diode
    - PESD0402-140

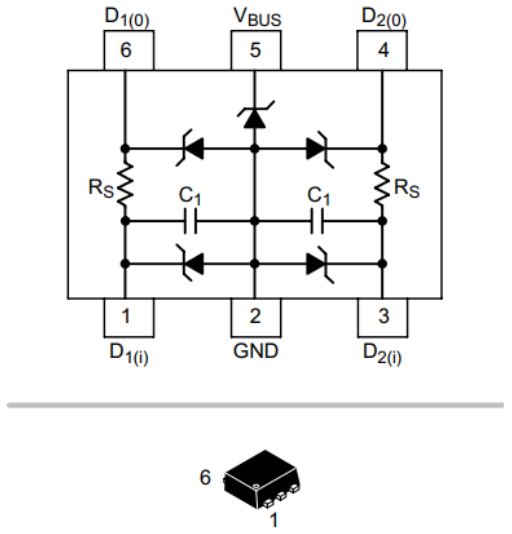


Multilayer Capacitor

Become familiar with installed sensors & chips

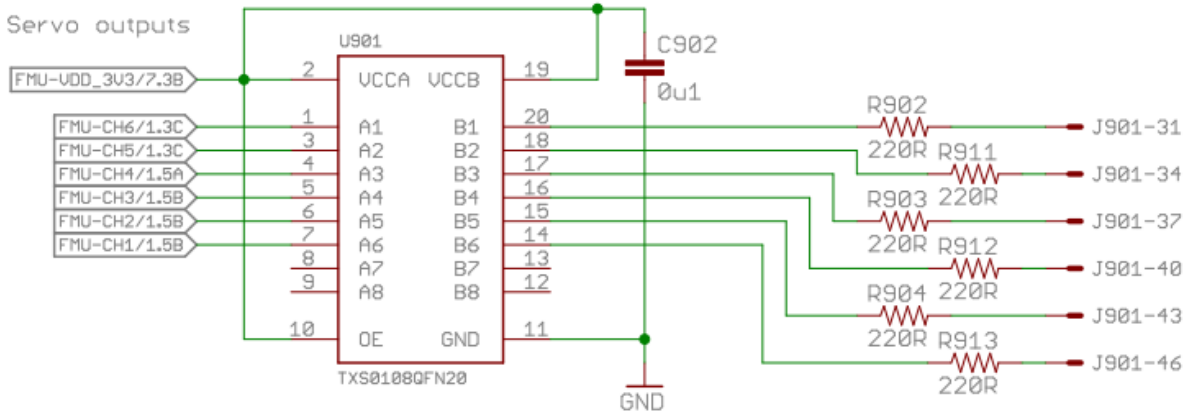
- ESD Protection
  - USB Protection
    - NUF2042xv6
    - **EMI Filtering** and **ESD Protection**





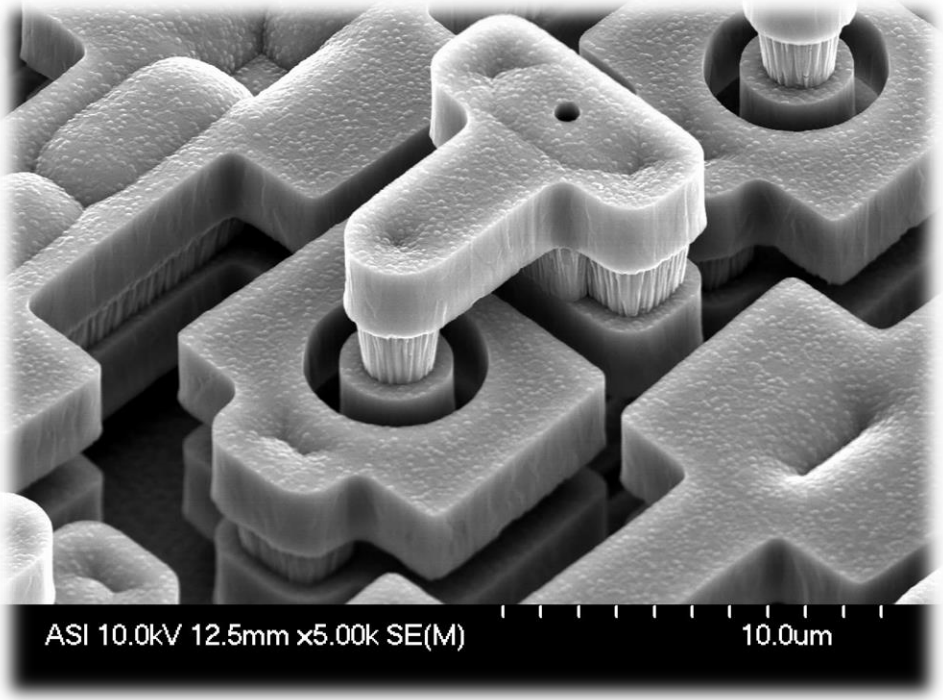
Become familiar with installed sensors & chips

- Level Shifter
  - Bi-directional
  - TXS0108E
  - Provides ESD Protection

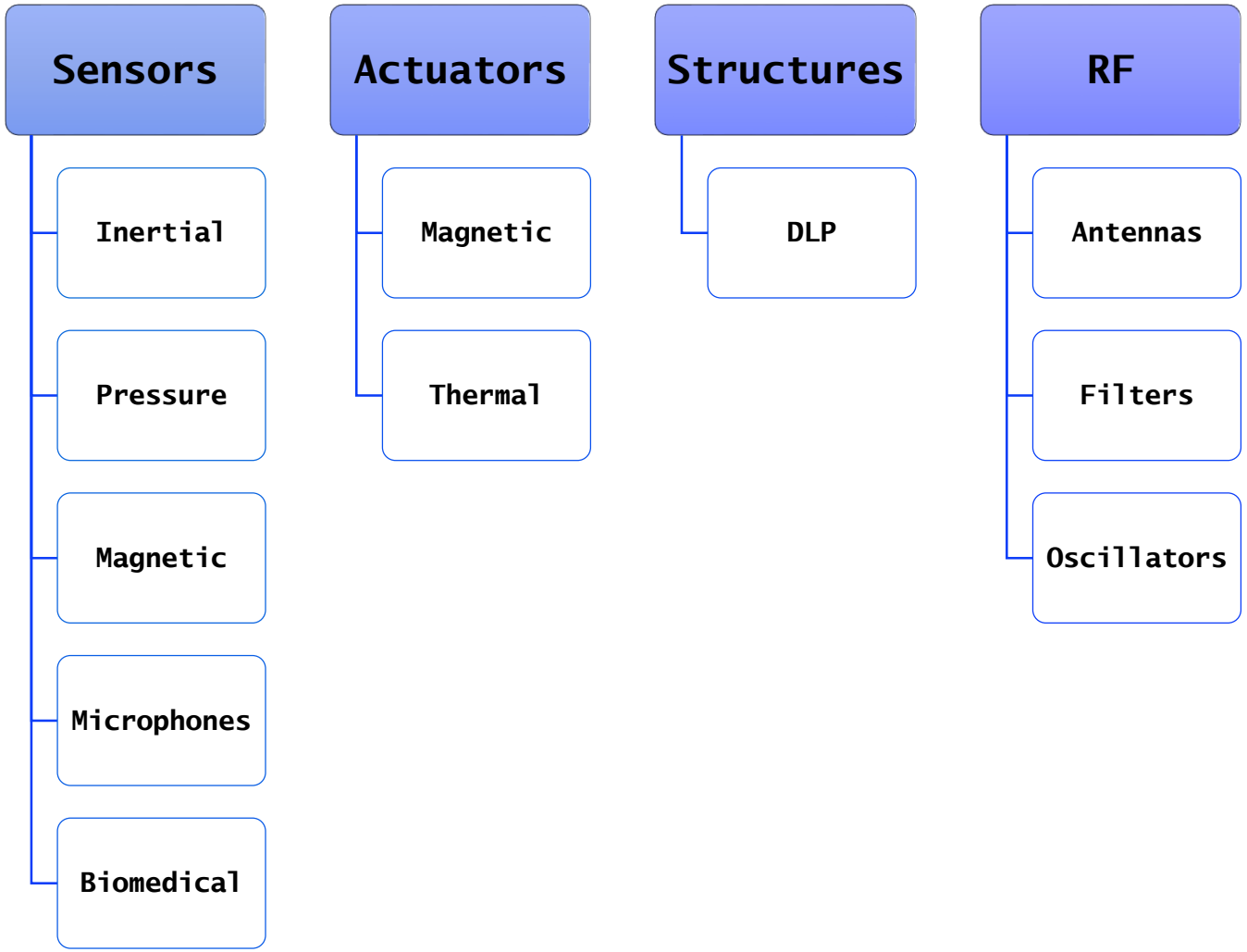


MEMS sensors

- **Micro Electro-Mechanical Systems**



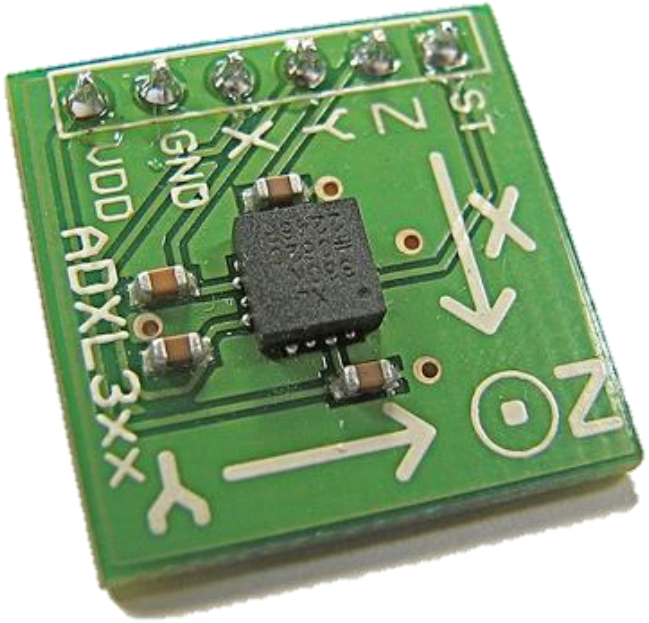
MEMS sensors CLAssification



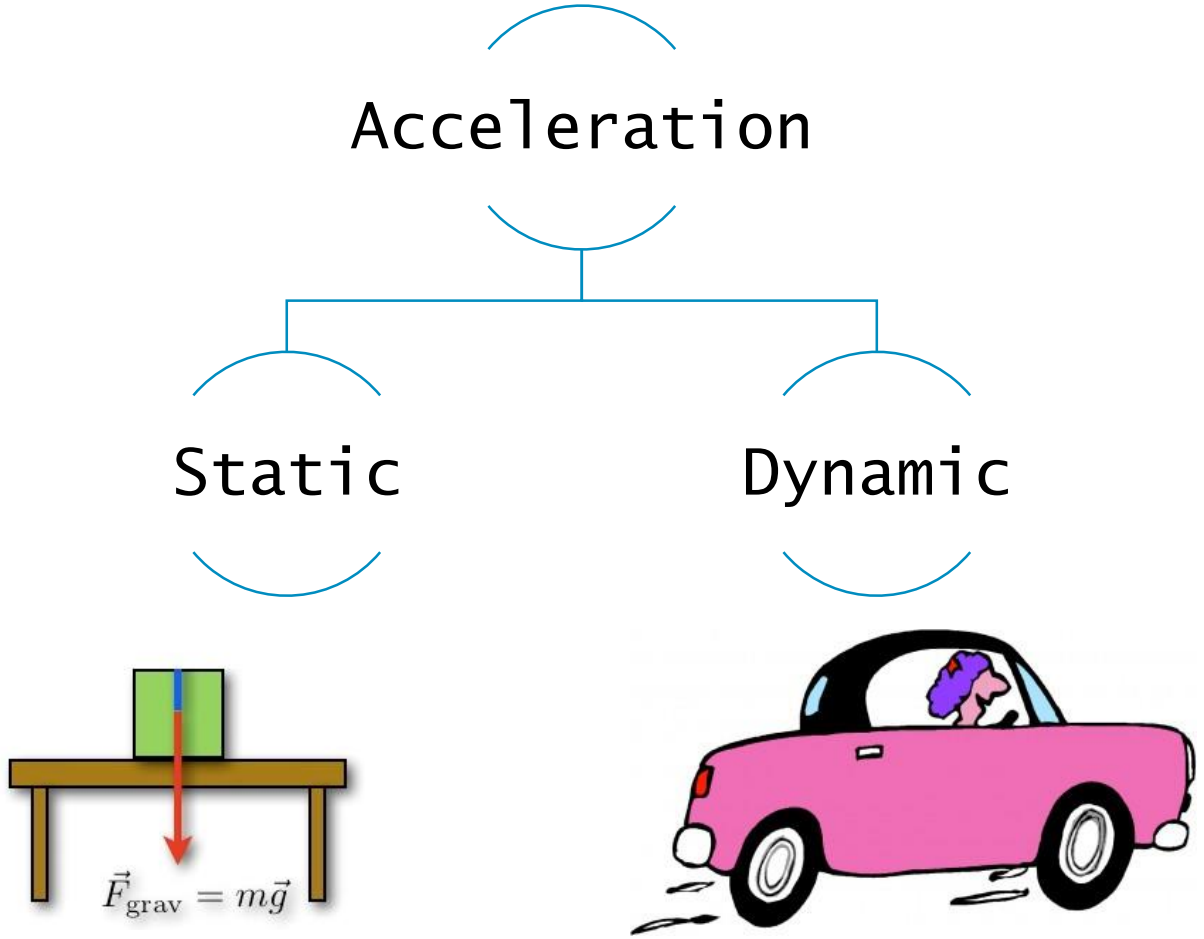
Inertial MEMS sensors

Accelerometers

Gyroscopes



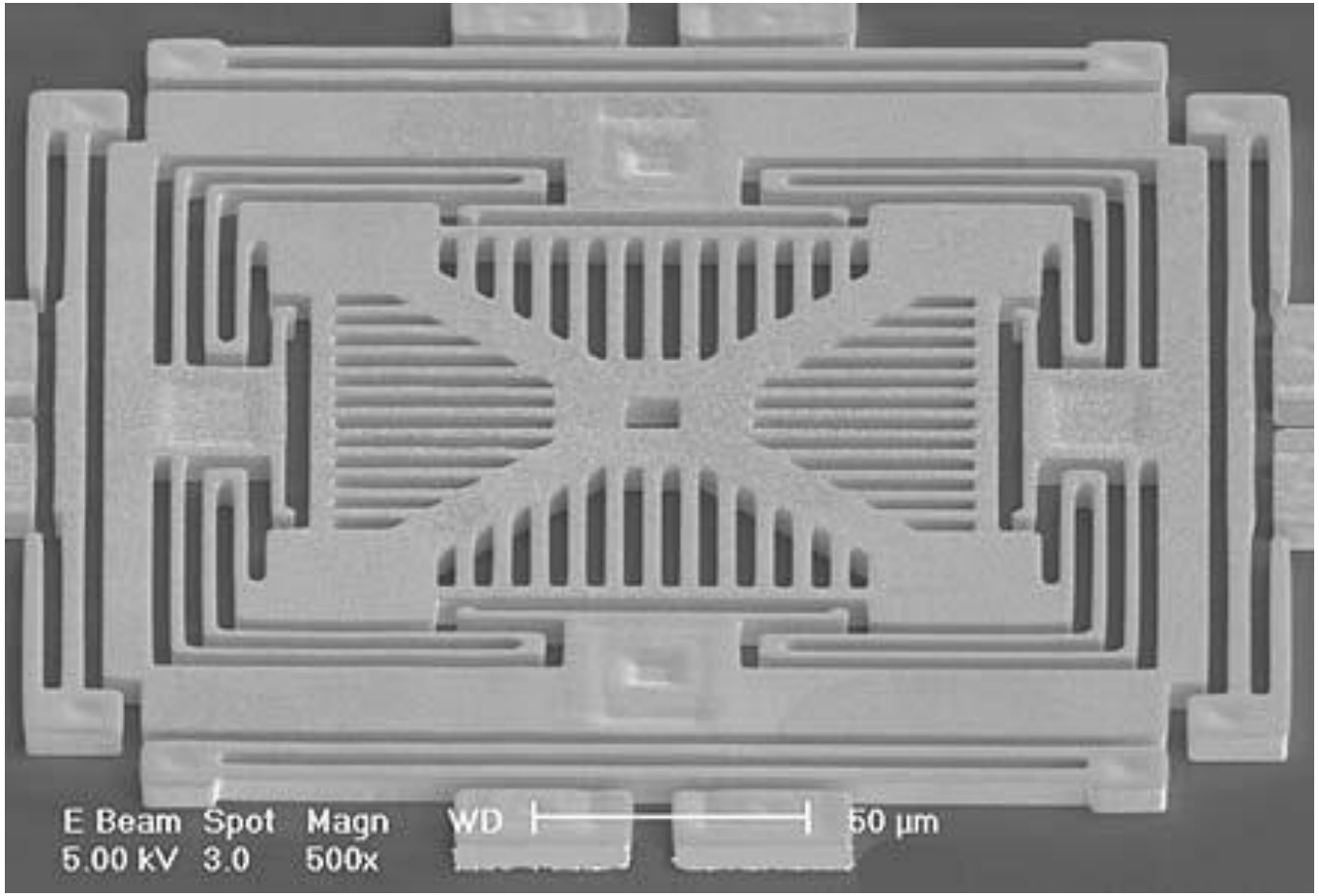
MEMS Accelerometer: Acceleration Types



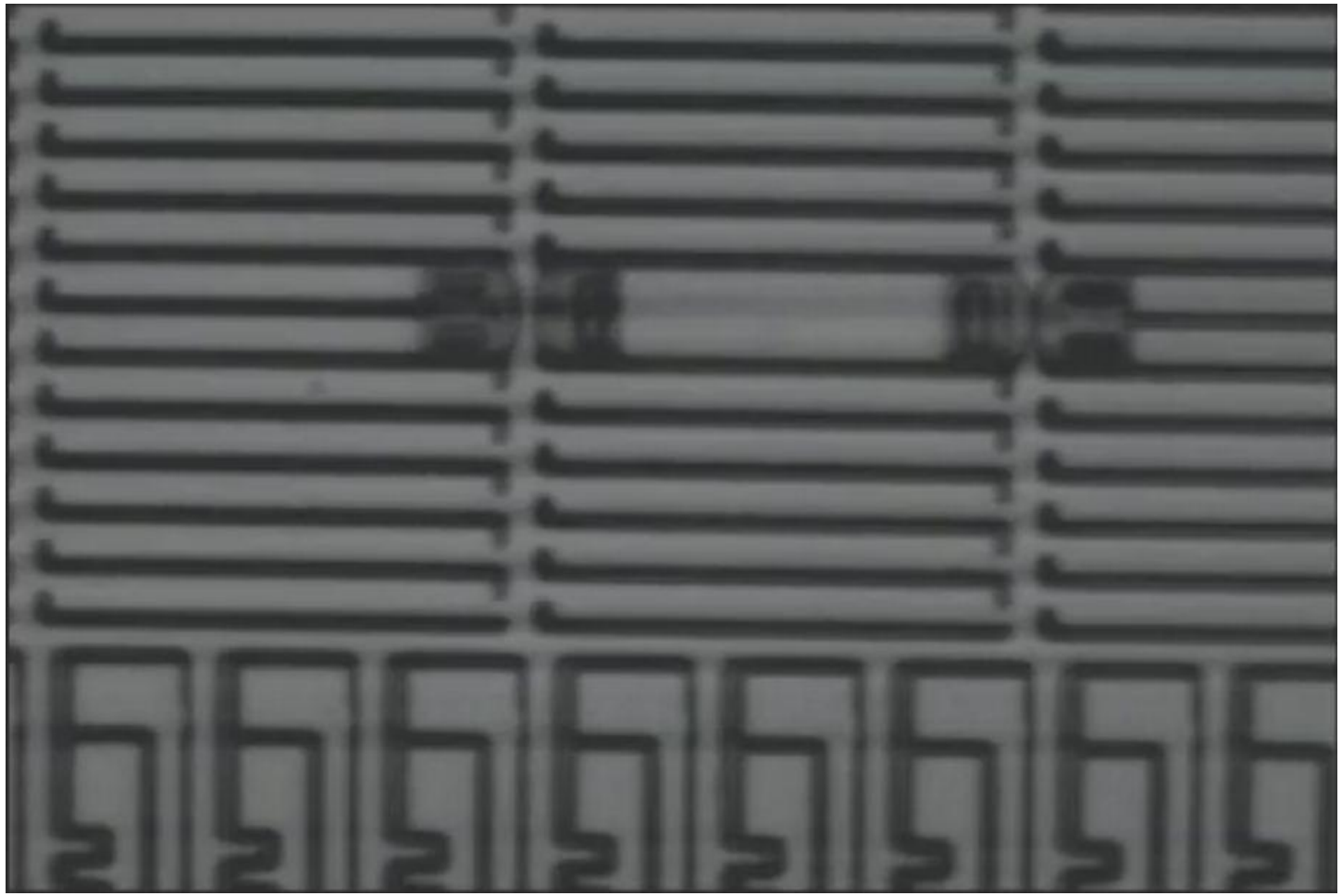
MEMS Accelerometer: Typical Values

Item	Acceleration
ABS comes in action	1G
Bugatti Veyron 0-100km	1.5G
Typical Puddle in Tehran	2G
High-G Roller Coaster	3.5G
F16 pulling out of dive	8G
Airbag Deployment	50G
Soccer Ball struck by foot	300G
Baseball struck by bat	3000G
Acceleration of proton in LHC	150,000,000G

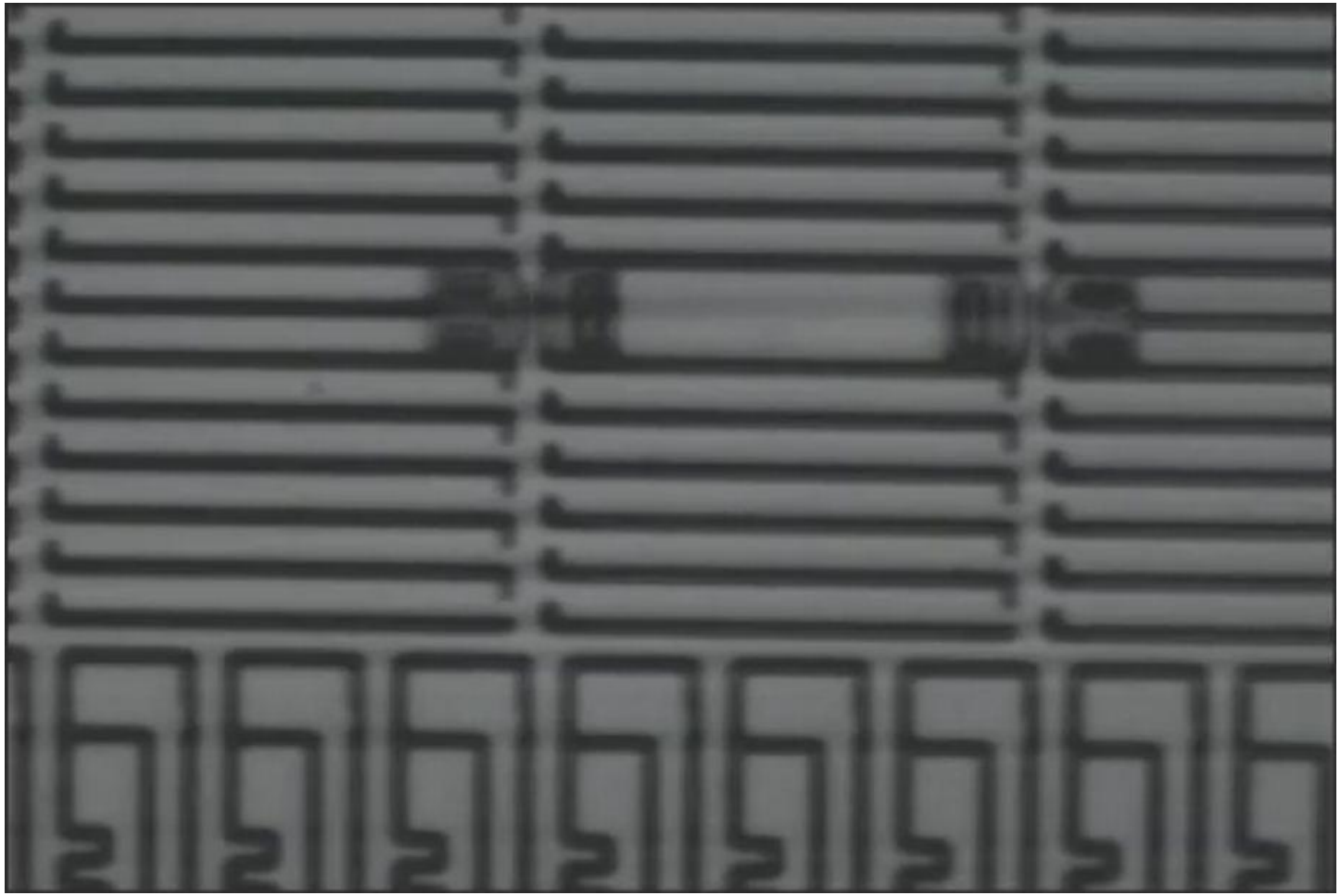
MEMS Accelerometer: Structure



MEMS Accelerometer in action



MEMS Accelerometer in action

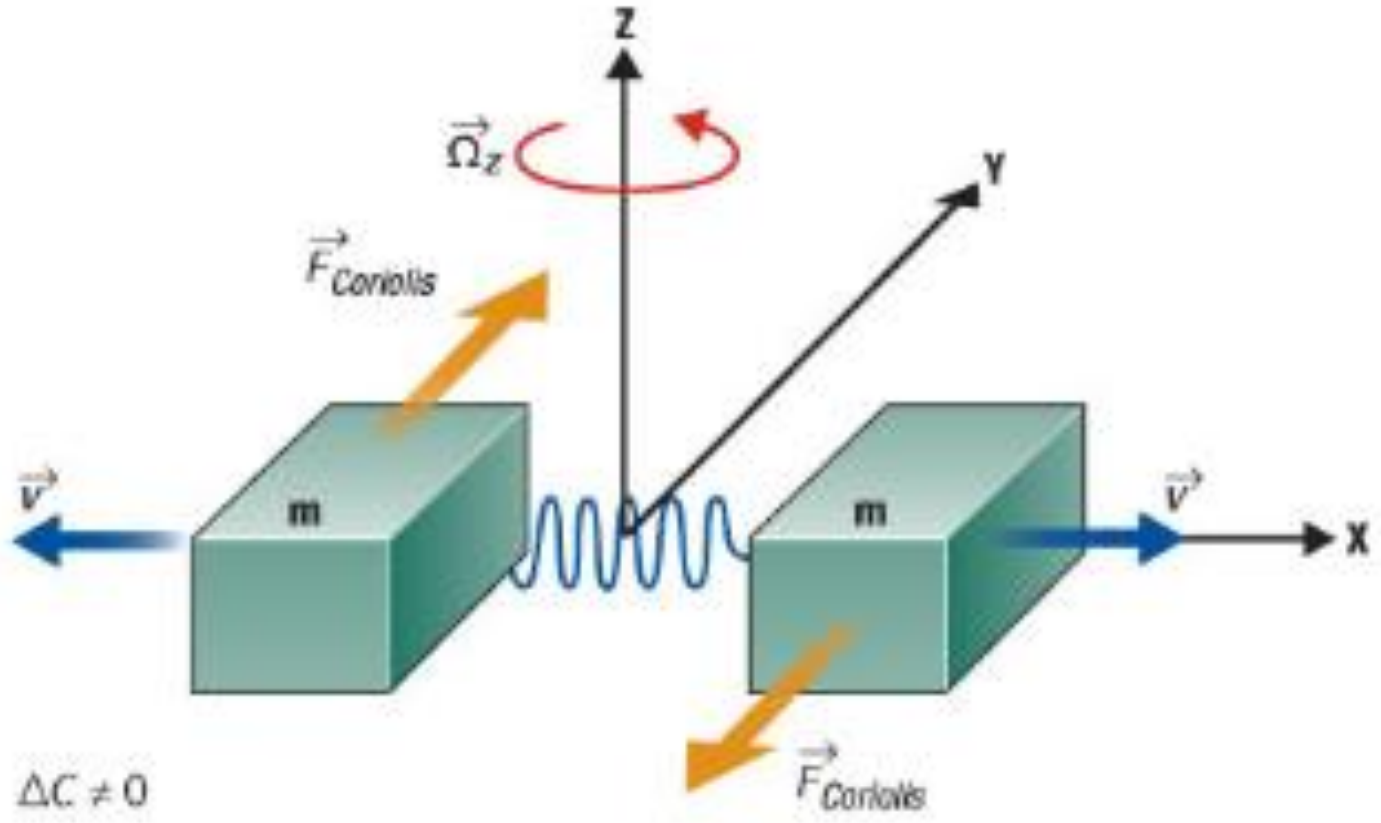


Become familiar with installed sensors & chips

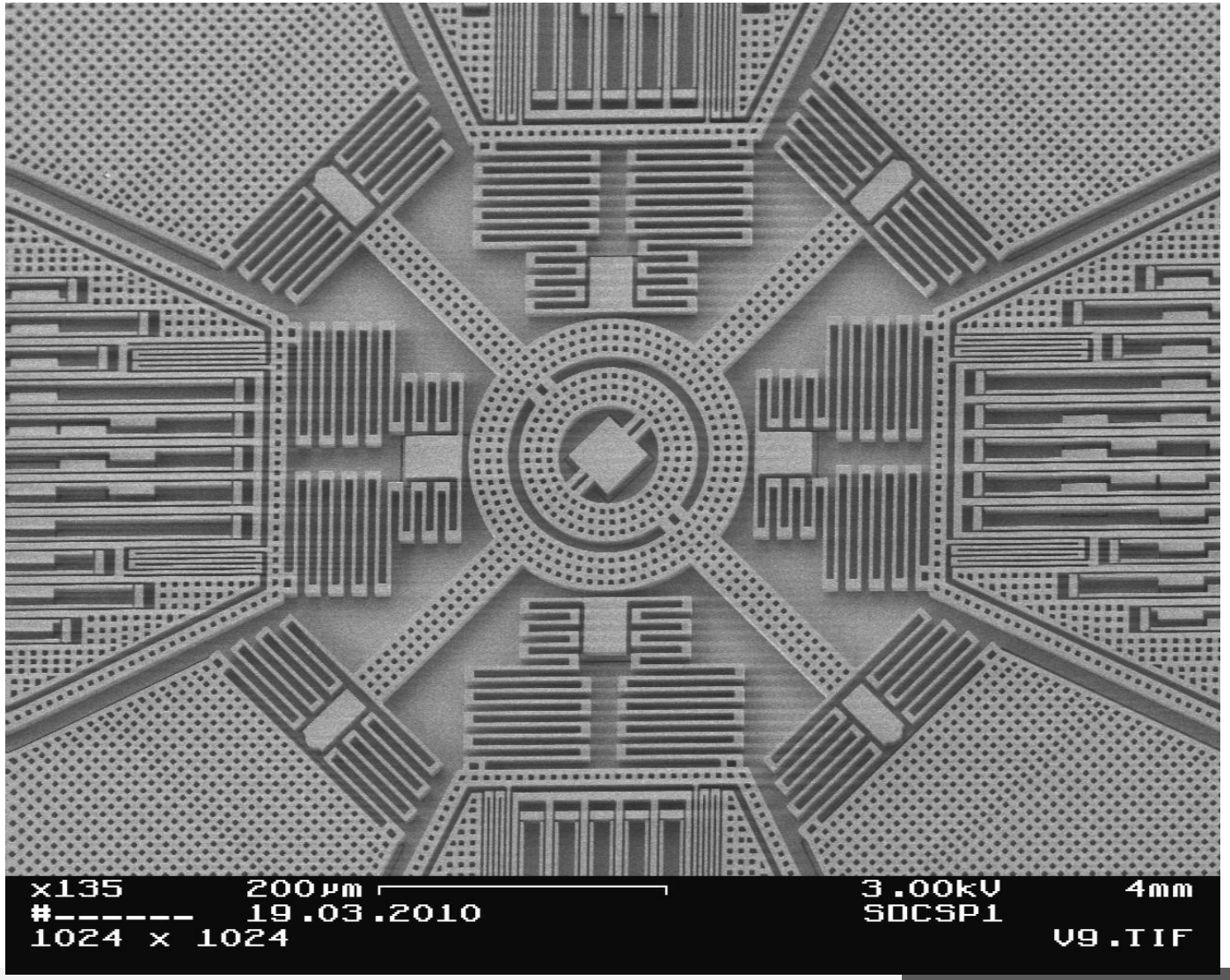
- ST Micro LSM303D 14 bit accelerometer / magnetometer

- Sensing Axis: X, Y, Z
- Acceleration: 2 g/4 g/6 g/8 g/16 g
- Sensitivity: 0.061 mg/LSB, 0.122 mg/LSB, 0.183 mg/LSB, 0.244 mg/LSB, 0.732 mg/LSB
- Output Type: Analog / Digital
- Interface: I2C, SPI
- Resolution: 16 bit

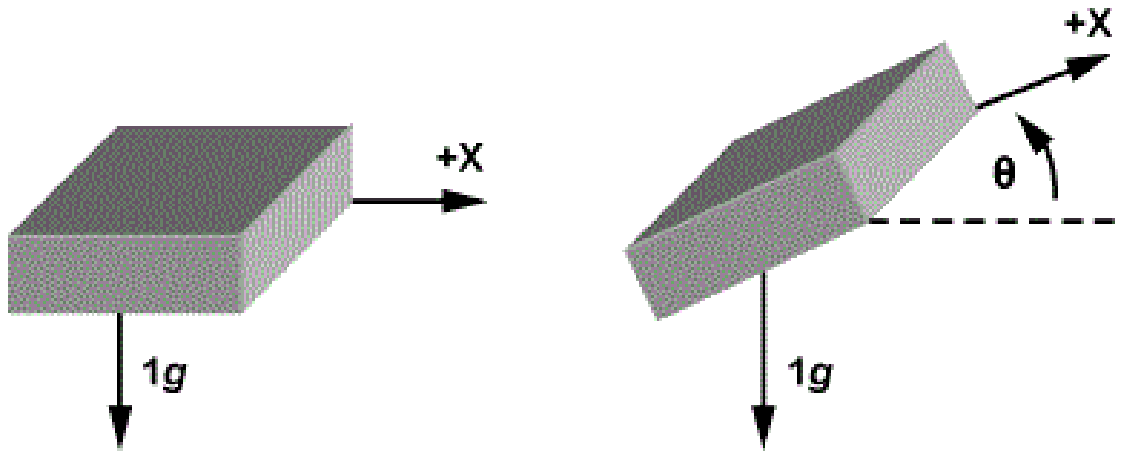
MEMS Gyroscope: Principles



MEMS Gyroscope: Structure



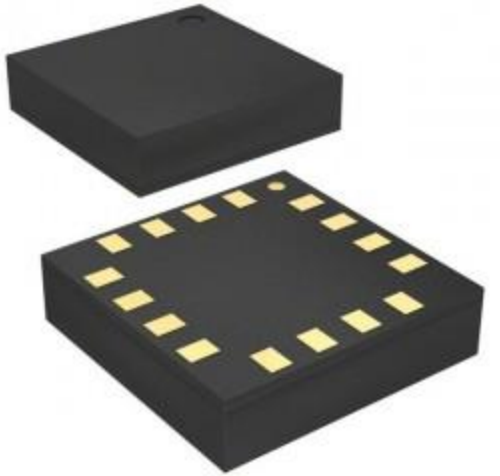
Tilt Sensing using Accelerometer



Become familiar with installed sensors & chips

- ST Micro L3GD20H 16 bit gyroscope

- Sensing Axis: X, Y, Z
- Range: +/- 245 deg/s, +/- 500 deg/s, +/- 2000 deg/s
- Acceleration: 1000g
- Sensitivity: 70 mdps/digit
- Output Type: Analog / Digital
- Interface: I2C, SPI
- Resolution: 16 bit



Become familiar with installed sensors & chips

- Invensense MPU 6000 3-axis accelerometer/gyroscope

- Discontinued!
- 3-axis gyroscope, 3-axis accelerometer
- 6-axis I²C MotionTracking device
- Digital Motion Processor™ (DMP)

Become familiar with installed sensors & chips

- MEAS MS5611 barometer

- High resolution pressure: 24bit ≈ 0,0024 mbar
- Resolution temperature: typ. <0,01°C
- Altitude resolution: 10cm
- Pressure range: 10 to 1200mbar
- Temperature range: -40 to 85°C
- I²C- and SPI-Interface

Peripheral hardwares

- GPS

- Ublox Neo-M8N GPS with Compass (Hobbyking)
- mRo GPS u-Blox Neo-M8N Dual Compass LIS3MDL+ IST8310 (mRo store)
- Drotek uBlox GPS/Compasses (drotek)
- Holybro Micro M8N GPS Module (getfpv)
- Holybro Ublox NEO-M8N GPS Module (getfpv)
- Holybro Pixhawk 4 GPS Module (UBLOX 8MN GPS + IST8310 compass + LED + Safet switch).
- Here GNSS GPS (M8N) (getfpv)
- Zubax GNSS 2 (zubax.com)
- 3DR uBlox GPS with Compass kit (getfpv) - *Discontinued*

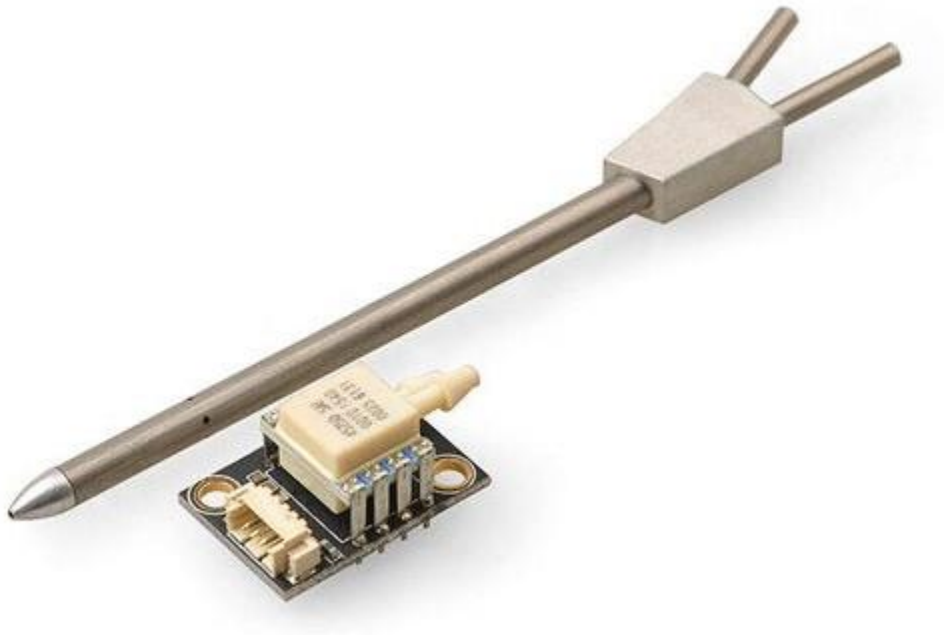
Peripheral hardwares

- RTK-GPS

- u-blox M8P
- CUAV C-RTK GPS
- Drotek XL RTK GPS
- Here+ RTK GPS
- Trimble MB-Two

Peripheral hardwares

- Airspeed



Peripheral hardwares

- MEAS Spec series (e.g. MS4525DO)
  - Differential Pressure Type
  - Accuracy +/- 0.25 %
  - Output type: Digital (I2C)
  - Temperature Range: -25C~105C

Peripheral hardwares

- EagleTree Airspeed MicroSensor V3
  - Measures airspeed from 9 MPH to 350 MPH (15KPH to 563KPH), with 1 MPH (1 KPH) Resolution
  - Power input (Standalone Mode) – 4V to 16V
  - Circuit Board: Weight 4 grams (0.15 oz), dimensions 28 mm x 16 mm x 10 mm (1.1" x 0.62" x 0.4")
  - Pitot Tube: Weight 3 grams (0.1 oz), length 80mm (3.2"), diameter 4 mm (0.16")
  - Pitot Tube Hose: Silicon, clear, 3 feet (1 meter), 1.5mm ID, 2.5mm OD
  - Precalibrated – no user calibration required
  - Advanced Temperature Compensation
  - Metric or English units

Peripheral hardwares

- mRo Next-Gen MS5525 Airspeed Sensor
  - Operating Pressure: 1 PSI (6.89kPa)
  - I2C and SPI protocol (SPI pins not fan out)
  - Accuracy: ±0.25% Span
  - Sensor supply voltage: 1.8V- 3.6V
  - Board Supply voltage: 5V
  - Maximum Pressure: 20 PSI (137.9kPa)
  - Operating Temperature: -40°C ~ 125°C
  - Weights:
    - 1.67g – Sensor
    - 3.15g - Pitot Tube
    - 4.12g - Tubing

Peripheral hardwares

- Sensirion SDP3X Differential Pressure Sensor
  - Smallest size (5 mm x 8 mm x 5 mm) currently available, opening up new dimension of integration and applications possibilities
  - Measurement range ±1500 Pa
  - Excellent accuracy and repeatability, even below 1 Pa
  - Maximum airspeed : 50m/s
  - No zero-offset, no drift
  - Calibrated and temperature compensated
  - Fast sampling time of 2 kHz at 16-bit resolution
  - Digital I2C version
  - Reflow solderable, shipped in tape-and-reel for pick-and-place
  - Smart averaging algorithm and other digital features

Peripheral hardwares

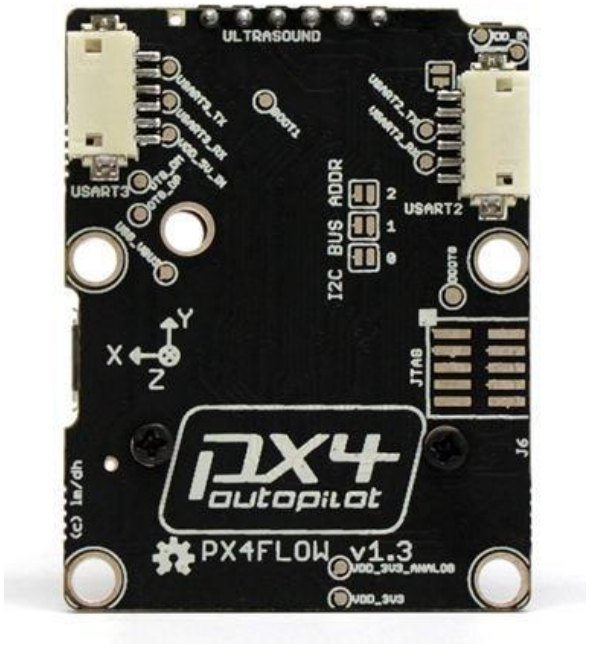
- Holybro Digital Air Speed Sensor

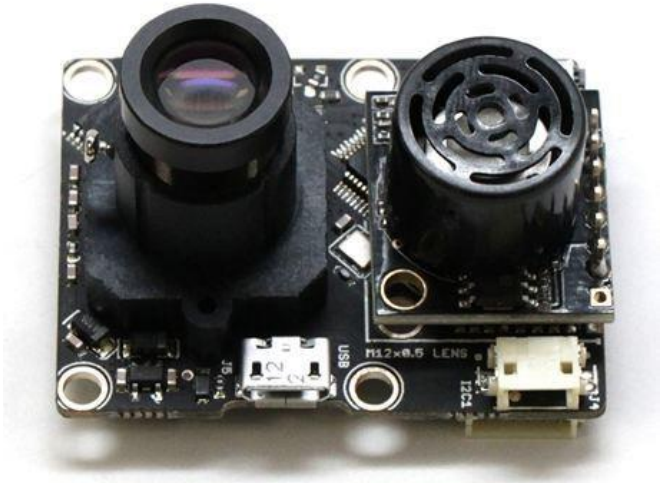
Peripheral hardwares

- Optical Flow
  - apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer and a scene
  - an image sensor chip connected to a processor programmed to run an optical flow algorithm
  - An example of this is a generic optical mouse sensor used in an optical mouse

Peripheral hardwares

- 3DR PX4Flow Smart Camera
  - 168 MHz Cortex M4F CPU (128 + 64 KB RAM)
  - 752×480 MT9V034 image sensor, L3GD20 3D Gyro
  - 16 mm M12 lens (IR block filter)
  - Optical flow processing at 4×4 binned image at 120 (indoor) to 250 Hz (outdoor)
  - Onboard sonar input and mount
  - Onboard Gyro





Peripheral hardwares

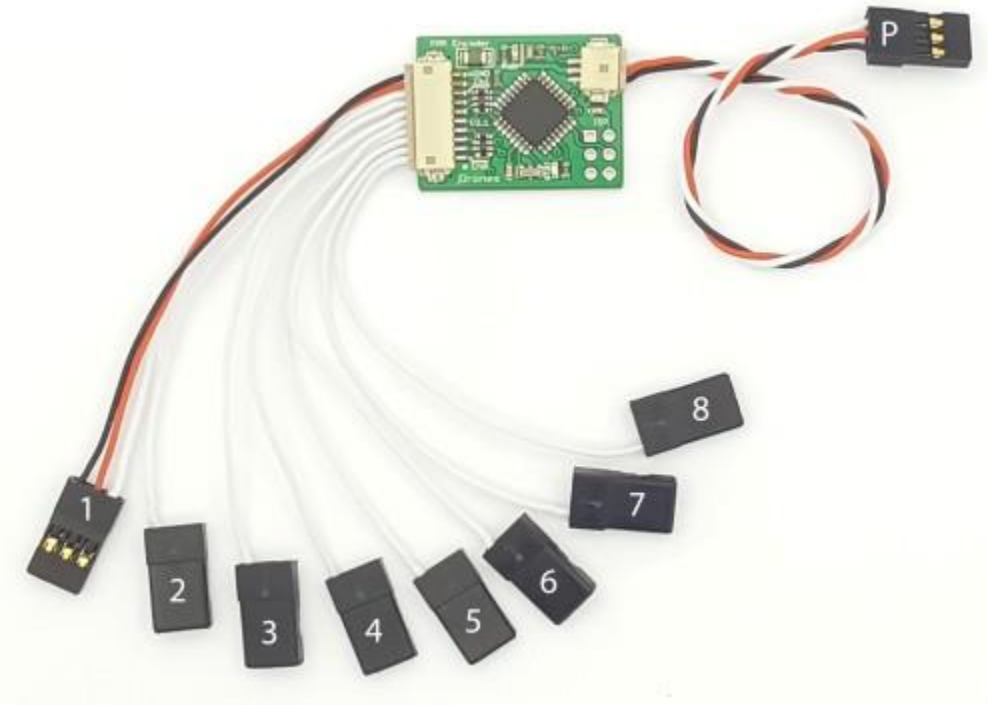
- Optical Flow
  - HK Pilot32 Optical Flow Kit With Sonar (Hobbyking)
  - Software-compatible, but not connector-compatible
  - 752×480 MT9V034 machine vision CMOS sensor with global shutter
  - Optical flow processing at 4×4 binned image at 120 (indoor) to 250 Hz (outdoor)
  - 16 mm M12 lens (IR block filter)
  - Onboard Gyro

Peripheral hardwares

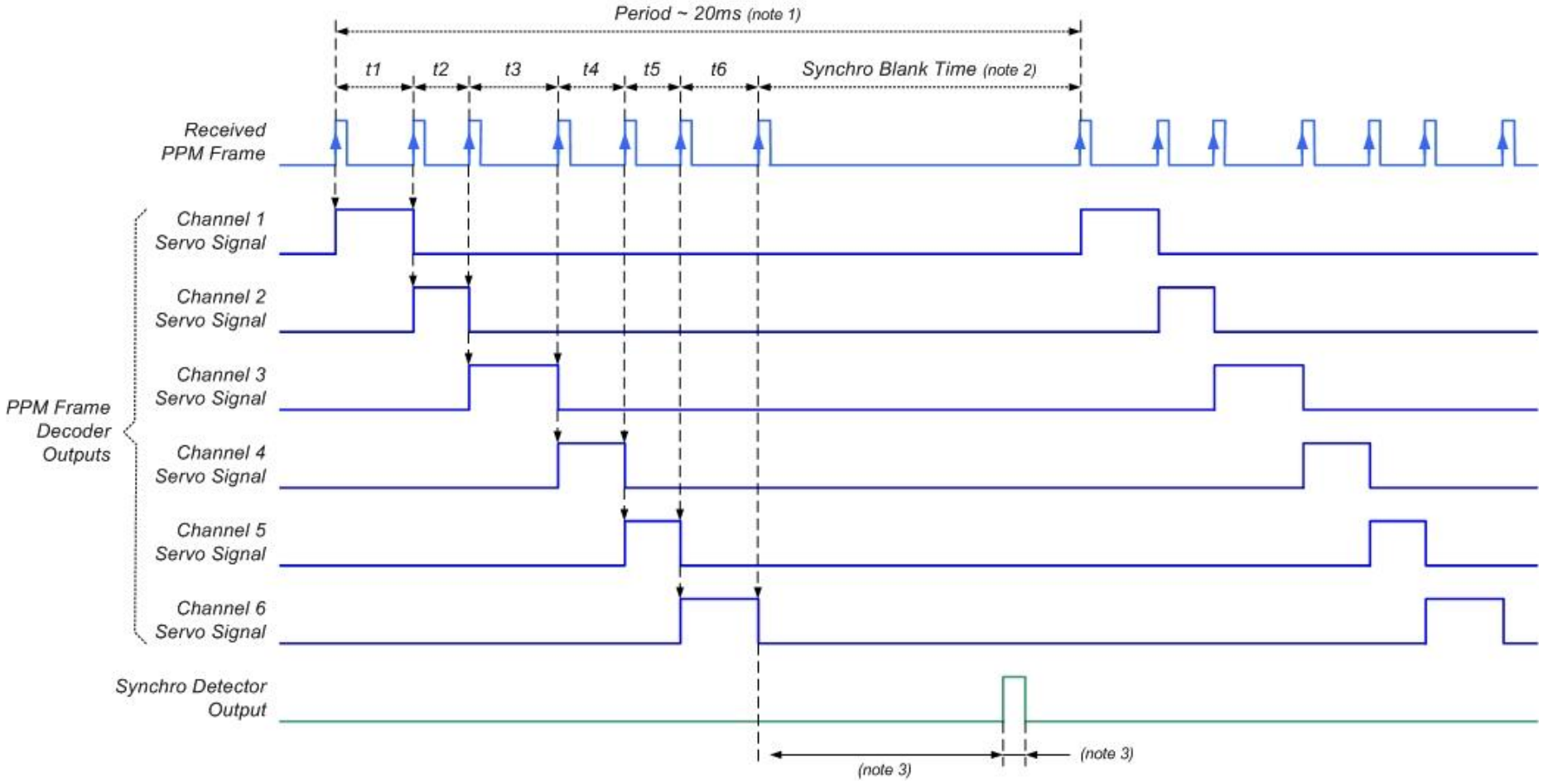
- ESC (Electronic Speed Controller)
  - PX4 supports ESCs that use:
    - PWM Input
    - ESC *OneShot* standard
    - UAVCAN ESCs
    - PCA9685 ESC (via I2C)
    - some UART ESCs (from Yuneec)
  - PX4 Does not support the *DShot* protocol

Peripheral hardwares

- PPM Encoder
  - Pulse-position modulation
  - One signal, instead of 8 signals
  - A complete frame is about 20 ms
    - Input: PWM
    - Output: PPM



Peripheral hardwares



Peripheral hardwares

- Telemetry Modules
  - SiK Radio
    - **RFD900 Long-Range Telemetry**
    - **HKPilot Telemetry Radio**

Peripheral hardwares

- Telemetry Modules
  - WiFi Telemtry
    - ESP8266 WiFi Module
    - 3DR Telemetry Wifi (Discontinued)

Compatible modules list

- Distance Sensor
  - Capacitive
  - Hall effect
  - Potentiometer
  - LVDT (Linear variable differential transformer)
  - Time of Flight
  - …

Compatible modules list

- **Lidar-Lite**

- compact, high-performance optical distant measurement rangefinder
- sensor range from (5cm - 40m)
- PWM or I2C ports

Compatible modules list

- **MaxBotix I2CXL-MaxSonar-EZ**

- suitable for assisted takeoff/landing and collision avoidance
- I2C port
- Resolution of 1 cm
- Up to 40Hz reading rate
- enabled using the parameter SENS_EN_MB12XX

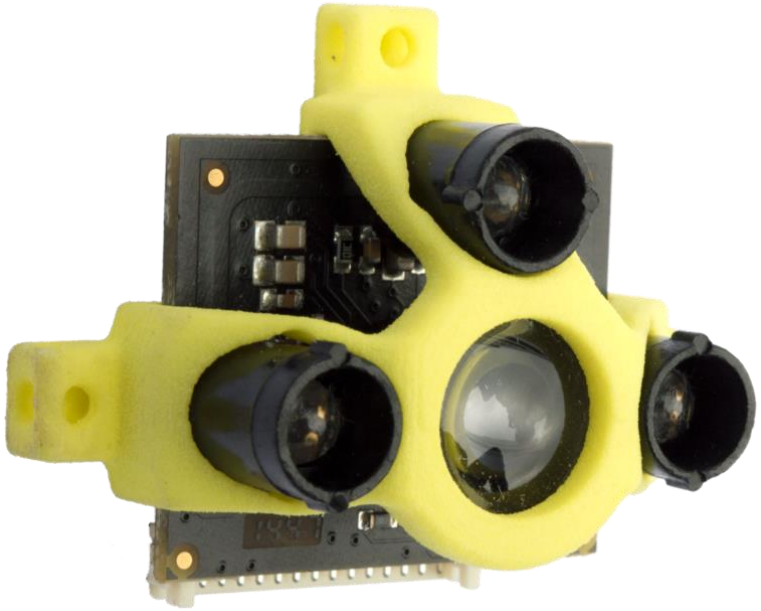
Compatible modules list

- **Lightware LIDARs**

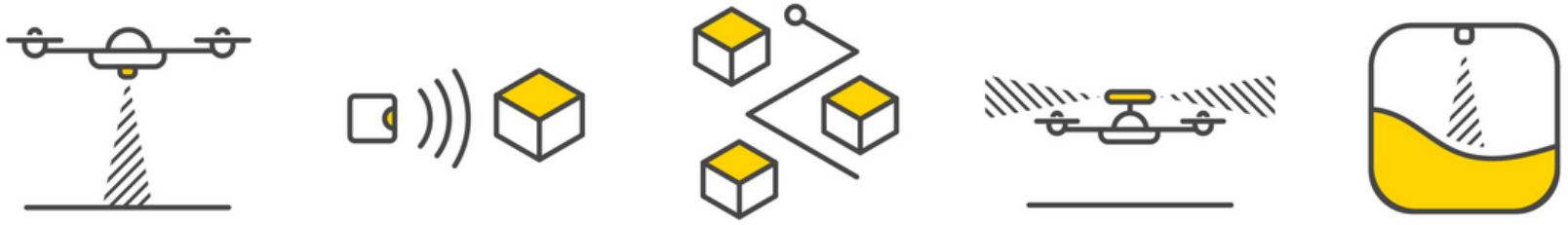
- SF02
- SF10/A (25 m)
- SF10/B (50 m)
- SF10/C (100m) (Discontinued)
- SF11/C (120 m)
- SF/LW20 (100 m) - Waterproofed (IP67) with servo for sense-and-avoid applications

- lightweight "laser altimeters"
- Drivers exist for both I2C and serial ports

Compatible modules list



- **TeraRanger Rangefinders**
  - based on infrared Time-of-Flight (ToF) technology
  - typically faster and have greater range than sonar
  - smaller and lighter than laser-based systems
  - PX4 supports the following models connected via the I2C bus: TeraRanger One, TeraRanger Evo 60m and TeraRanger Evo 600Hz



Drone altimeter and precision landing | **Distance measurement applications** | **Robot navigation, anti-collision** | **Drone obstacle avoidance** | **Level sensing**

Compatible modules list

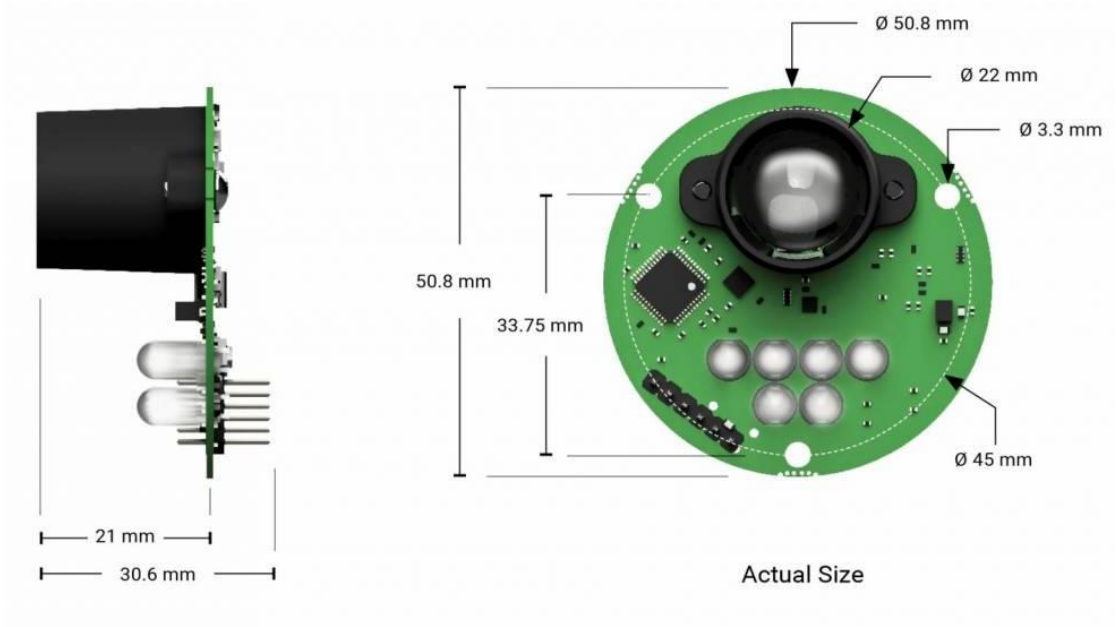
- **uLanding Radar**

- compact microwave rangefinder
- sensing range of 45m
- can operate effectively in all weather conditions and over all terrain types (including water)
- Maximum Update Rate: 766 Hz (every 1.31 ms)

Compatible modules list

- **LeddarOne**

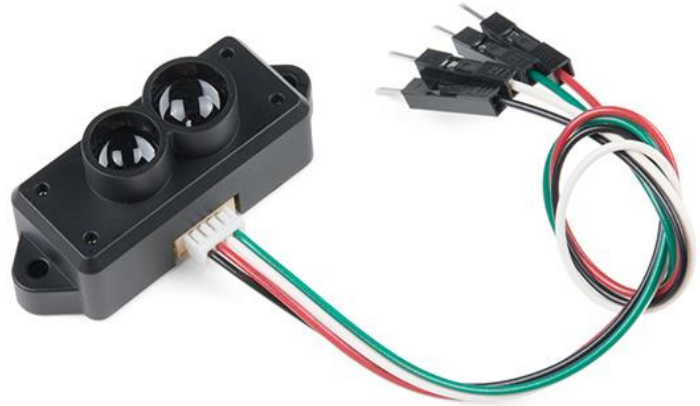
- small Lidar module with a narrow, yet diffuse beam
- sensing range from 1cm to 40m
- connected to a UART/serial bus
- Refresh rate up to 140Hz



Compatible modules list

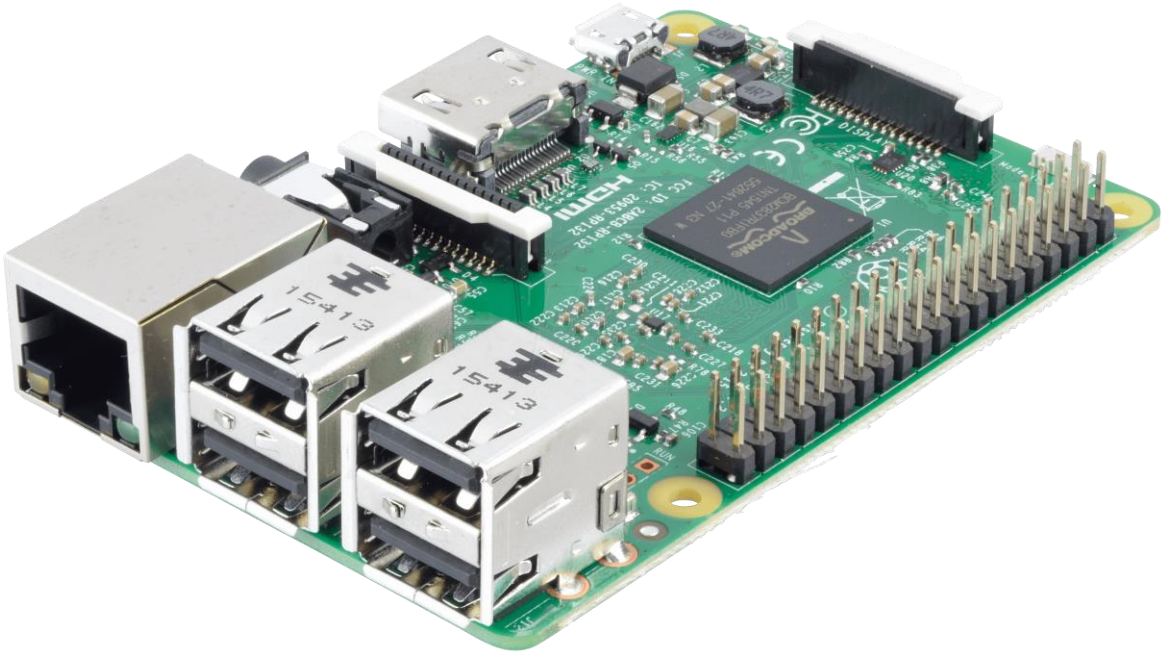
- **TFmini**

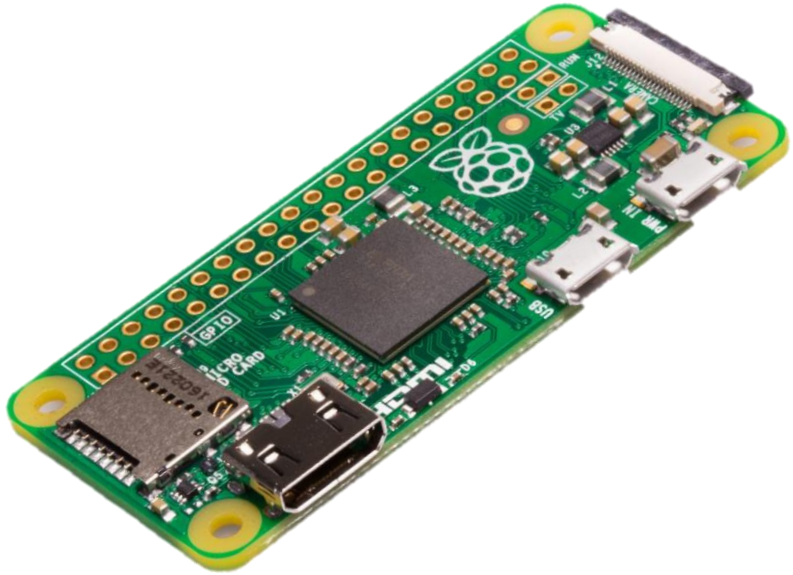
- tiny, low cost, and low power LIDAR with 12m range
- ToF (Time of Flight) LiDAR sensor
- UART at 115200 baud
- Resolution: 5mm
- Minimum Detected Object Size at 2m: 20mm
- Operating Wavelength: 850nm



Useful compatible Companion Computers (CC)

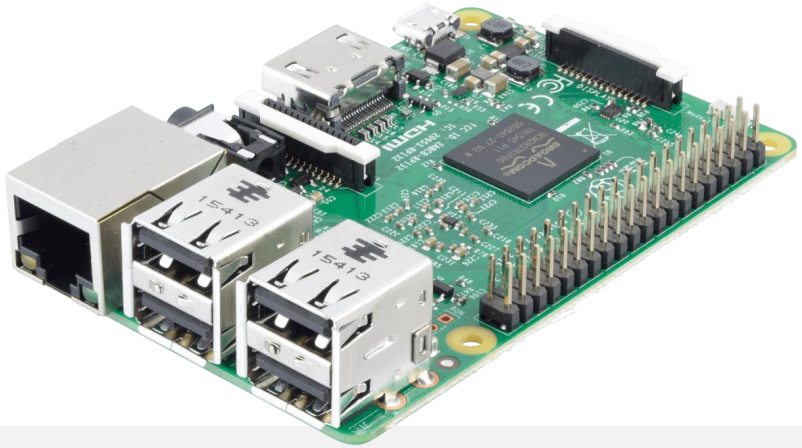
- Raspberry Pi



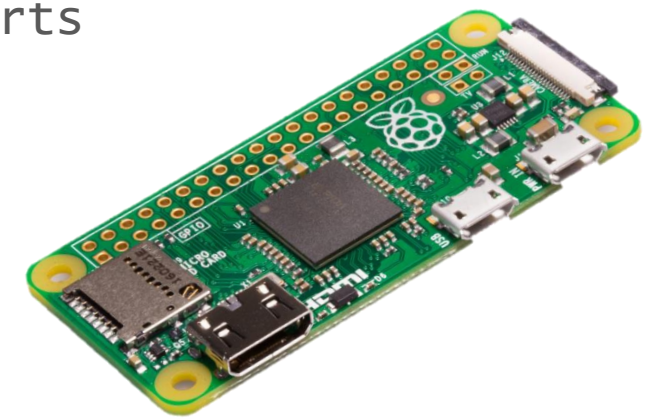


Useful compatible Companion Computers (CC)

- Raspberry Pi 3
  - Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
  - dual-band wireless LAN
  - Bluetooth 4.2/BLE (Bluetooth Low Energy)
  - 1GB SDRAM
  - Full-size HDMI

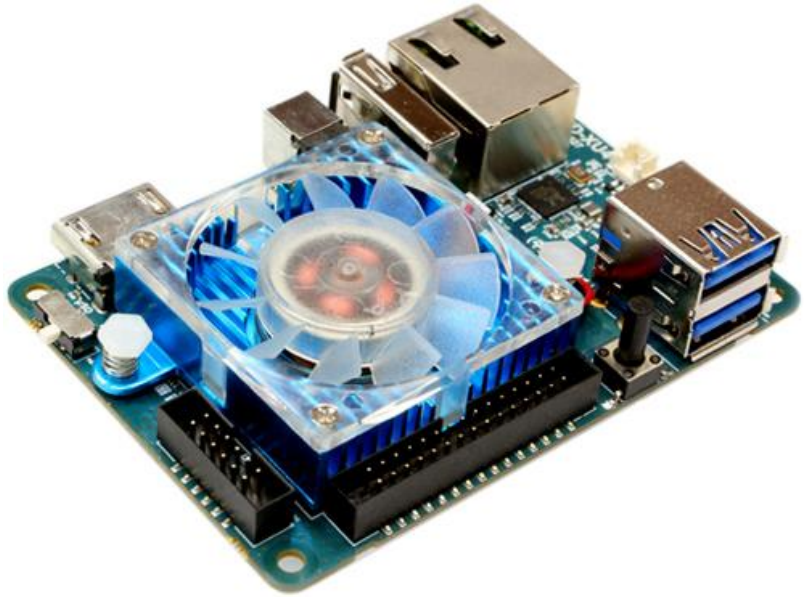


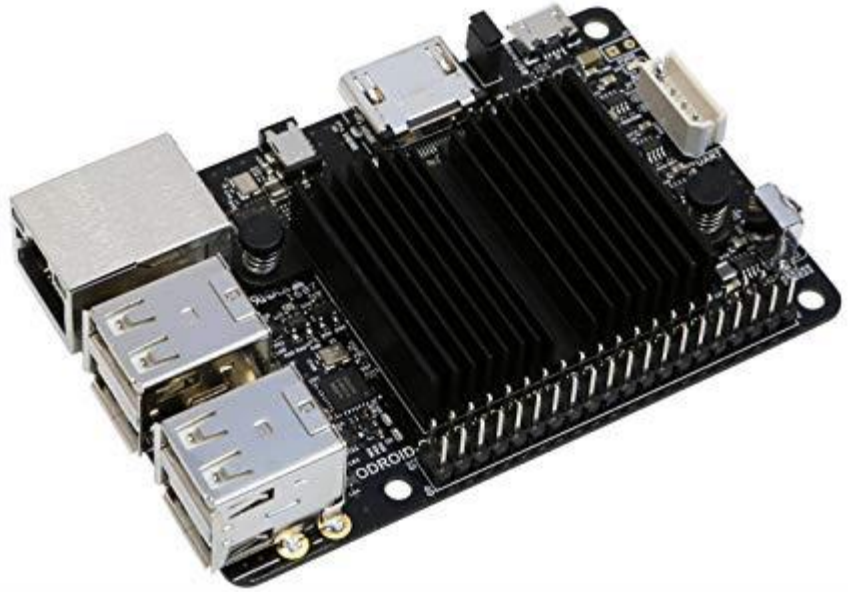
- Raspberry Zero W
  - 1GHz, single-core CPU
  - 802.11 b/g/n wireless LAN
  - Bluetooth 4.1/BLE
  - 512MB RAM
  - Mini HDMI and USB On-The-Go ports



Useful compatible Companion Computers (CC)

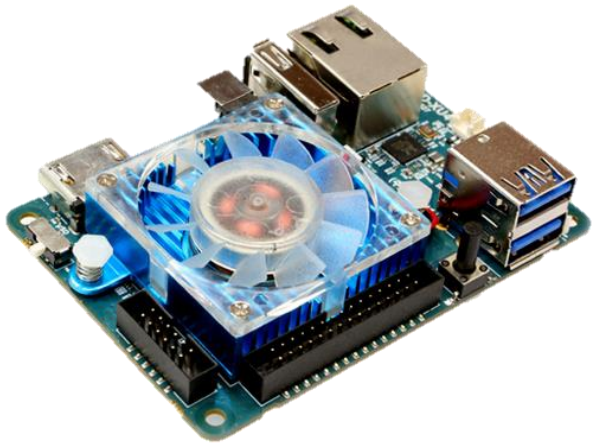
- Odroid



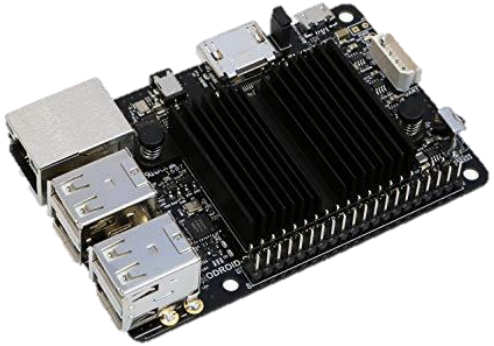


Useful compatible Companion Computers (CC)

- Odroid XU4
  - Samsung Exynos5422 Cortex™-A15 2Ghz and Cortex™-A7 Octa core CPUs
  - Mali-T628 MP6
  - 2Gbyte LPDDR3 RAM
  - eMMC5.0 HS400 Flash Storage
  - HDMI 1.4a for display



- Odroid C2
  - Amlogic ARM® Cortex®-A53(ARMv8) 1.5Ghz quad core CPUs
  - Mali™-450 GPU
  - 2Gbyte DDR3 SDRAM
  - HDMI 2.0 4K/60Hz display
  - eMMC5.0 HS400 Flash Storage slot / UHS-1 SDR50 MicroSD Card slot
  - Ubuntu 16.04 or Android 6.0 Marshmallow based on Kernel 3.14LTS



Useful compatible Companion Computers (CC)

- Up Board

Up²

AI Edge

Up

Useful compatible Companion Computers (CC)

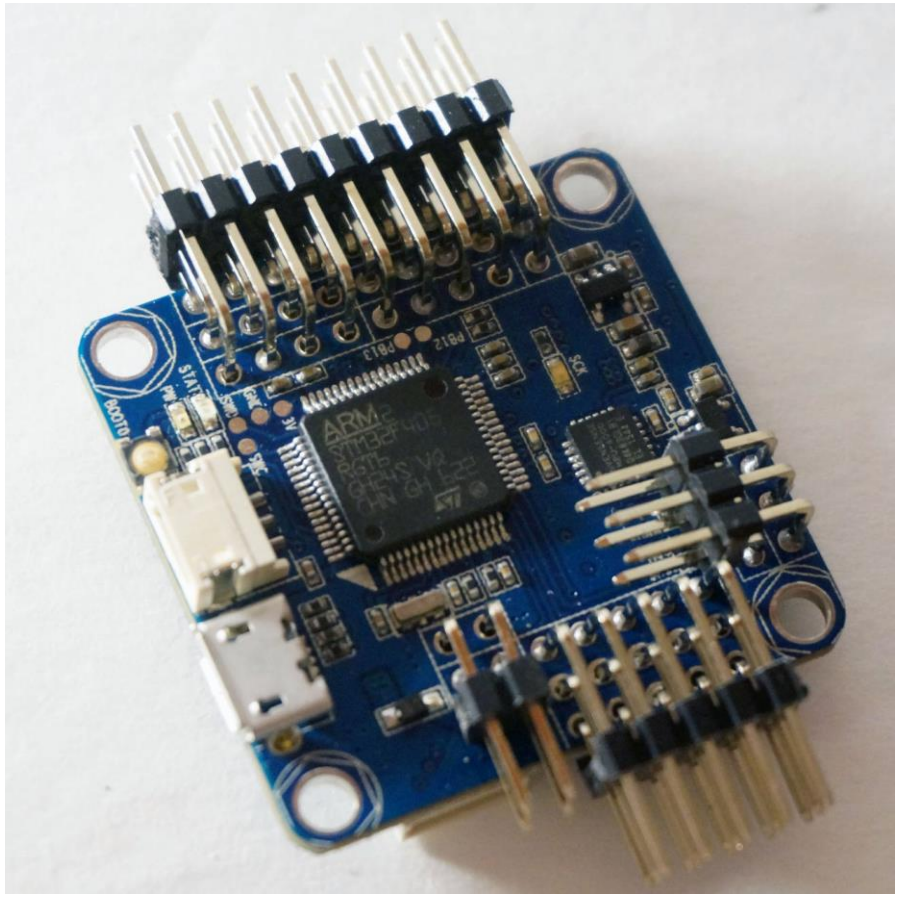
- Up^2
  - Intel® Celeron™ N3350 (up to 2.4 GHz)
  - 2GB (single channel) LPDDR4 4GB
  - Intel® Gen 9 HD, supporting 4K
  - 32 GB / 64 GB / 128 GB eMMC

- Up
  - Intel® Atom™ x5-Z8350 Processor
  - Up to 4GB DDR3L-1600
  - Intel® HD 400 Graphics
  - 16GB / 32 GB / 64 GB eMMC

3rd party compatible code hardwares

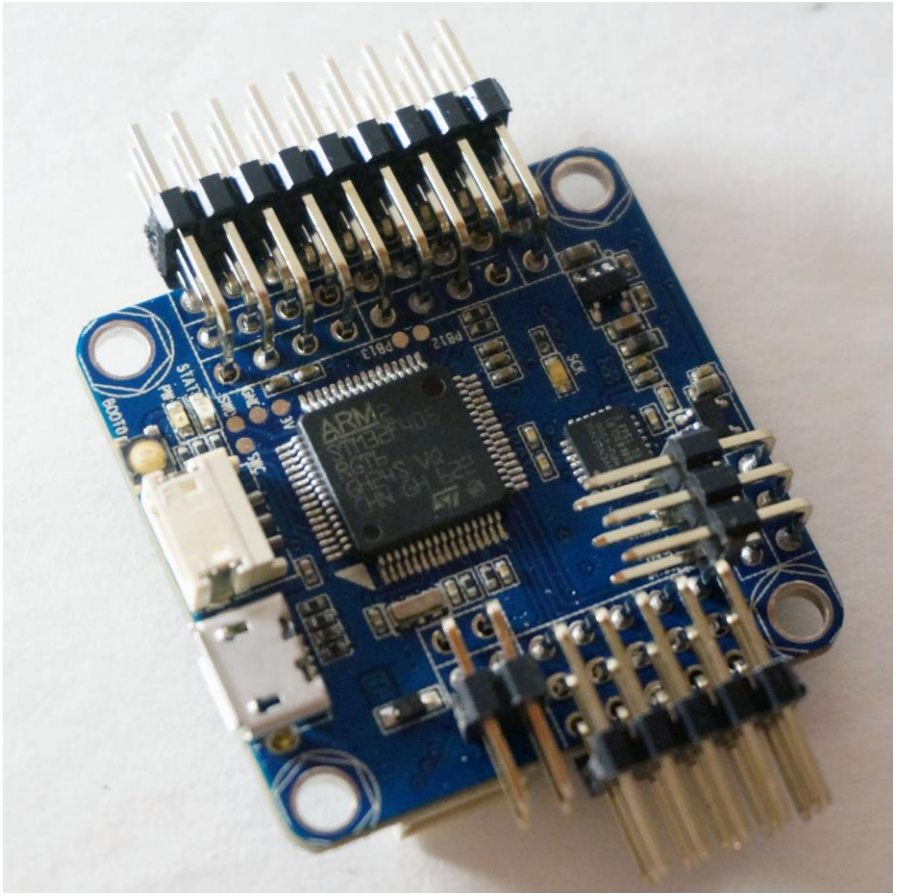
- Omnibus

- A controller board designed for racers
- Some additional features in contrast to a typical racer board
  - SD card and a faster CPU



3rd party compatible code hardwares

- Compared to Pixracer
  - Lower price
  - Fewer IO ports (though it's still possible to attach a GPS or a Flow sensor for example)
  - Requires external pull up resistor on the I2C bus for external GPS, see I2C below.
  - Less RAM (192 KB vs. 256 KB) and FLASH (1 MB vs. 2 MB)
  - Same board dimensions as a *Pixracer*, but slightly smaller form factor (because it has less connectors)
  - Integrated OSD (not yet implemented in software)



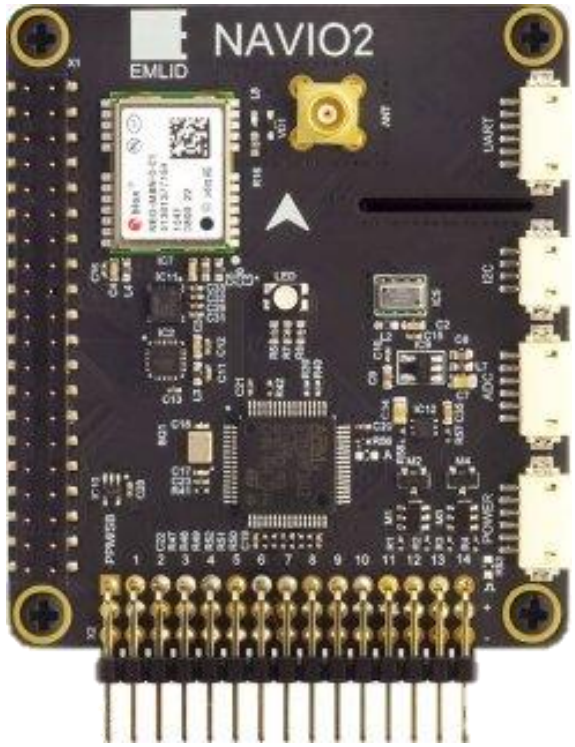
3rd party compatible code hardwares

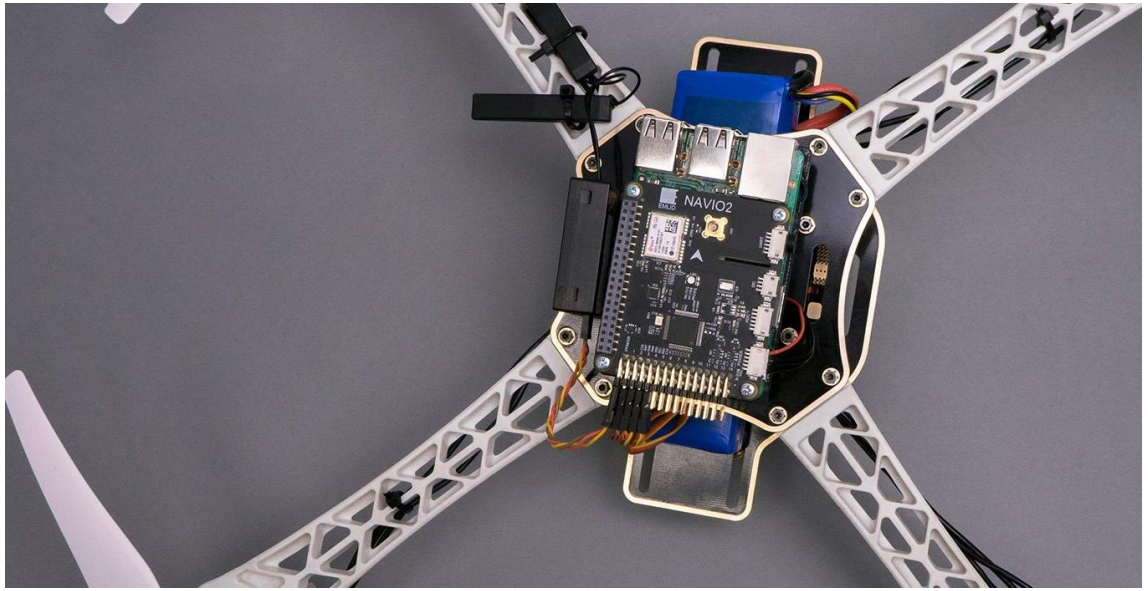
- Snapdragon

- *Qualcomm Snapdragon Flight* platform
- high-end autopilot / onboard computer
- runs the PX4 Flight Stack on the DSP on the QuRT real time operating system using the DSPAL API for POSIX compatibility

3rd party compatible code hardwares

- Raspberry Pi NavIO

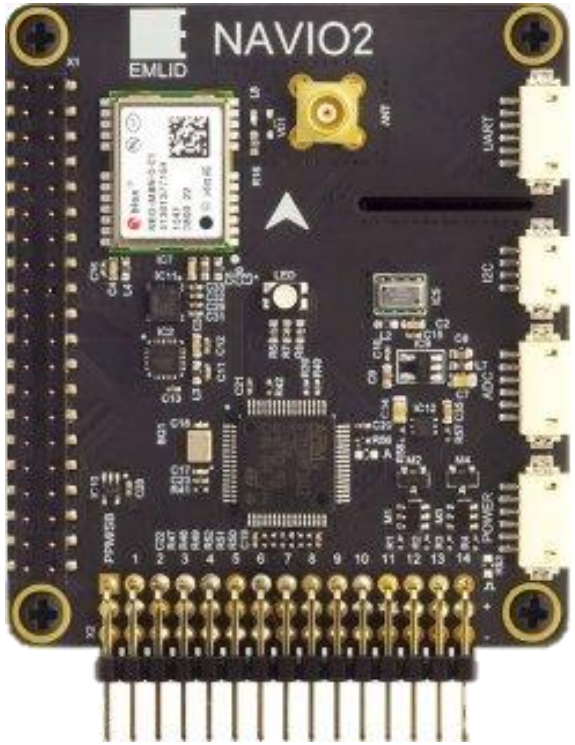




3rd party compatible code hardwares

- Raspberry Pi NavIO

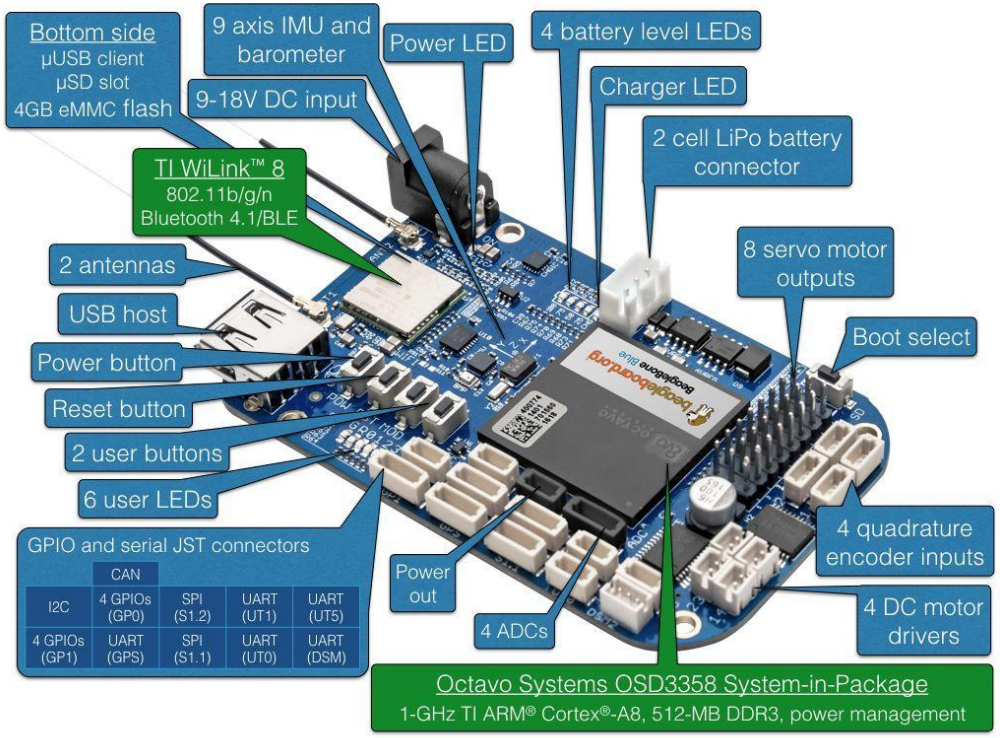
- **RC I/O co-processor**
  - Cortex-M3 I/O co-processor
  - Accepts PPM/SBUS input and provides 14 PWM output channels for motors and servos
- **Dual IMU**
  - Accelerometers, gyroscopes and magnetometers for orientation and motion sensing
- **GNSS receiver**
- **High resolution barometer**
  - Senses altitude with 10 cm resolution
- **Extension ports**
  - Exposed ADC, I2C and UART interfaces for sensors and radios



3rd party compatible code hardwares

- BeagleBone Blue

- all-in-one Linux-based computer
- optimized for robotics
- compact and inexpensive
- Has all necessary sensors and peripherals needed by a flight controller



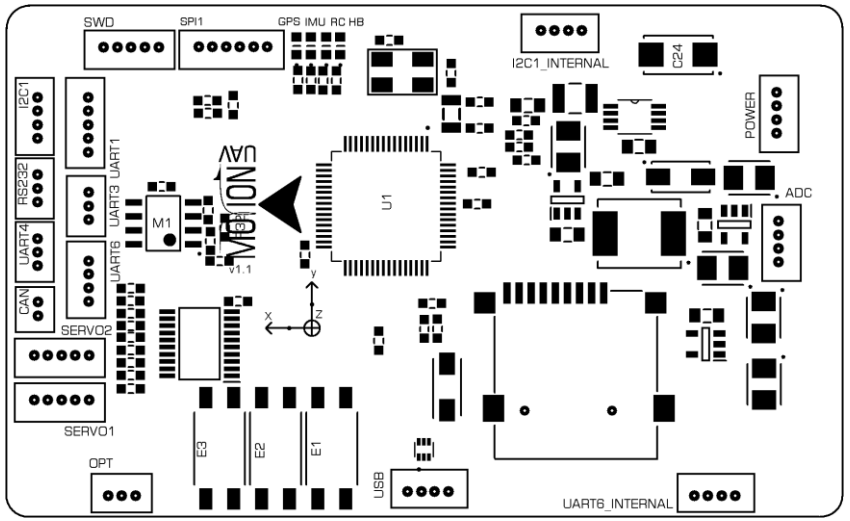
3rd party compatible code hardwares

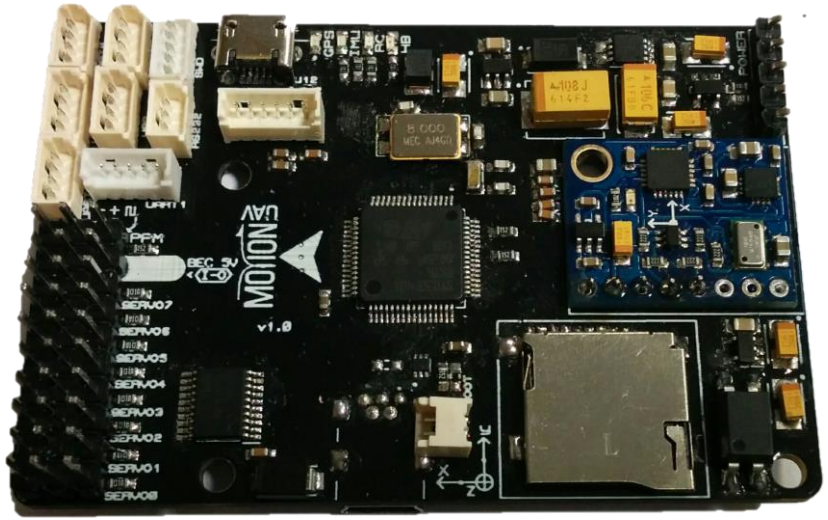
- **OcPoC-Zynq Mini**

- FPGA+ARM SoC based flight control platform
- enhanced I/O flexibility and increased processing power
- great solution for commercial UAS developers and researchers
- capabilities such as triple redundancy in GPS, magnetometers, and IMUs
- lightweight, compact footprint, leaving more space and weight on the airframe for sensor and peripheral expansion

3rd party compatible code hardwares

- **MotionUAV**
  - STM32F405
  - MPU6050
  - HMC5883
  - MS5611
  - Onboard SD-CARD
  - CAN / SPI / I2C / RS-232





Ready made vehicles based on Pixhawk

- **Crazyflie 2.0**
  - Main System-on-Chip: STM32F405RG
    - CPU: 168 MHz ARM Cortex M4 with single-precision FPU
    - RAM: 192 KB SRAM
  - nRF51822 radio and power management MCU
  - MPU9250 Accel / Gyro / Mag
  - LPS25H barometer
- PX4 can be flashes into it

Ready made vehicles based on Pixhawk

- **Crazyflie 2.0**
  - 4 x 7mm coreless DC-motors
  - maximum takeoff weight of 42g
  - weighs only 27g

Ready made vehicles based on Pixhawk

- Parrot Bebop 2
  - DIMENSIONS: 200 x 180 x 110 mm
  - WEIGHT: 500 g
  - fly distances of up to 1.24 miles
  - 25-minute battery life
  - Camera: 14 mega-pixels with fish-eye lens
  - Telemetry over Wi-Fi

Ready made vehicles based on Pixhawk

- **BetaFPV Beta75X 2S Brushless Whoop**
  - Weight: 41g (without battery)
  - Motors: 1103 11000KV with connector
  - Props: 40mm 4-blades props, 1.5mm shaft hole
  - Camera: Z02 AIO Camera 35 degree
  - Receiver Option: Frsky XM+ / DSMX / Futaba S-FHSS / Flysky
  - Battery:350mah 2S Battery (Stock battery)/ 300mah 1S Battery
  - Flight time: 2 minutes and half with 350mAh 2S battery (smooth flight in a windless environment)

Ready made vehicles based on Pixhawk

- **DeltaQuad VTOL**
  - 1 Kg payload
  - 100Km range

  - Runs PX4 out of the box!

Ready made vehicles based on Pixhawk

- **Teal one**
  - 15min flight time
  - 60mph top speed
  - 40mph wind resistance
  - Communication:
    - WiFi 802.11b/g/n
    - 600ft range
    - 720p live video stream

Ready made vehicles based on Pixhawk

- **HCS XENO FX - Fixed Wing Mapping sUAS**

TECHNICAL SPECIFICATIONS

Weight with Standard Camera:	Approx. 2.35 lbs. (1.1 kg)
Material:	Durable Elapor® Foam Construction / Carbon Fiber Tubing
Wingspan:	49 in. (1245 mm)
Cruise Airspeed:	27-45 MPH
Flight Time:	60 Minutes
Max. Survey Range	Up to 675 Acres per Flight (2.73 km2) @ 400' AGL

Ready made vehicles based on Pixhawk

- **BlueROV2**
  - Live **1080p HD video**
  - Highly maneuverable **vectored thruster configuration**
  - Stable and optimized for **inspection-class** and **research-class missions**
  - **Easy to use,** cross-platform user interface
  - **Highly expandable** with three free cable penetrators and additional mounting points
  - Standard **100m depth rating** and up to 300m tether available
  - 6 T200 Thrusters and Basic ESCs for a **high thrust-to-weight ratio**
  - **Quick-swappable** batteries for all-day use
  - Highly flexible topside enclosure for a **clean connection** from the the BlueROV2 to a compute