TBS DISCOVERY PRO Quadrotor

Durable and crash resistant multirotor perfect for amateur and pro aerial videographers

Revision 2014-03-04

The TBS DISCOVERY PRO gimbal frame is the perfect tool for amateur and pro aerial videographers. Sporting a fully stabilized, vibration isolated camera gimbal it is the most powerful, compact, robust and versatile "take anywhere" quadrocopter for filming available to date. All the wiring is integrated into the frame, the copter is easy to build and outperforms similar quads in terms of FPV range, flight time and video link quality.

By implementing the wiring into the frame, the copter is easy to build and outperforms similar quads in terms of FPV range and video link quality. The DJI Flamewheel arms as predetermined breaking point protect your electronics and are easily replaceable in the field.

Features

- Integrated brushless gimbal & control board (plug & play!)
- Built-in camera switch (GoPro live-out and pilot's camera)
- Frame acts as power distribution board
- Ready for long range FPV
- TBS CORE (On Screen Display) with digital current sensor
- Lightweight anodized CNC aluminum gimbal
- Custom Gimbal IMU board
- Tried and proven frame design - based on the world's most popular FPV quad!
- Integrated brushless gimbal controller (BaseCam)

Before we begin

Thank you for buying a TBS product! The TBS DISCOVERY PRO is a new multirotor aircraft from Team BlackSheep (TBS) for hobbyist, semi-pro and pro aerial videographers. It features the best design practices available on the market to date, providing great flying stability and incredible FPV characteristics.

Please read this manual carefully before assembling and flying your new TBS DISCOVERY PRO quadrotor. Keep this manual for future reference regarding tuning and maintenance.

Disclaimer

Our request to you; the aircraft may not be used to infringe on people's right to privacy. We have designed a toy with mind blowing capabilities. It is your responsibility to use it reasonably and according to your experience level. Use common sense. Fly safe. You are on your own. TBS has no liability for use of this aircraft.

- Locate an appropriate flying location
- Obtain the assistance of an experienced pilot
- Practice safe and responsible operation
- Always be aware of the rotating blades
- Prevent moisture
- Keep away from heat or excessive amounts of sunlight

Specifications

Type:	Asymmetric spider quadrotor
Airframe:	Reinforced black fiberglass (rear top RF transparent, bottom PDB)
Battery:	4S (14.8V) 3300 to 4500mAh LiPo pack, max. 31 x 47 x 157mm
Propellers:	9x5-inch or 10x5-inch (2xCW, 2xCCW)
Motor:	2216 class, ~900kV, 180-220W, 16x19mm mount pattern
Speed controllers:	18 to 30A 400Hz Multirotor ESCs
Receiver:	6 channels or more, 8 channels recommended
Flight controller:	Standard quadcopter controller with optional GPS module
Current sensor:	50A on-board
Camera gimbal:	GoPro HD Hero1/2/3 supported, 2-axis, roll and tilt stabilization
Gimbal controller:	BaseCam 12V, tied to CORE to auto-switch profiles, GB2208-80 motors
Center of Gravity:	15mm in front of Center of Thrust mark
Duration:	8 to 13min (dependent on drive train and battery system)
Distance:	up to 4km range (and return)
Altitude:	up to 1.5km / 5000ft
All-up-weight:	1500 to 2000g

Required tools

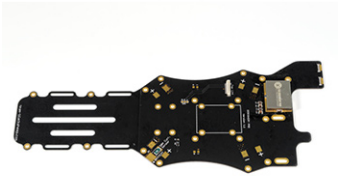
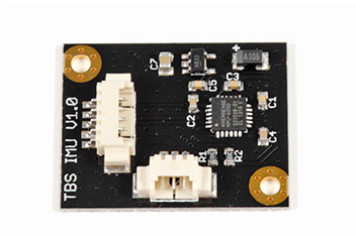
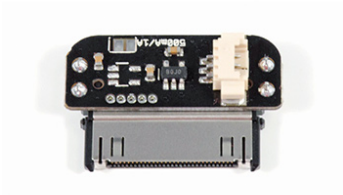
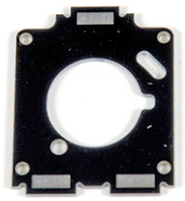
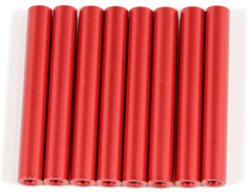
- Hex (Allen) screwdrivers (0.9mm, 1.5mm, 2.0mm, 2.5mm)
- Soldering iron (50 to 100W recommended)
- Solder ($Sn_{60}Pb_{40}$ or $Sn_{62}Pb_{36}Ag_2$, multicore flux)
- Propeller balancer (recommended)

There will be some soldering required to connect the speed controllers, battery lead, R/C header and CORE voltage configuration for the video transmitter and camera. We offer most of the following items on our website individually or as part of an *Almost-Ready-to-Fly* (ARF) kit.

The equipment and parts we offer has been truly tried-and-tested to meet our standards for an excellent flight experience. But you can of course replace these with equal components or of similar type.

Parts list

Before building your TBS DISCOVERY PRO, make sure the following items are included in your kit.

 1x Top frame plate	 1x Bottom frame plate	 1x Gimbal IMU board
 1x GoPro link card	 1x Pilot camera mount plate	 7x Red aluminum spacers
 1x Battery pigtail 14AWG with XT60 connector	 2x VTx and camera Molex Picoblade cables	 4x Black Molex 1.25 Picoblade cables
 3x Pin headers for R/C and RSSI connections	 4x Hex screws bags (M2.5x5, M3x6.5, M2.5x6, M3x4+M2x6+M2x12)	 10x Black anodized aluminium gimbal parts
 1x Gimbal bearing	 2x Gimbal motors	 25x Orange/Red/Green gimbal dampeners

Required parts

To get in the air the following equipment and parts are needed for assembly.

 4x DJI Flame Wheel arms	 4x 400Hz Multirotor Speed Controller 18-30A	 4x 900kV brushless motors (incl. prop adaptor and mounting screws)
 4x 9x5 or 10x5-inch propellers (2xCW, 2xCCW)	 1x 4S 3300 to 4500mAh LiPo battery	 1x Multicopter flight controller
 1x R/C receiver (6-channels or more, 8-channels preferred)	 1x R/C transmitter (6-channels or more, 8-channels preferred)	 1x LiPo battery charger
 1x Pilot camera (32x32mm)	 1x HD recording camera (GoPro HD Hero 1/2/3)	 1x Video transmitter
 1x Equipped ground station	 3x Velcro straps - now included!	**Other essential parts:** 1x Threadlock (purple/blue) low strength 20x Zip-ties 2x Self-adhesive foam pads

Build guide

The TBS DISCOVERY PRO comes in the usual quality finish and plug & play style the TBS DISCOVERY line is famous for. The essentials are fully integrated on the plates, to make the final assembly as easy as humanly possible. No separate boards, wire spaghetti, purchasing stuff from multiple sources or components that don't match. It is all in the box, just take it out, mount the ESCs, motors and props, a flight control and you are ready to shoot videos.

TBS CORE

The CORE has won over the FPV enthusiasts worldwide and as the easiest to use OSD module. Clean data layout and only the most important information presented on screen. Clutter-free, permanently visible, zero wires for installation, and nicely tucked away under a tin shield. The most robust and secure solution for on screen telemetry.

Features:

- Accurate flight pack voltage and mAh consumption display
- Reliable power supply for FPV camera and transmitter
- Flight time shown once a minute
- Display RSSI (R/C signal strength) from all major UHF systems and some regular R/C systems
- Single battery FPV system - less chance of failure!

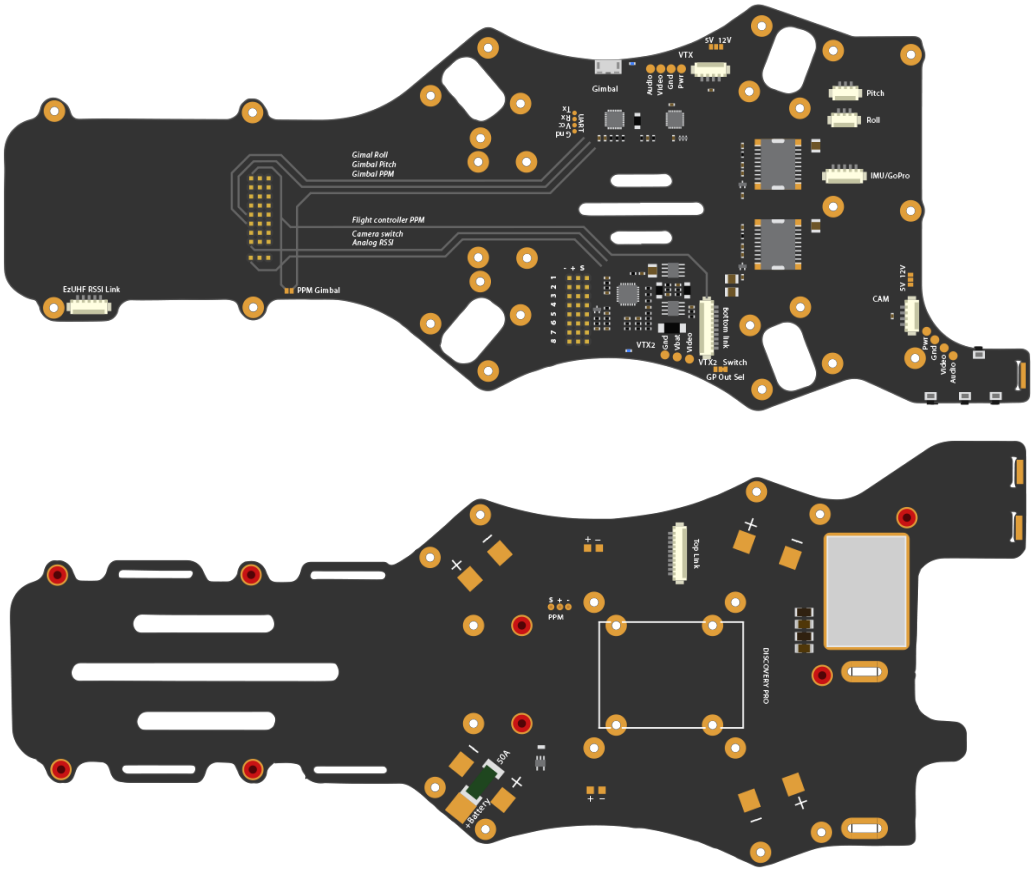
At the heart of the TBS DISCOVERY PRO sits a new CORE integrated into the frame. It provides a rudimentary OSD and clean power distribution to the FPV camera (user installed), video transmitter (user installed), gimbal electronics, IMU board and gimbal motors, regardless of input voltage (2S-10S). It delivers up to 2A at 5V and 0.65A at 12V, though the 12V rail is powered from the 5V part to support a wide input voltage range, so make sure to leave enough headroom when picking gear. If you need more power than that you have to power your equipment (e.g. VTx, camera, LEDs) separate from another power source (supply pads +/- on bottom frame and/or additional voltage regulators)!

The frame includes a 50A current sensor which is connected directly to the CORE. If you are planning to fly with UHF, we made sure to cover the CORE with a tin shield to isolate the CORE nicely from the rest of the electronics on frame. Configuring the CORE is made easy via the readily available buttons on the top plate. This means that CORE is neatly tucked away and protected under the tin shield, while making changes can be done with a few button presses.

Note: If you draw more current than provided, the DC-DC board will shut down due to overheat/ overcurrent protection! This might occur when powering a powerful video transmitter. When that happens, you will not damage your DCDC but be aware that the video link/gimbal will experience drop-outs during this period. Test it on the ground for several minutes before you maiden your PRO with equipment other than TBS recommended gear.

Frame layout

The TBS DISCOVER PRO frame is designed to reduce wiring and clutter. With simplicity in mind, we put all the electronics for the CORE, brushless camera gimbal and camera switching nicely integrated onto the top and bottom plates. All connections for the brushless gimbal motors, gimbal IMU and GoPro feed is plug&play. Calibrating the gimbal and configuring the CORE is made easily accessible via 4 push-buttons. A plate-to-plate bottom link connector shares the required power and signals between the plates. There are also two blue LEDs to indicate the state of the CORE and gimbal controller. There is even a special EzUHF “OSD Link” connector for extended R/C uplink stats on the video display.



With the advent of PPM compatible receivers and flight controllers, setting up a multirotor was made really easy; just plug in a single cable into the flight controller. PPM essentially stacks all the channels after another in a sequentially stream requiring only one hardware pin, while the traditional PWM channels all require its own dedicated hardware pin.

The advantage of PPM really becomes apparent when paired up with additional controllers (e.g., gimbal.) By sharing the same PPM output, a controller can demux only the needed channels, for instance a flight controller can demux channel 1 to 4 for R/C control, while a gimbal controller can use channel 5 and 6 for tilt/roll. Compared to traditional PWM, this removes 5 servo-cables from the system and really simplifies the build process.

Vibration free recordings

The TBS DISCOVERY PRO is designed with a new vibration damping system where the gimbal rests on an array of 8+2 silicone mounts to form a push-pull compression system. This eliminates vibrations from propagating to the gimbal frame and HD camera.

We provide 5 rounds of damping balls (soft, medium, hard, harder, extra hard)) which are interchangeable and mixable to support a wide range of setups and scenarios. A late addition to the damping system was a lever arm on the back of the roll motor to reduce slow oscillating jolts from showing on the HD footage.

Think of the entire damping layout as accumulating hardness. The green damping balls are the softest, red the medium and orange the hardest. Vary between the colors and layouts, keeping the left and right half of the gimbal symmetrical to find the system that works for you. Top and bottom do not need to remain identical.

TBS can only ensure proper operation with the TBS-approved setup: 900kV motors, 9x5 Graupner propellers, TBS BULLETPROOF ESCs. All other layouts are subject to optimization. Use the provided damping balls to experiment to find an optimal combination. With a bit it testing, you will be able to get the “jello”-effect out of any setup.

The drivetrain should be balanced and tracking before trying to reconfigure the damping balls. The primary culprit for vibrations are unbalanced propellers, followed closely by unbalanced motors/shafts and bad bearings. Fortunately, balancing them is a relatively easy task. TBS is offering a Prop Balancer for this purpose and more details on how to perform the procedure, please see our support forum section at fpvlab.com.

Long range photography

Team BlackSheep are the undisputed kings of long range FPV. With the TBS DISCOVERY PRO you can make camera shots that rival those of real helicopters. You can chase BMX drivers down an entire slope. You can film boats and yachts from the shore. You can shoot breathtaking action scenes from the director's seat! Since you're piloting from the camera view, your skill is the limit.

We offer 2 basic setups, each with their different flavors of ranges. The TBS 5.8GHz FPV system gives you ranges between 500m (25mW) to 3km (600mW). Please make sure your 2.4GHz R/C can match this distance!

To fly further, we offer the EzUHF Tx & Rx long range control system and the Lawmate 2.4GHz long range video system. Compatible with all remote controls! With the 11dBi Yagi ranges of 10km or more are easily achieved. The battery life now is your limit.

Frequency choice

Frequency choice depends on the ranges you want to fly. Using 5.8GHz video is an ideal frequency if you do not plan on flying far away from yourself or behind objects. It is compatible with 2.4GHz remote controls.

Using 2.4GHz video (TBS video frequency of choice) will give you nearly unlimited range and far superior link quality, but you can not use your 2.4GHz remote control on the same quad because of limited separation (it is no problem for our R/C buddies to fly with 2.4GHz remote controls next to you though!). You will need an EzUHF or any other UHF control system available on the market.

1.2GHz works very well in urban environments where the 2.4GHz band is completely polluted.

By using the same connector type across all transmission frequencies, the TBS eco-system allows quick and effortless switching between the frequencies.

Typical ranges (based on customer feedback) with omnidirectional antennas:

- Lawmate 2.4GHz 500mW - 4km
- TBS 5.8GHz 25mW - 400m
- TBS 5.8GHz 200mW - 1.4km
- Boscam/Foxtech/HobbyKing 5.8GHz 500mW - do NOT buy, bad design!
- Boscam/Foxtech/HobbyKing 5.8GHz 400mW - 2.5km
- ImmersionRC 5.8GHz 600mW - 1.5km

More range can be achieved by using higher gain (directional) antennas. With the 11dBi TBS Yagi on 500mW Lawmate 2.4GHz gear, 10km of range is no problem at all. The battery normally only lasts for 8km of flight (4km and return.)

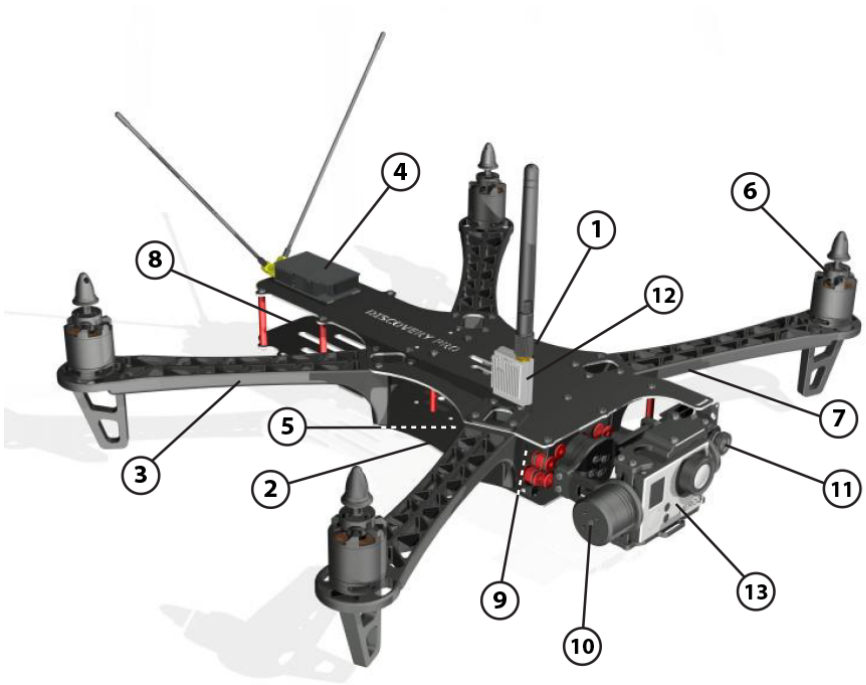
Video switching

Another great feature of the TBS DISCOVERY PRO is the ability to switch the video feed between the live FPV pilot camera and the gimbal camera. Fly through the FPV camera to line yourself up for a shot and then switch to the GoPro footage to position the camera (2-axis). Depending on if it is a close flying area or wide open field, switch back to the FPV feed to maneuver the quadcopter. Pay attention when flying through the GoPro feed because the gimbal will make it hard to judge the quad's attitude and flying direction.

Switching the video feed is done through a dedicated R/C channel on the receiver. Similarly, one or two slider switches on your R/C transmitter allows control over the 2-axis gimbal. Connect a servo-cable from the R/C receiver to the designated connectors on the top plate of the frame.

Electronics installation

The electronics installation is split into two sections; one for the R/C equipment and the second for the FPV gear. We recommend finishing and dry-testing the R/C system before moving on to the FPV section to simplify troubleshooting. A detailed overview diagram of the electronics installation is available as an appendix to this document.



1. Top plate
2. Bottom plate
3. Frame arms
4. R/C receiver
5. Flight controller
6. Brushless motors
7. Speed controllers
8. Battery
9. Integrated CORE and gimbal controller
10. Brushless gimbal
11. Pilot camera
12. Video transmitter
13. HD recording camera

Before adding the equipment to the frame it is a good idea to become familiar with the recommended positioning of the equipment, as shown in the image above.

TBS DISCOVERY PRO

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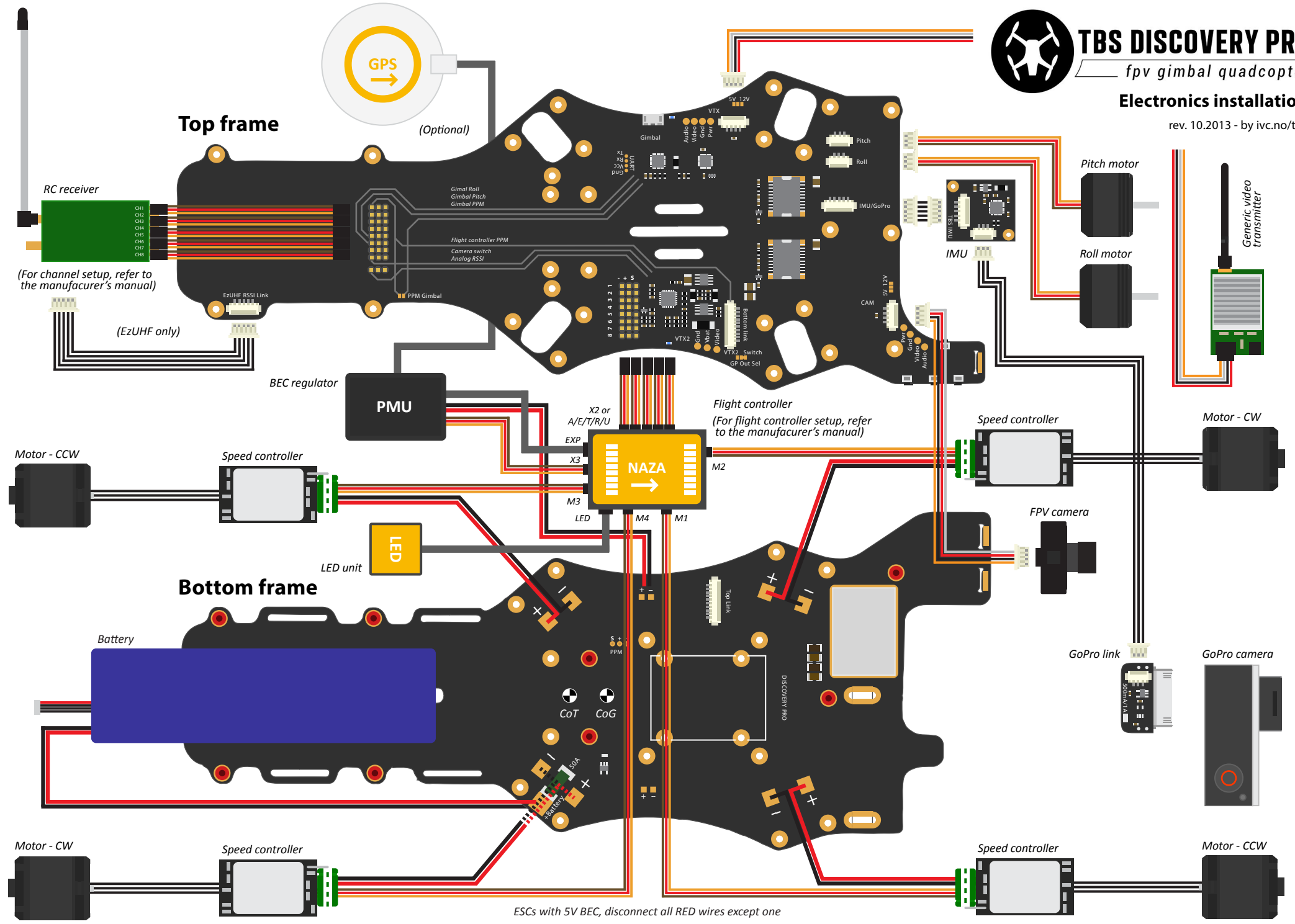
Electronics installation

rev. 10.2013 - by ivc.no/tbs



Choosing the right setup

If you are just getting into the hobby and you have absolutely nothing, consider the following components to buy. Use these suggested setups as a “shopping list” if you are just getting started. Any existing gear you already own (e.g. remote controls, chargers, batteries) can be used with the TBS DISCOVERY PRO.

These setups, with the exception of the Camera Tripod and the Remote Control, are available from Team BlackSheep. Remote controls can be purchased at your local hobby shop, camera tripods are available from big electronics wholesalers or Ebay.

TBS DISCOVERY PRO setup for short range flights

- Expected flight time: 10-12 min
- Approximate cost: US$ 2’350 - US$ 2’750
- Experience level: Beginner to Expert
- Ideal for: Parks, R/C clubs, front lawns

R/C transmitter/receiver:	Graupner MX-12 2.4GHz radio with bundled receiver (GR-6) or Futaba 8FG / 7C 2.4GHz radio with included receiver (R6208SB / R617FS)
Quadrotor equipment:	4x DJI Flame Wheel F450 arms 4x TBS BULLETPROOF 30A 5V SBEC speed controllers 4x TBS 900kV2 brushless motors 4x Graupner E-Prop 9x5-inch propellers 1x DJI NAZA-M flight controller (optional GPS add-on)
Battery:	TBS 4S (14.8V) 3300mAh - 4500mAh 35C Lipo pack
Battery charger:	Graupner Ultramat 14S (premium) or TBS B6AC 80W (budget)
FPV transmitter:	TBS ROOKIE BOSCAM 5.8GHz 200mW video transmitter
FPV receiver:	TBS RC508 5.8GHz video receiver or Dominator 5.8GHz module
FPV pilot camera:	TBS 59 or TBS 69 FPV camera
FPV goggles:	FatShark Dominator video glasses
HD camera:	GoPro HD Hero 3 Black edition
Ground station accessories:	TBS 3S 5000mAh Ground Station Lipo Camera Tripod to mount your gear (e.g. Cullmann Primax 150)

TBS DISCOVERY PRO setup for long range flights

- Expected flight time: 10-12 min
- Cost range: US$ 2’500 - US$ 3’000
- Experience level: Expert
- Ideal for: Long, wide open fields, plains, coastlines and valleys or urban flying

R/C transmitter/receiver:	Futaba 8FG / 7C or Graupner MX-12 radio + EzUHF 433MHz transmitter module and SRH-771 UHF antenna + EzUHF Lite 8-channel 433MHz receiver
Quadrotor electronics:	4x TBS BULLETPROOF 30A 5V SBEC speed controllers 4x TBS 900kV2 brushless motors 4x Graupner E-Prop 9x5-inch propellers 1x DJI NAZA-M flight controller (optional GPS add-on)
Battery:	TBS 4S (14.8V) 3300mAh - 4500mAh 35C Lipo pack
Battery charger:	Graupner Ultramat 14S (premium) or TBS B6AC 80W (budget)
FPV transmitter:	Lawmate 2.4GHz 500mW Video Tx (stock or tuned)
FPV receiver:	Lawmate 2.4GHz Video Rx (stock or tuned) with 11dBi Yagi
FPV pilot camera:	TBS 59 or TBS 69 FPV camera
FPV goggles:	FatShark Dominator video glasses
HD camera:	GoPro HD Hero 3 Black edition
Ground station accessories:	TBS 3S 5000mAh Ground Station Lipo Camera Tripod to mount your gear (e.g. Cullmann Primax 150)

Camera gimbal assembly

Start by assembling the brushless gimbal. There are a few steps which requires extra attention to detail in order to get the desired silky smooth operation of the gimbal. These are outlined in the following sections.

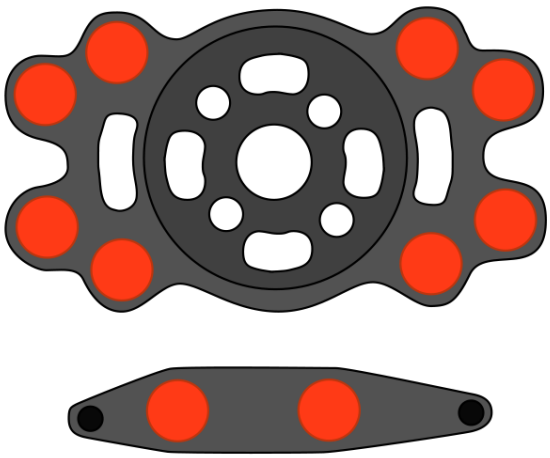
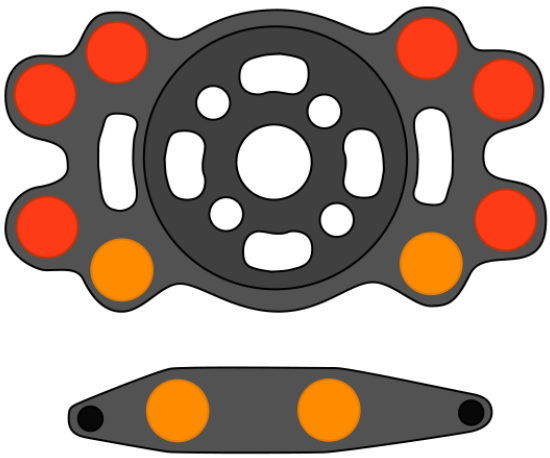
Vibration damping system

Start by inserting the damping balls on the mounting plate and frame brackets. This makes it easier to install the main mounting plate later on.

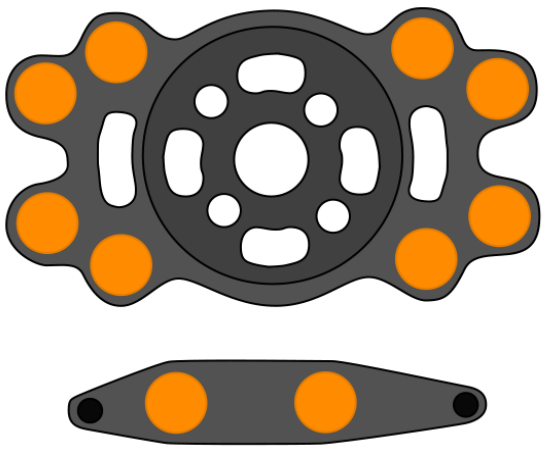
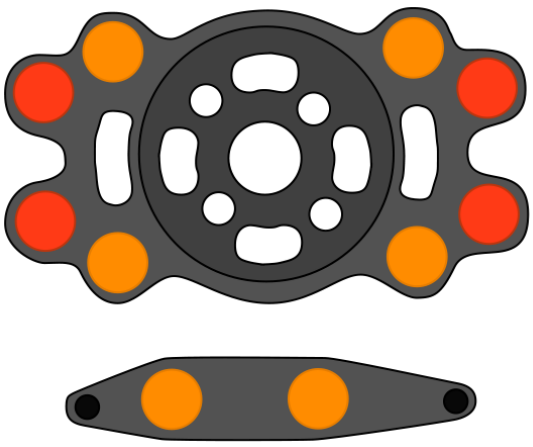
- The kit includes 35 damping balls of varying elasticity. Play around with different combinations to find an optimal match which opposes/absorbs the vibrations from the frame. In general it is recommended to go as hard as possible up to the stage where vibrations/"jello" begin to propagate.
- The harder you go on the front mounting brackets, the softer you can go on the back lever plate.
- A list of suggested combinations are available below.
    - **Green** - soft silicone (5)
    - **Red** - medium silicone (10)
    - **Orange** - hard silicone (10)
    - **Yellow** - harder silicone (5)
    - **Black** - extra hard silicone (5)

- On the main mounting plate, the cable for the motor will exit on the top notch and the plate needs to be oriented accordingly. Four of the top damping balls will face forward (toward the gimbal) holding the mounting bracket to the top frame, while the bottom four damping balls will point the opposite direction (backward) and hold the bottom end of the mounting bracket. This creates the ideal push-pull compression state where the gimbal rests nicely on the damping balls and allows them to operate under ideal conditions.
- Start out by using the recommended damping layouts shown below and experiment.

GoPro HD Hero1 & 2

Alternative #1	Alternative #2
	

GoPro HD Hero3 & 3+

Alternative #1	Alternative #2
	

- Use a short length of a servo-wire or a piece of string to more easily feed the damping balls through the 16 holes on the base mounting plate and frame mounting brackets. Wrap the wire or string inside the groove of the balls, one or two turns, feed both ends into the hole, and pull through using a plier.

- The same applies for the lever arm, only this time it is best to start with lever then work on the plate.

Gimbal assembly

The gimbal screws use 1.5mm (M2), 2.0mm (M2.5) and 2.5mm (M3) hex screwdrivers. Keep the screws loose at the start and fully tighten them at the end of the assembly, this makes it easier to align all the parts. For a good secure fit, use a very small amount of light/medium strength threadlock on all metal-to-metal-screws.

- Begin by putting on the gimbal motors on the gimbal arm and black plate. For the tilt/right motor, make sure to align the motor cable so it protrudes hidden behind the inner side of the mount. Mount it with 4x M3x4mm hex screws. For the roll/rear motor, orient the motor so that shaft/cable is pointing away from the back mounting plate. Here, use 4x M2.5x6mm screws. Take note of the four adjustable mounting holes on the roll/rear motor, use these to balance the GoPro at the end of the build.
- Connect the 5-pin Molex connector to the TBS IMU (Inertial Measurement Unit) board and feed the cable through the hole on the top gimbal cage plate. Align it with the two holes and use 2x M2.5x6mm screws to secure it.
- Attach the left side cage wall, bottom cage floor, and right side cage wall to the top cage plate using 8x M2.5x6mm screws. The axis shaft flange on both walls should face outwards and the notches for the cable zip-tie should be positioned up. This completes the central gimbal cage assembly.

- Next, put the bearing into the housing the left gimbal arm and use the long M2x12mm screw to compress the gap until the bearing stays in place - do not overtighten, just clamp the bearing.

Note: Parts with the same number belong to the same group.

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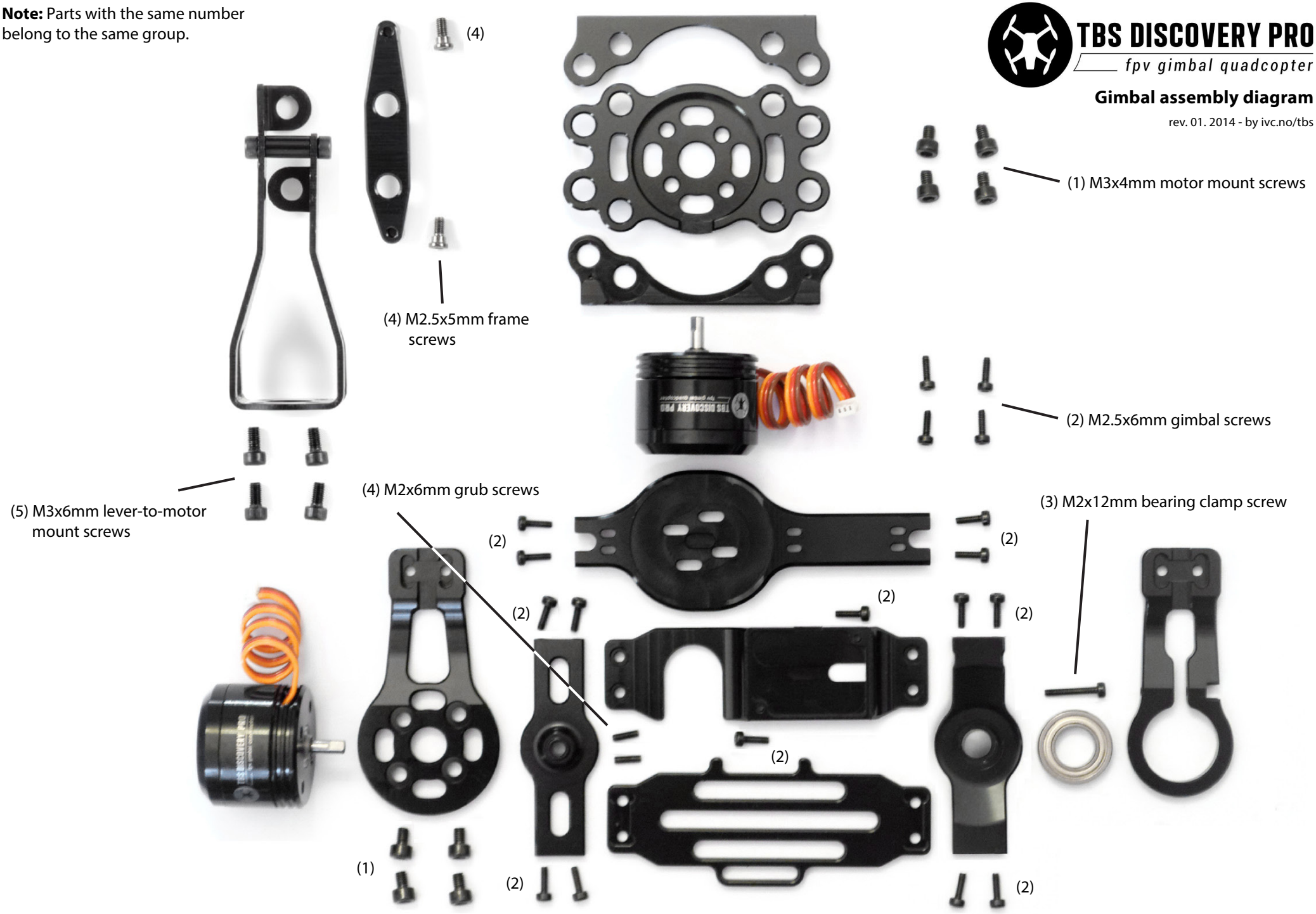
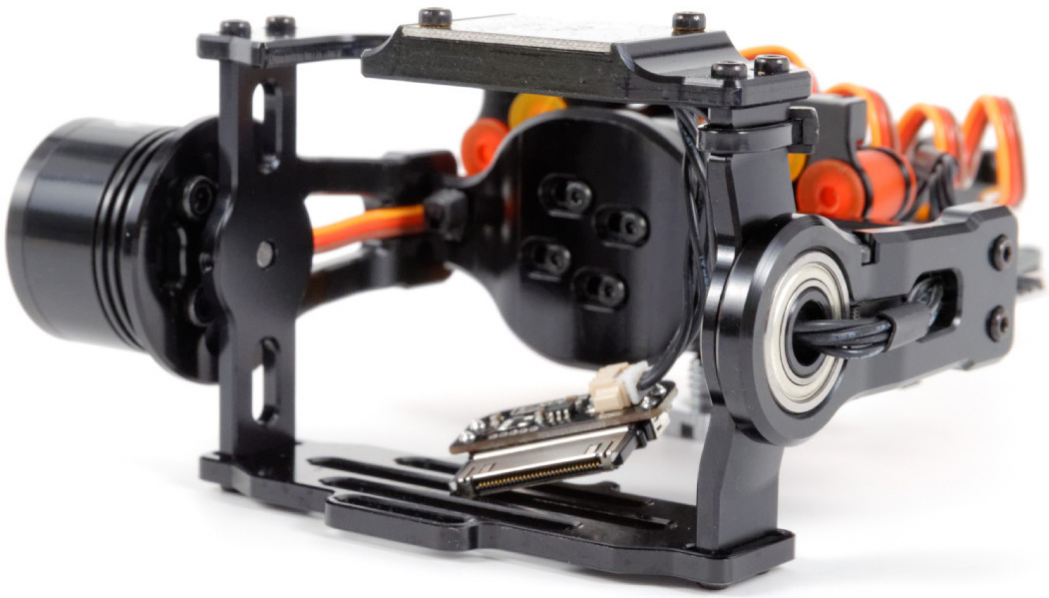
Gimbal assembly diagram

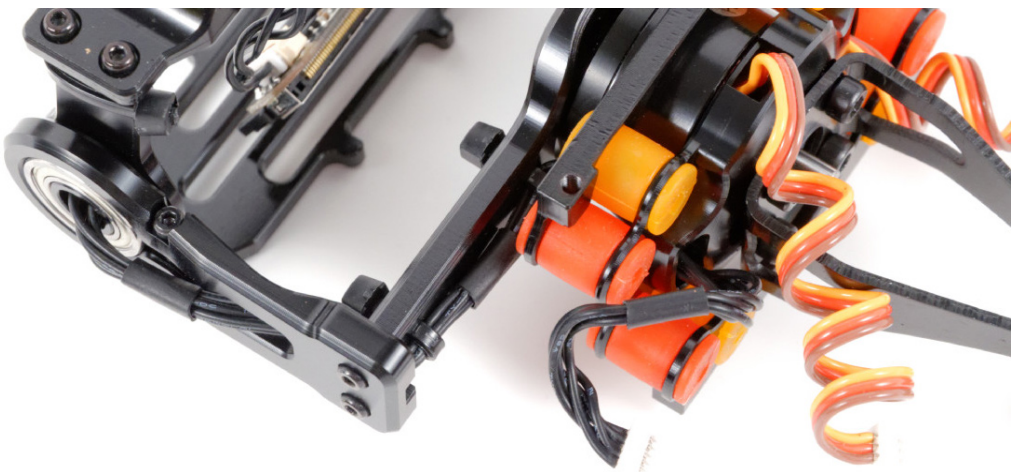
rev. 01. 2014 - by ivc.no/tbs



- To minimize cable tension and friction, feed the 5-pin Molex connector through the bearing and slide the bearing over the flange on the left side of the gimbal cage (completed previously).
- Align the shrink tube pieces in such a fashion that there is no shrink tube on the inside corner of the cage or in the bearing channel. Feed the remainder of the 5-pin cable length through the hole on the left gimbal arm.



- Align and attach the roll/rear motor mounting plate to the left gimbal arm. Pass the 5-pin cable through the inner “U”-gap. Do the same for the right gimbal arm.
- Use the small 2x M2x6mm grub screws to secure the tilt/right motor shaft to the gimbal cage. This requires a 0.9mm hex (Allen) key. Align the two notches on the motor shaft with the grub screw holes. Ensure that both screws are properly tightened, but do not overtighten as the screws could strip.
- Strap down the cables using 4 zip-ties, use the designated holes around the inner bends of the gimbal arms and cage. The zip-tie on the cage for the IMU cable needs to be positioned with the zip-tie head facing backwards to avoid binding/hitting the left gimbal arm.

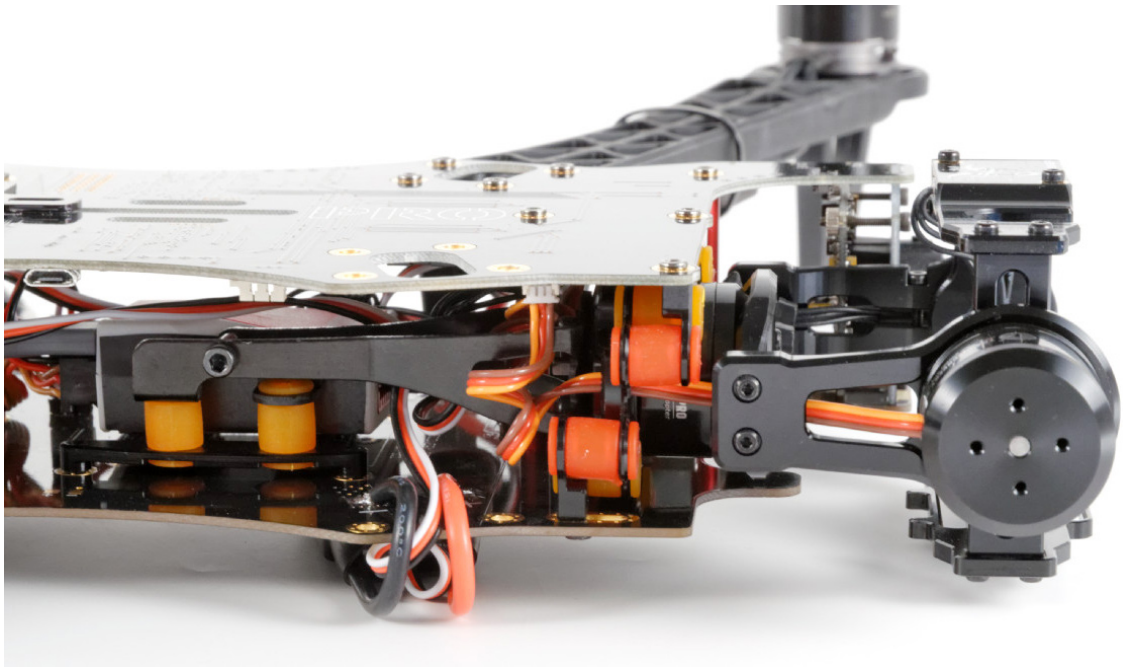


- Continue by attaching the main damping mounting plate (completed previously) and back lever arm to the rear/roll motor. Align the cable with the notch in the mounting plate and secure it using 4x M3x6mm screws. Feed the remaining cables through the two oval holes on either side of the plate. Make sure the cables does not obstruct free movement or is under tension. Also check that the cage can move freely and there is no binding (rubbing) on either side.

- Mount lever arm with the flat surface with the holes pointing down. The lever plate should have the protruding thread holes also pointing down. This completes the gimbal arm and cage assembly!

Post frame assembly

- Continue assembling the rest of the DISCOVERY PRO frame and at the end of the build, slide in the gimbal assembly, plug in the 3 cables for pitch, roll and IMU to the designated location and secure the gimbal using 6x M2.5x5mm frame (arm) screws. Double check that the right/tilt motor is connected to the “PITCH” connector and the back/roll motor to “ROLL”. The cables should move freely.

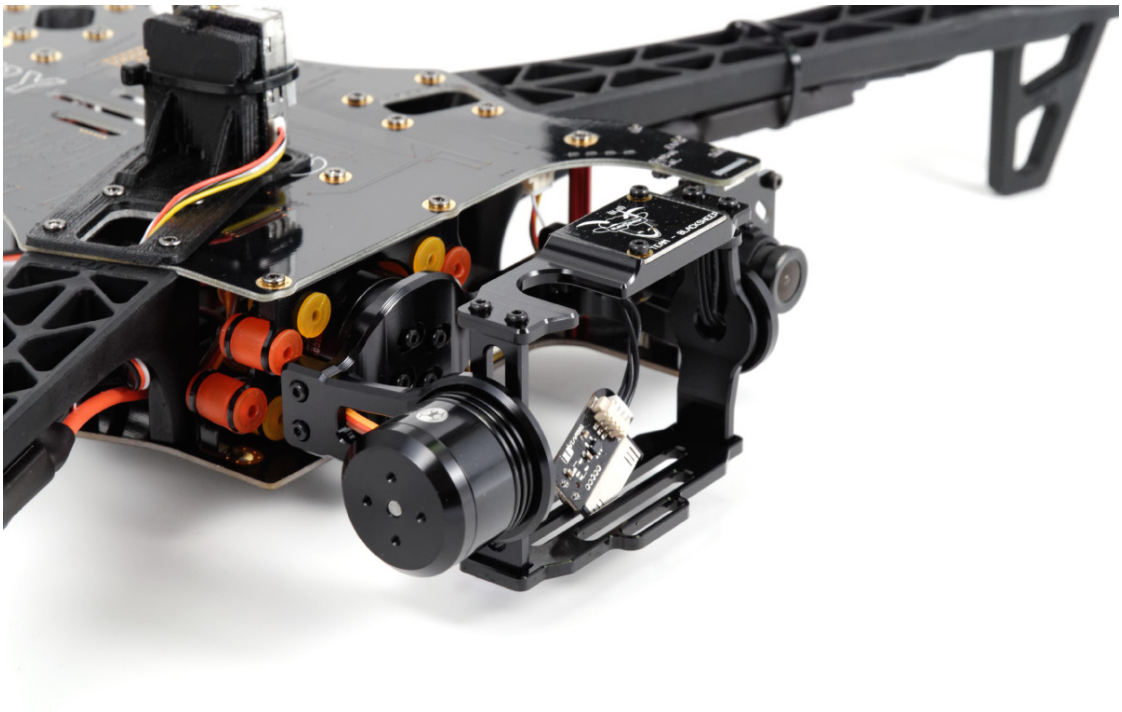


- Adjust the gimbal so that it is parallel and true to the frame. The arms and motors should *not* be tilting at an angle, looking from the side. Use the sliding position holes on the bottom plate to make the final adjustment.
- If the mounting brackets are slipping, add a washer to the screws to keep them in place.

- If the lever arm touches the flight controller when installed, either move the controller slightly or

remove the spacer and two screws (these are not absolutely necessary).

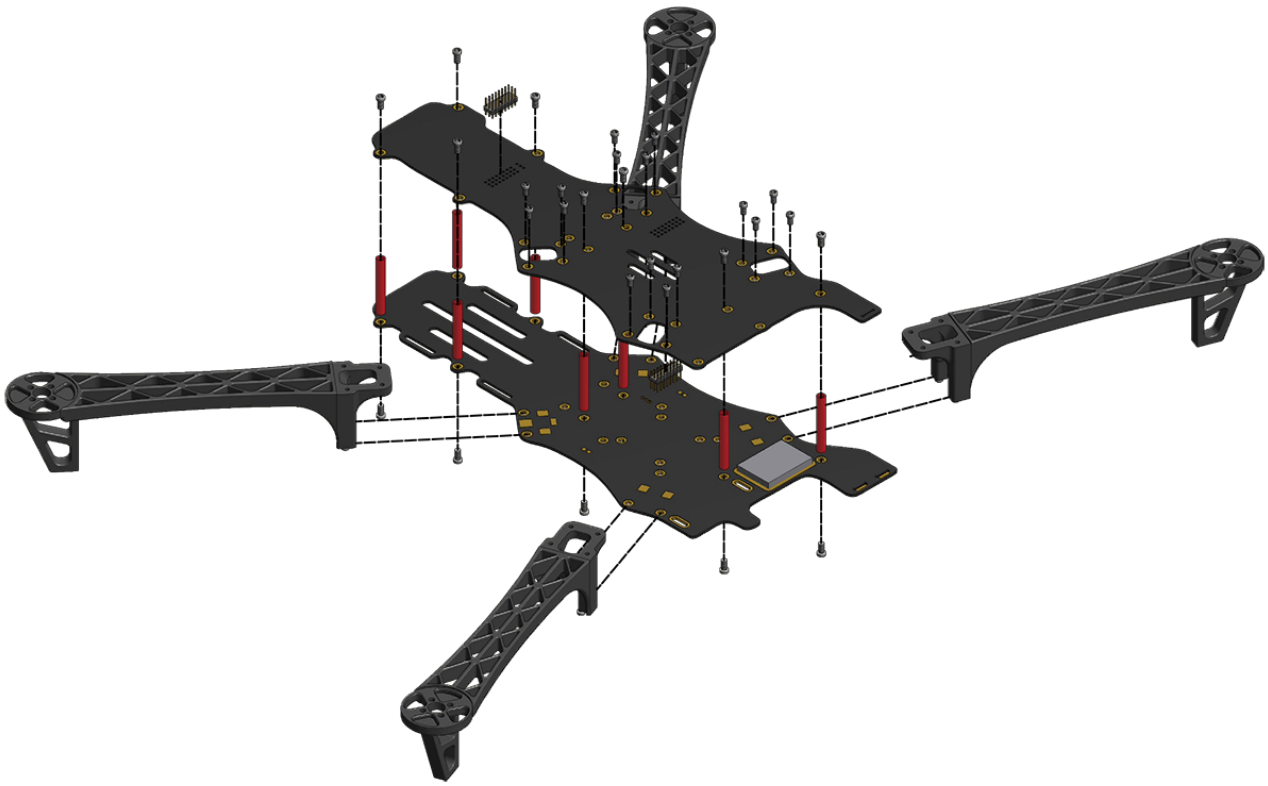
- Finally, feed the GoPro gimbal velcro strap through the slots on the bottom cage mounting plate. Properly strapped down the GoPro before flying to reduce vibrations/jello on the footage. Adjust the balance on both the tilt and roll axis by moving the GoPro back/forth and adjusting the mounting screws on the motor behind the GoPro, respectively. With no power applied, the gimbal should stay perfectly still and not lean in either particular direction.



Important: Avoid rotating the gimbal multiple full turns on the tilt-axis. This puts tension on the IMU cable which in turn introduces counter-forces and interferes with the normal operation of the gimbal.

Frame assembly

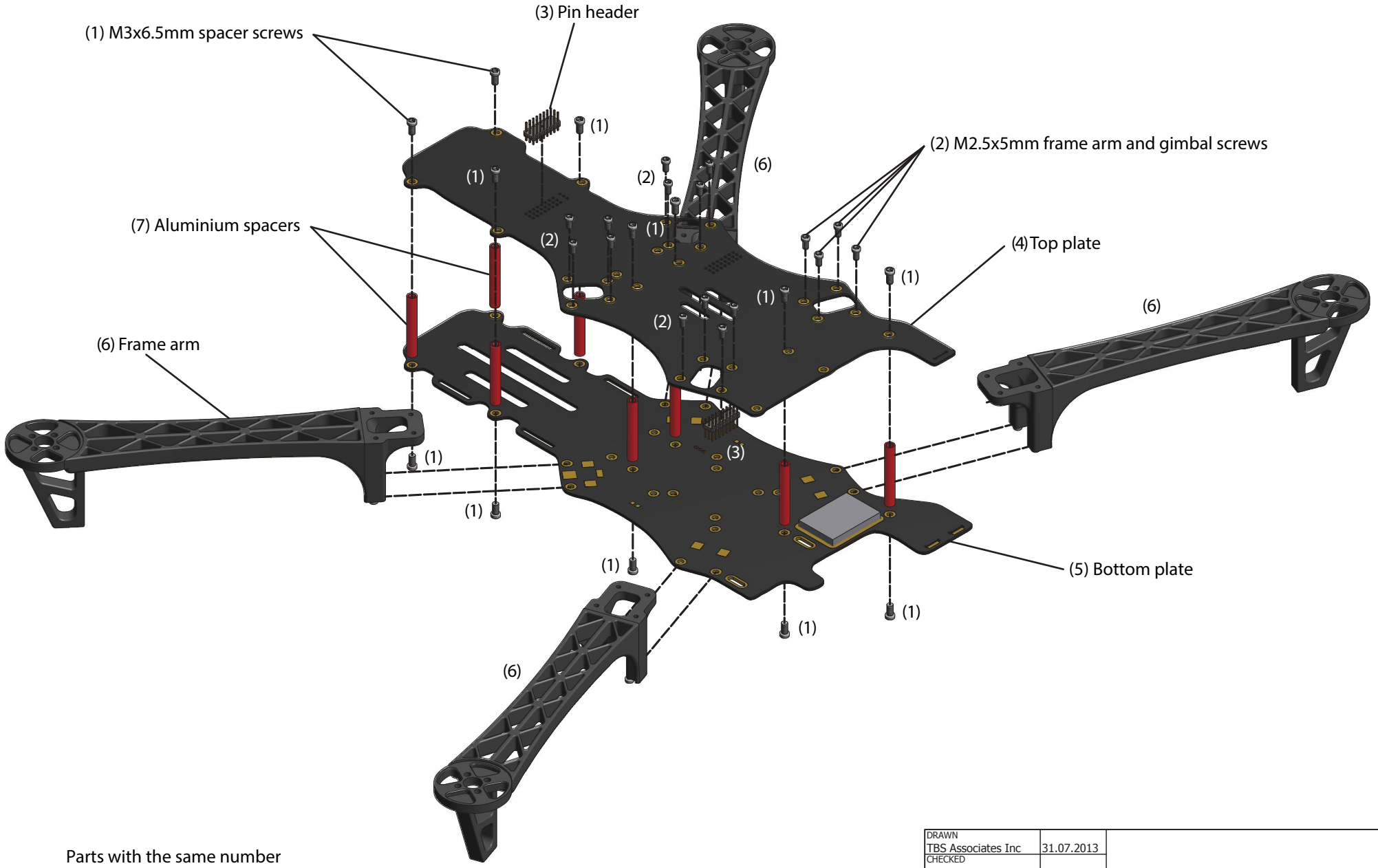
The following sections will show you the essential steps to assembling the base of the frame and connect the electronics to the frame. In addition to the following assembly instructions, we have produced a both a summarized "How To" video and a full length "How to" build video showing the assembly and electronics installation. A full resolution image of the frame assembly is available as an appendix to this manual.



Bottom plate

Power distribution

- Start by pre-tinning (add solder to) the battery pads, speed controller pads, auxiliary power pads (for flight controller power), speed controller power leads and the battery pigtail. If needed, desolder and change the XT60 connector to your preferred connector of choice (e.g. Deans, EC5.)
- Cut the the battery pigtail to 14cm and pre-tin the ends. Solder the wires to the positive (red) and negative (black) pads located on the back-right side on the frame.
- Pick one of the available auxiliary power pads (smaller squares) and solder the flight controller power unit and/or voltage regulator(s) to the frame. We recommend the pads on the middle-left side.



Parts with the same number belong to the same type.

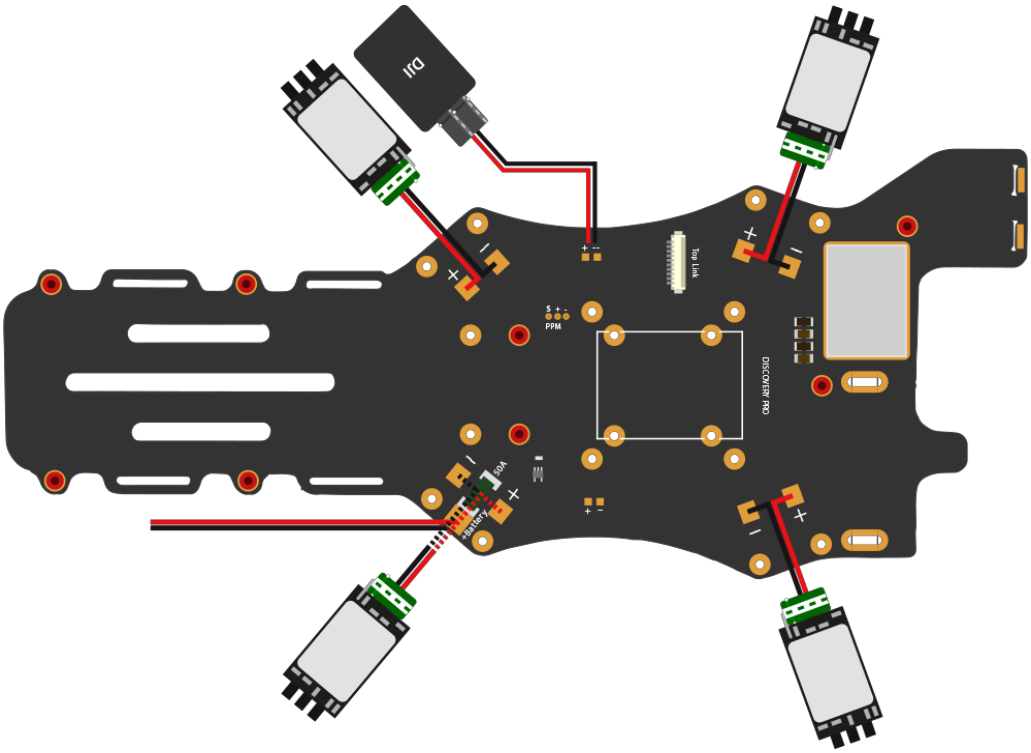
DRAWN	TBS Associates Inc	31.07.2013	
CHECKED			TITLE
QA			
MFG			
APPROVED			
		SIZE A2	DWG NO tbs_disc_pro_frame_assy REV
		SCALE	SHEET 1 OF 1

Spacers

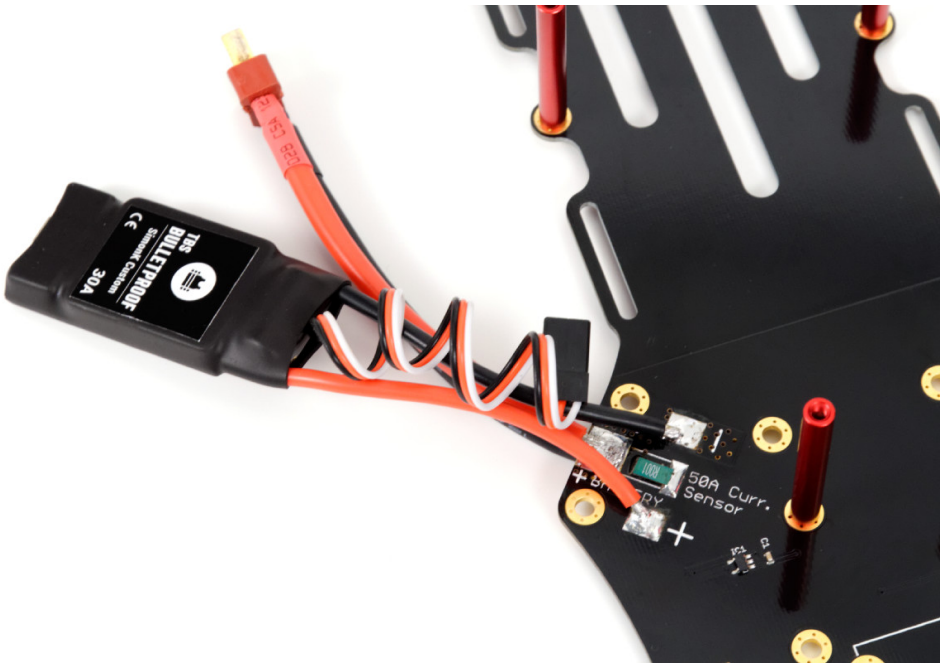
- Next, add the red spacers (posts) to the bottom frame plate using the supplied M3x6.5mm hex screws. Add a small drop of threadlock to help secure the frame. It is recommended to only apply on the bottom screws for easy repairs/maintenance.
- There are three spacer positions in the battery compartment to make it easy to balance (CG) the frame. The rear spacer position is great for 4S 3300-3700mAh packs, while the most forward position is great for larger 4S 4000-4500mAh packs (shown in the image below.)

Speed controllers

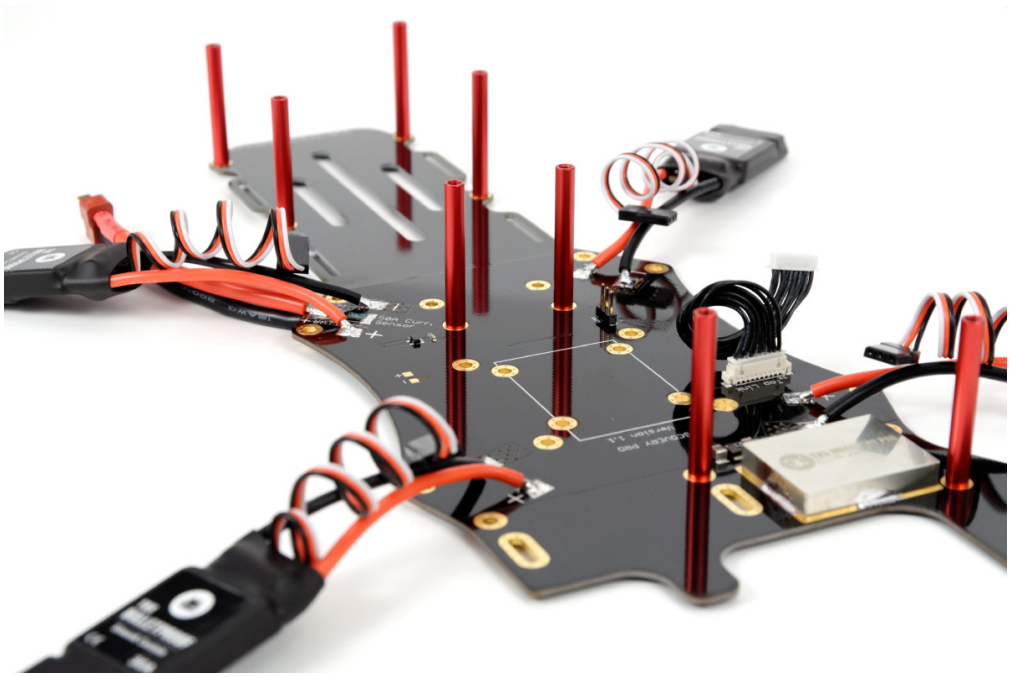
- Position the ESC with the label facing up. Solder the positive and negative leads on the speed controllers to the corresponding square pads on the bottom frame. The pads are located next to the two frame arm screw holes. Heat the solder pad, hold the cable in a slight angle (so both cables will form a “V”), remove the solder iron and keep still until the solder has had time to cool down and settle nicely.



- Calibrate the throttle range for each ESC individually (except for DJI and TBS BULLETPROOF ESCs) by connecting the ESC directly to the throttle channel on the receiver and setting the throttle stick high (Wide Open Throttle - WOT) on power-on and then low until a confirmation beep is heard (motors attached). The ESC has to be connected directly to the R/C receiver for this procedure to work. TBS is offering a handy calibration cable for this purpose. If you are using EzUHF, set WOT as failsafe to avoid start-up timing issues.

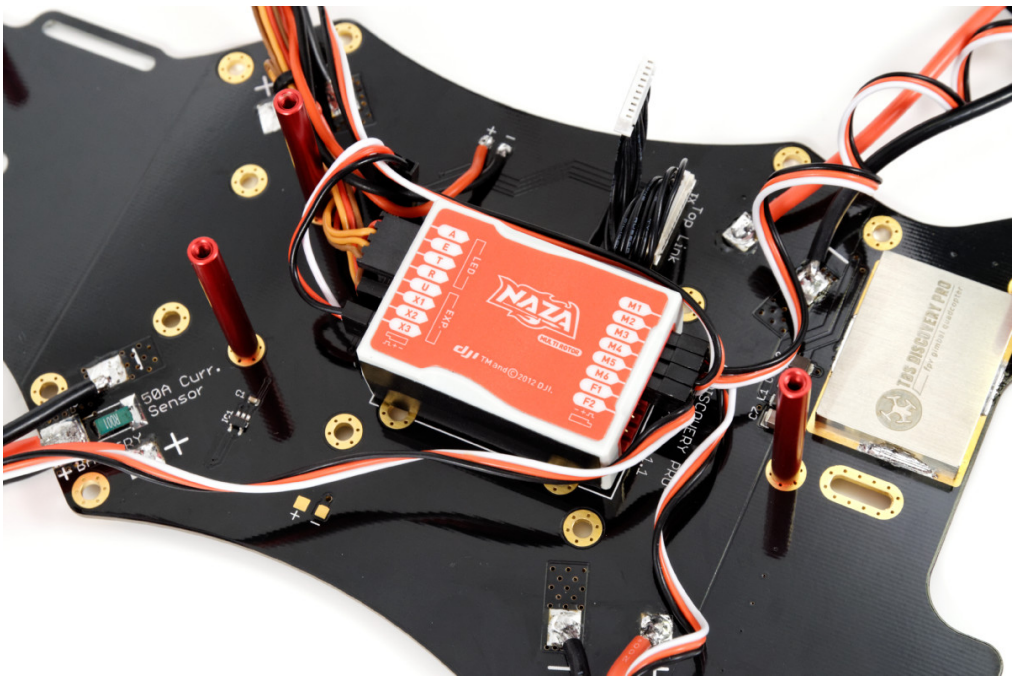


- One important note for ESCs that do not carry the “OPTO” label or are not TBS BULLETPROOF designs, is that only one of the four ESCs should provide 5V BEC power to the flight controller. The middle red wire on the end connector should be disconnected on three of the ESCs. If the flight controller is providing power (e.g. NAZA-M PMU/V-SEN-unit), all ESC BECs should be disconnected. The reason for this is to avoid voltage oscillations caused by erroneous voltage-regulator feedback.

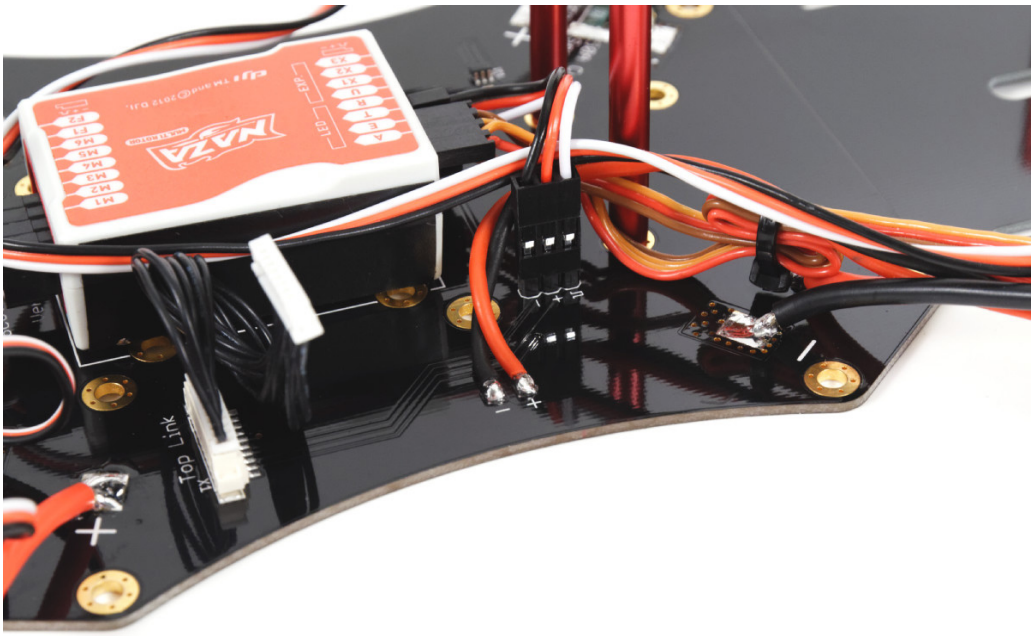


Flight controller

- Decide whether you want to use traditional PWM or PPM/S.BUS control signal mode. The frame is laid out to work with both types of setups. As of writing, TBS suggests the DJI NAZA-M flight controller in PPM/S.BUS mode (together with a compatible receiver) and an optional GPS add-on (for return-to-home capability) for a clean wiring layout and great out-of-the-box experience.



- Plug in all the R/C and ESC servo-cables to the flight controller according to the flight controller instructions. Mount the unit on the bottom plate in the centre of the white rectangle. Use a self-adhesive foam pad (normally included) to mount the controller. Be sure to double check the orientation of the flight controller for proper operation.
- When using PPM/S.BUS, there is a handy easy-to-reach PPM header output located on the bottom frame. Also be sure the radio and receiver is properly mapping the channels in the PPM stream.
- For setup and tuning parameters of the flight controller, refer to the manufacturer manual or guides on fpvlab.com. See the table below for initial TBS recommended NAZA-M gains.
- (DJI NAZA only) Open NAZA Assistant and disable the “Voltage Monitor Protection”. This prevents the DISCOVERY PRO from prematurely descending on low battery. Use the CORE OSD to watch the battery condition instead. Never let the voltage go past 3.5V x cell count (i.e. 3S 10.5V, 4S 14.0V) or deplete the battery past 20% (e.g. max. 3600mA discharged on a 4500mAh battery pack.)



- (DJI NAZA only) To save weight and space, the PMU (V2) can be disconnected and removed after the final configuration has been made. Although, 5V power still has to be provided from at least one of the ESCs.

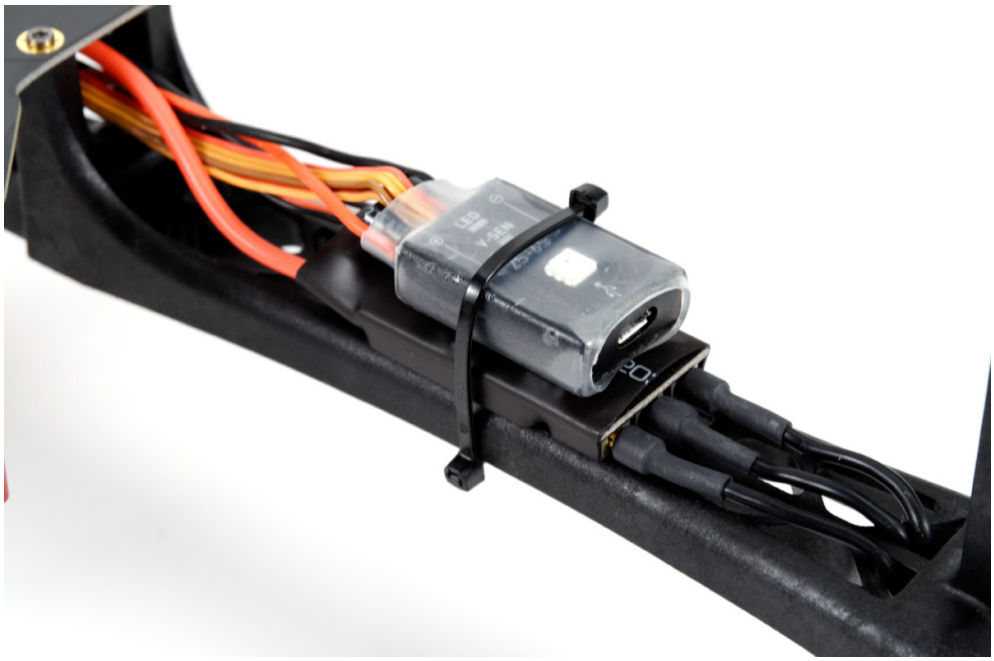
Start out using the following suggested gains for NAZA-M Autopilot and *tune accordingly*.

Setup	Gain	Pitch	Roll	Yaw	Vertical
TBS 900kV2 9x5 4S4500mAh 30A	Basic/manual	135%	129%	133%	176%
NAZA-M Lite	Attitude	130%	130%		
TBS 900kV2 9x5 4S4500mAh 30A	Basic/manual	130%	100%	120%	120%
NAZA-M V2	Attitude	150%	150%		
Other drivetrains (general starting point)	Basic/manual	130%	120%	110%	130%
NAZA-M V1/V2/Lite	Attitude	130%	130%		

Note: The pitch axis gain will in most cases be greater than the roll axis gain because of the inherent asymmetric design and weight distribution on the frame.

Frame arms

- Install the frame arms on the four designated locations using the long-neck M2.5x5mm screws. Feed the speed controller wires through the gap between the frame arm and bottom plate.
- With the speed controllers soldered (completed previously) and frame arms mounted, use the zip-ties to mount the speed controllers to the underside of the arms. Avoid putting tension or stress on the motor- or speed controller-cables. Use a self-adhesive pad to mount any BEC or control unit (e.g. NAZA PMU/LED/V-SEN-unit.) to the underside of the back-left speed controller.

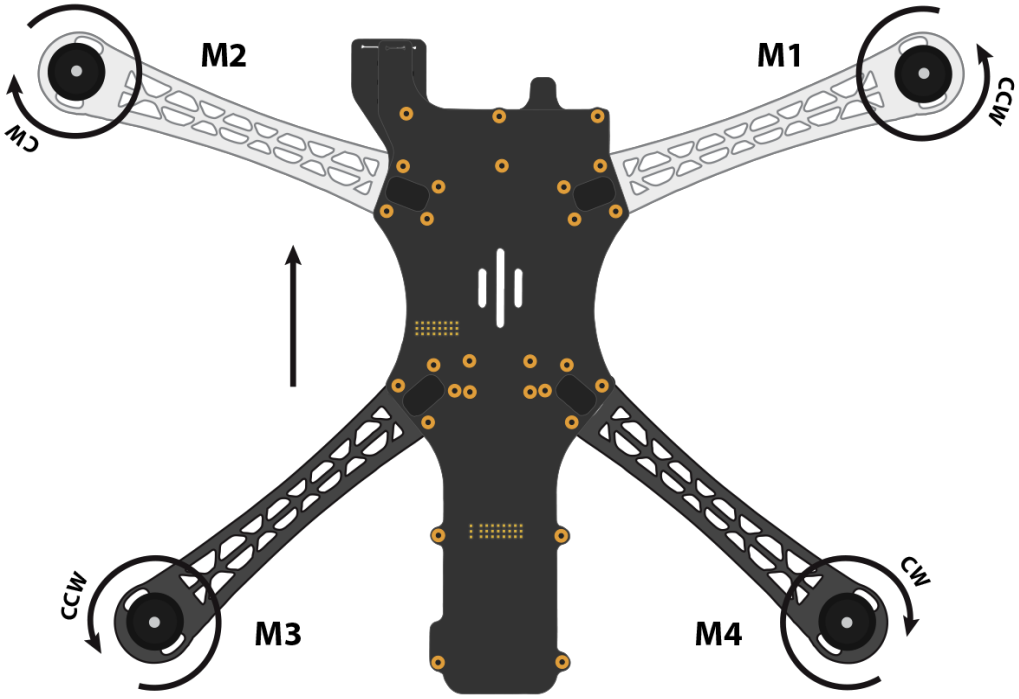


- Feed the battery straps through the two slots in the battery compartment. Only one strap is really necessary to provide adequate friction to keep the battery fastened.

Optional: Use different colored frame arms for the front and back pair to make it easier to identify the orientation of the quadcopter in the air.

Motors

- Mount the brushless motors to the frame arms using the supplied M3x6.5mm hex screws. There is no need to add an X-mount to the motors. Apply a small drop of medium threadlock to a secure the base. Feed the motor wires through the frame arm comb-pattern to minimize clutter.

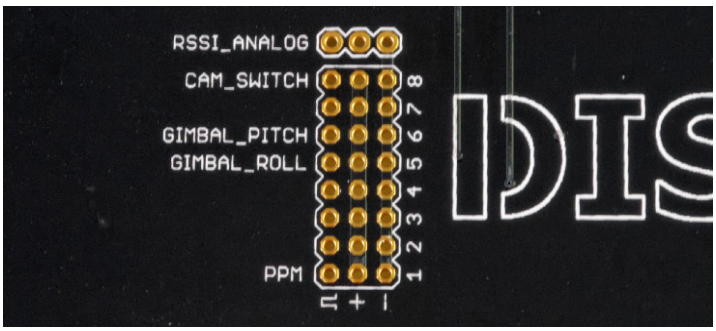


- Plug in the bullet-connectors to the speed controllers. Swap any two wires to change the direction of rotation if they do not rotate as shown below. See the image above for the most commonly used motor setup (e.g. NAZA-M.)

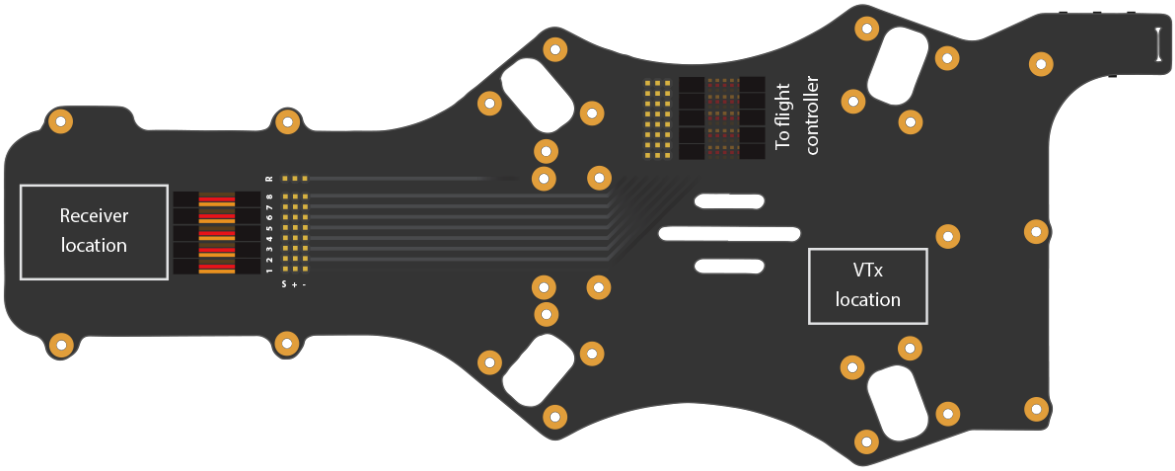
Top plate

R/C control signal headers

- To get a clean R/C receiver-to-flight controller wiring, it is recommended to use the header on the top plate. There are 8 traces to support up to equally many PWM (Pulse Width Modulation) channels. When using a PPM (Pulse Position Modulation) compatible receiver and flight controller, only one trace (Channel 1) is used.



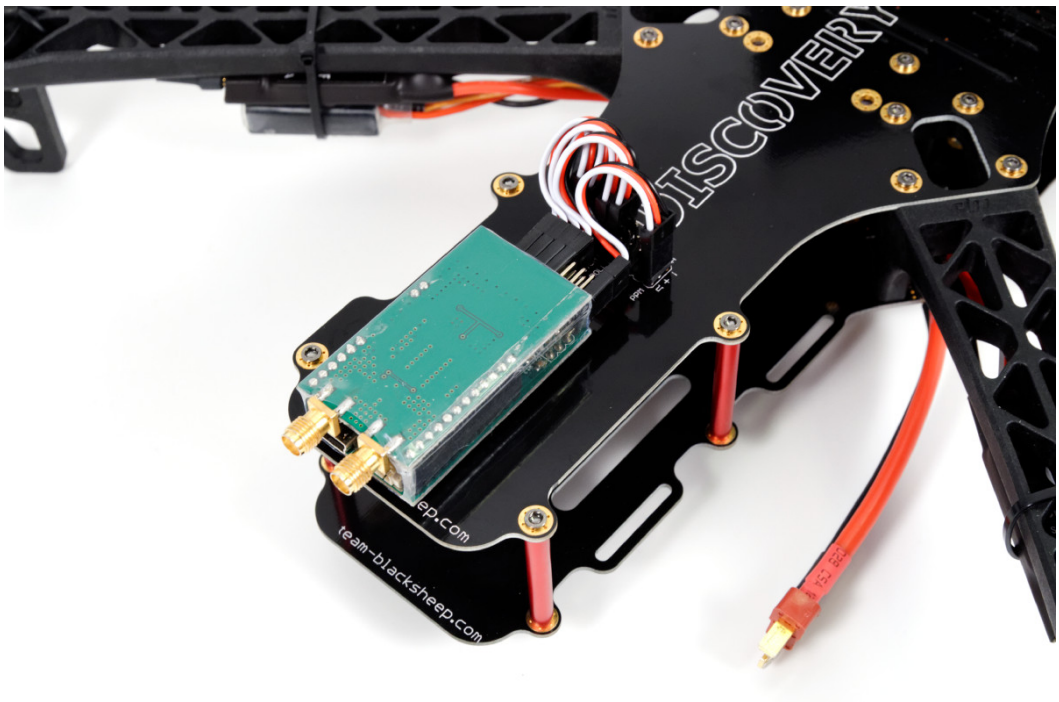
- Solder the supplied pin header to the 8x3-pads and the single 1x3-header to the separate RSSI pad. Install the first header on the R/C receiver side (back-end) with the pins pointing up and, if you are using PWM control signals, solder the second header with the pins pointing down (towards the bottom plate/flight controller.) Use tape to keep the header in place while applying a reasonable amount of solder to all of the pins while applying heat. The flux in the solder will make the solder flow around the pins.
- The layout of the header is as follows:
    - **channel 1** for PPM stream or **channel 1 to 4** for PWM aileron/elevator/throttle/yaw control
    - **channel 5** for PWM gimbal horizontal roll control (rarely needing adjustments)
    - **channel 6** for PWM gimbal tilt pitch control
    - **channel 7** for PWM flight mode selection (i.e. attitude, manual, GPS assisted)
    - **channel 8** for PWM camera switch (i.e. fpv camera or GoPro feed)
    - a dedicated **RSSI_ANALOG** header for CORE OSD signal strength read-out



- The channels with a text label, i.e. PPM, GIMBAL_ROLL, GIMBAL_PITCH, CAM_SWITCH and RSSI_ANALOG, has the signal pin (⎍) hardwired directly to their respective electronics section on the top frame (i.e. flight controller PPM break-out, gimbal controller roll/tilt, camera switcher, and CORE RSSI signal). No further wiring is needed to enable those systems.
- Either gimbal channels and/or camera switch channel can be omitted if desired to free up channels (e.g. to use a 6/7 channel PWM receiver.) But you will of course lose direct control over those systems.
- See the “FPV gear and gimbal” in the electronics installation section for further details.

R/C receiver

- Plug in the short servo extensions on the header on the top plate and connect them to the R/C receiver. Use a self-adhesive foam pad to mount the unit to the back-end of the top plate. Mount the antenna(s) in a vertical and/or “V”-formation using nylon antenna tube(s).



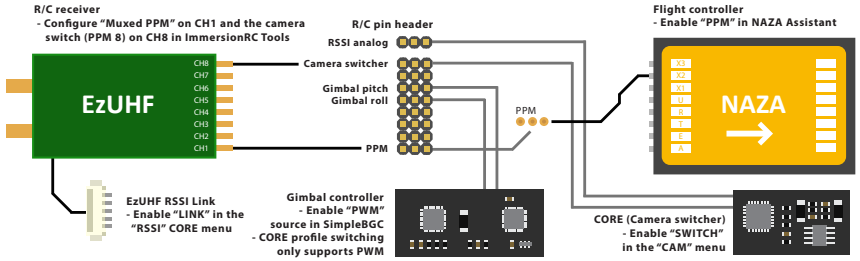
- Channel 5, 6 and 8 pin headers can be used for other purposes (e.g., NAZA X1, X2) by disabling the gimbal R/C mapping via SimpleBGC and/or camera switcher via CORE Menu.

R/C receiver	Ch. 1	Ch. 2	Ch. 3	Ch. 4	Ch. 5	Ch. 6	Ch. 7	Ch. 8
Fligth controller	Aileron/PPM	Elevator	Throttle	Rudder	Gimbal Roll	Gimbal Pitch	Flight mode	Camera switch

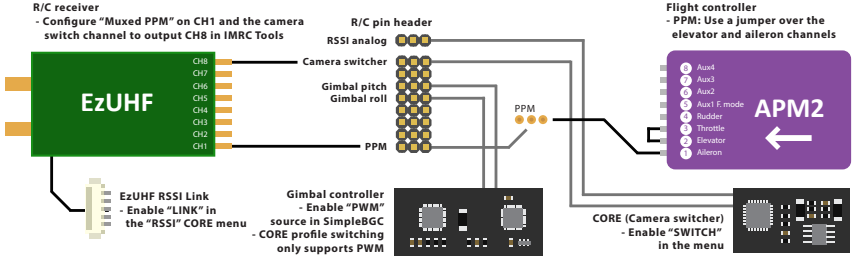
- When using the RSSI (Received Signal Strength Indication) signal from a compatible R/C receiver, use the header labeled RSSI_ANALOG to supply the signal directly to the CORE. Or, leave the header unused and connect the output to your OSD system of choice.

TBS DISCOVERY PRO - Common receiver and flight controller setups

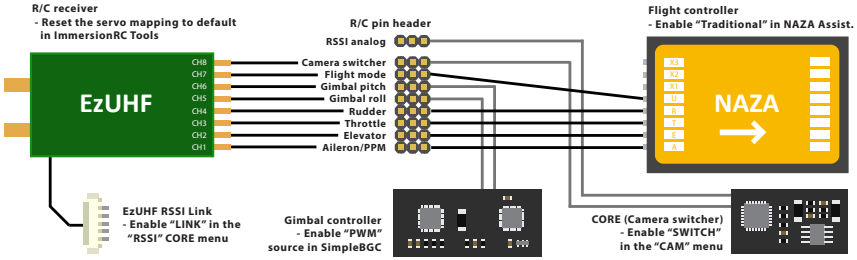
EzUHF - NAZA - PPM - RSSI Link



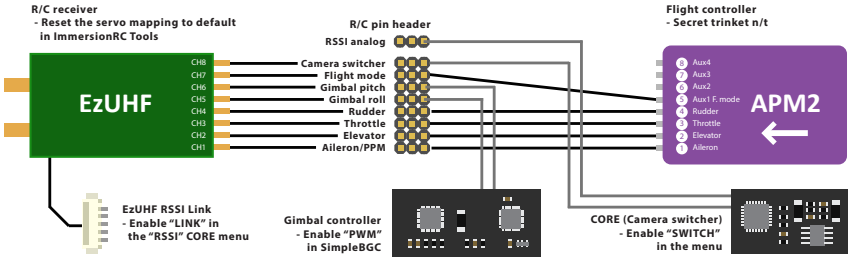
EzUHF - APM2 - PPM - RSSI Link



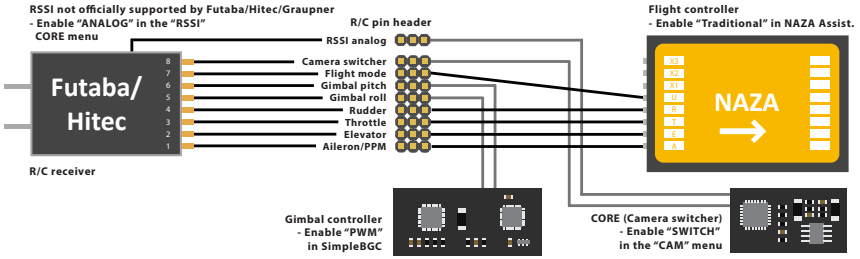
EzUHF - NAZA - PWM - RSSI Link



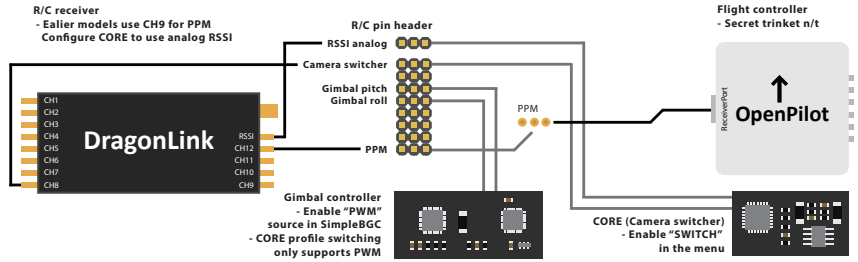
EzUHF - APM2 - PWM - RSSI Link



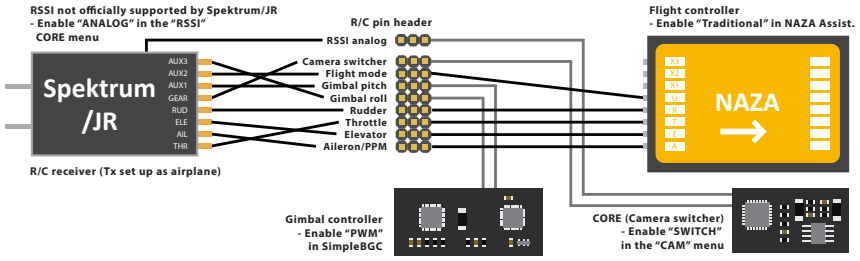
Futaba/Hitec - NAZA - PWM - Analog RSSI



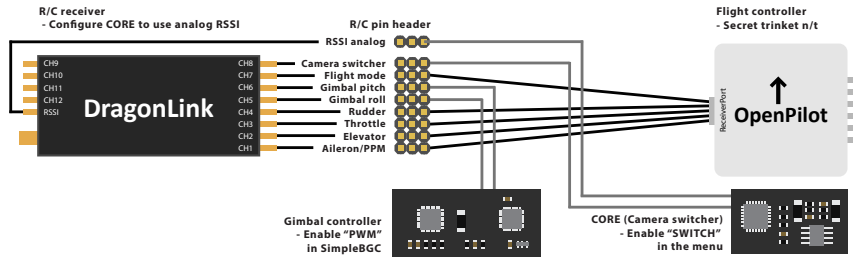
DragonLink - OpenPilot - PPM - Analog RSSI



Spektrum/JR - NAZA - PWM - Analog RSSI



DragonLink - OpenPilot - PWM - Analog RSSI



- (EzUHF Rx 8ch only) The CORE can decode the digital RSSI signal from the receiver via the separate "OSD Link" port and display RSSI on each of the two antennas and overall signal quality (including packet loss) of the R/C uplink. A 5-pin Molex cable is included which plugs into the EZUHF_RSSI_LINK connector on the top plate. For this feature to work the CORE's RSSI setting needs to be set to "LINK". There is no need to calibrate the RSSI in this scenario.

Propellers

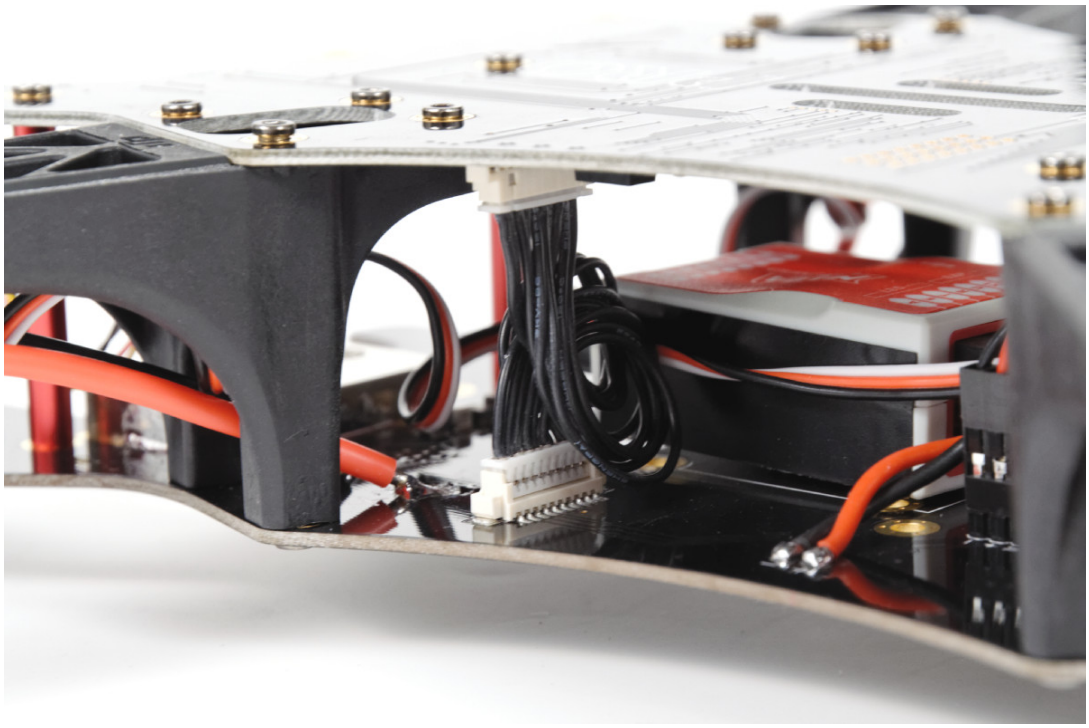
- Before adding the propellers it is a good idea to be sure they are balanced, as mentioned later on. To avert any chance of injury, **leave the propellers off** until the flight controller configuration has been completed.
- The only recommended propeller installation method is to use a precisely manufacturer prop adaptors (never prop-saver with o-ring.) The layering should be as follows; *prop adaptor*, *optional reduction ring, propeller*, *washer* and (*lock) nut*. You can skip any bell screw as it may add unnecessary vibrations.

- The TBS 900kV motors have a 5mm prop shaft. This is compatible with Graupner 9x5-inch propellers. For Graupner 10x5-inch propellers you will need aluminium 8mm-to-5mm reduction spacers available separately.
- Try to match the motor and propeller to suit your particular need. For extended flight time try to achieve optimal efficiency. For agile-flight look at a responsive combination. Our general recommendations are listed in the table below.
- A thumb of rule would be that smaller props equals less flight time, and higher kV motors equals smaller props or lower battery cells count (than the reference below.) Note that 10-inch is the maximum propeller size that can fit on the DISCOVERY PRO.

Motor type	Propeller	Flight characteristic
TBS 900kV brushless motor	9x5-inch Graupner type	responsive, locked in
	10x5-inch Graupner type	long flight time

Bottom link

- Attach the the 9-pin plate-to-plate bottom link cable to the designated connector on the bottom plate. It carries carries current sensor signal, Vbatt, ground, +V5, +V12 up and PPM down. When closing the frame, plug in the cable to the corresponding connector on the top plate.

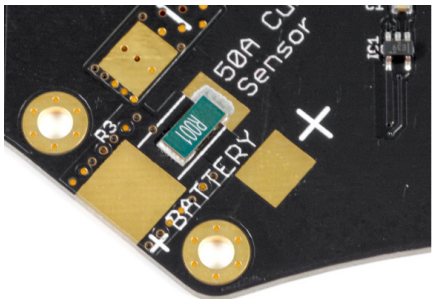


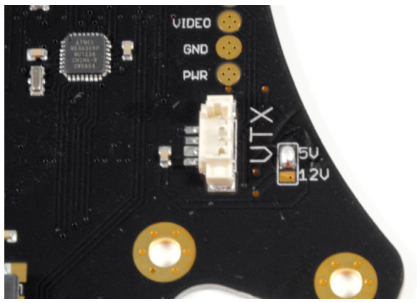
FPV and gimbal gear

The FPV gear is designed to be installed on the front section of the frame to achieve as much separation between the R/C- and FPV-radio environment as possible. Keep in mind that the former is listening while the latter is broadcasting. The quieter the receiving conditions are, the better range and system reliability will be.

CORE power supply

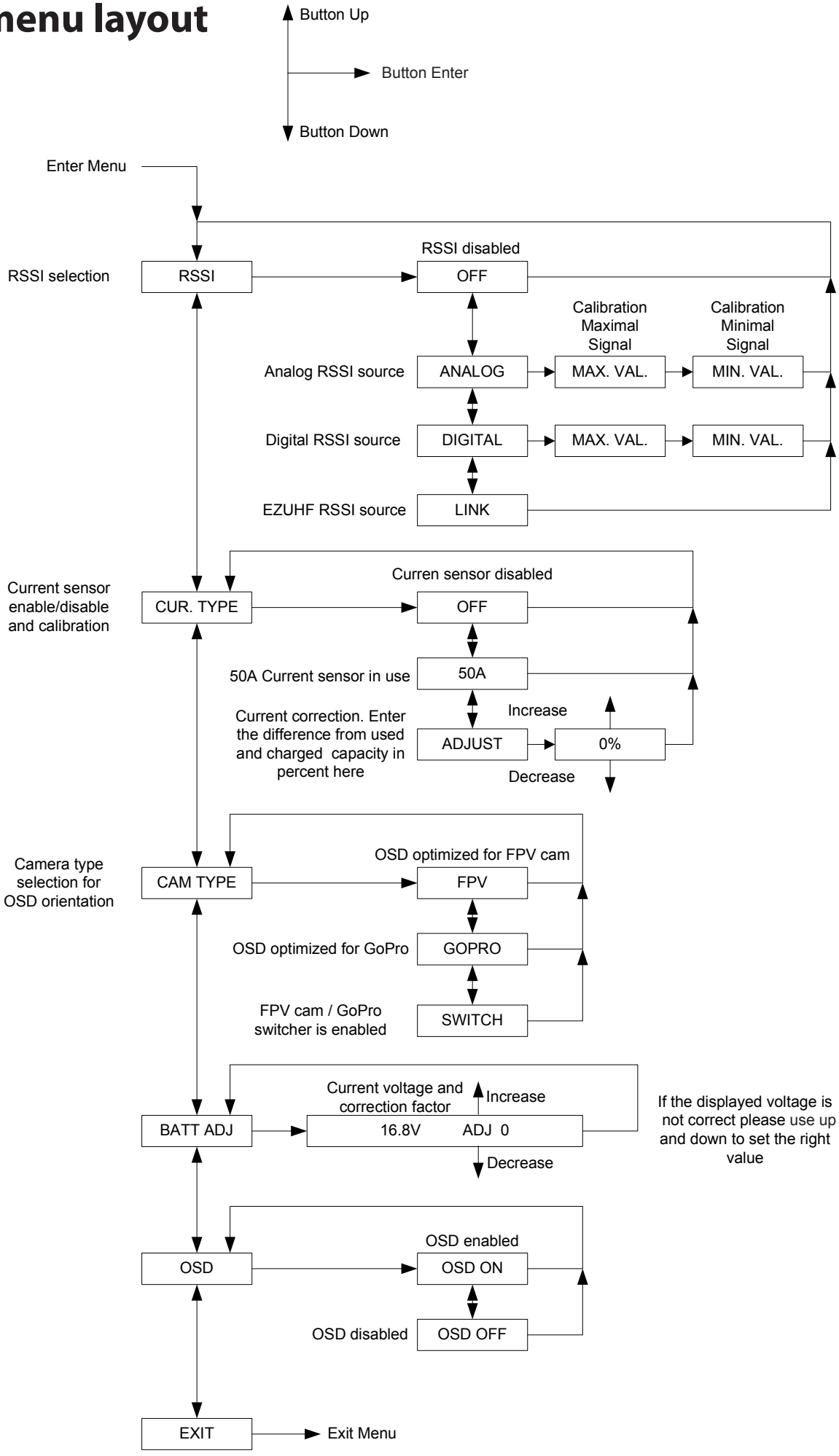
- To eliminate noise from causing problems on the FPV-side of the system, a properly filtered TBS CORE is integrated right into the frame. It is made to provide selectable 12V (0.65A max.) or 5V (2A max.) to the video transmitter and FPV camera via on-board solder pads. The CORE and R/C power rails are completely separated and is by design not dependent on either system in order to function properly. Interference and noise from the driver train is isolated nicely from the rest of the electronics on the frame.





- Configure the required voltage for your FPV gear by soldering a dab to the pads labeled VTX and CAM on the top plate (as shown in the pictures above.) The frame already comes pre-configured for 5V video transmitters and 12V FPV cameras. Adjust the output voltage by soldering the middle pad and either side pad for 12V or 5V. Do not solder all three pads (short-circuit.)
- When you first power up the CORE, it will ask you to cycle through the buttons “DWN”, “ENTR” and “UP” accordingly to verify that they work properly. This is also a good time to get familiar with the CORE menu layout.

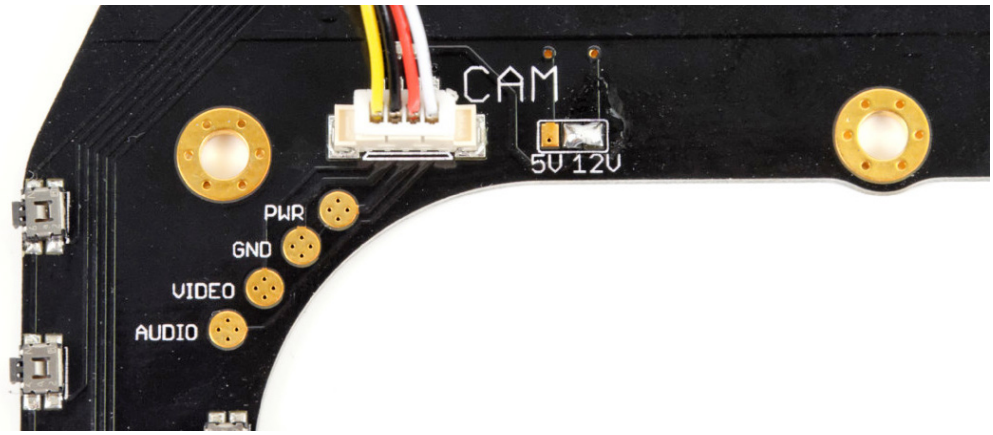
CORE menu layout



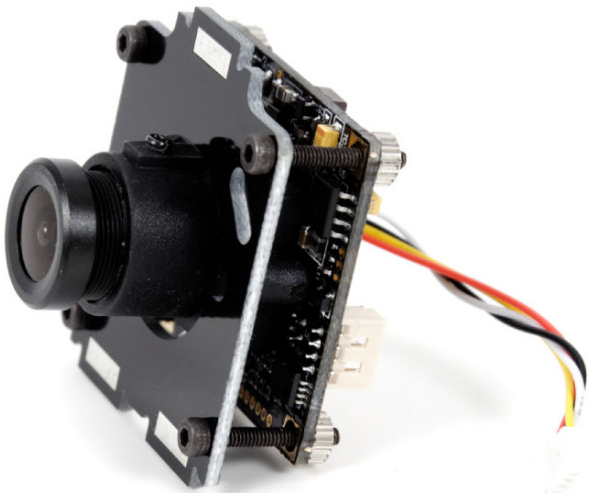
- The solder pads next to the sockets can be used to connect your gear, but try to connect your FPV camera and video transmitter via the Molex connectors on the board. With that, you will not risk ripping off the pads from the frame when pulling too heavy on a cable. Modify our cable harness when using other than TBS suggested gear.
- A pre-installed tin shield makes the DC-to-DC switching voltage conversion part of the CORE isolated from the rest of the electronics on frame.
- A full menu layout of the CORE menu system is available as an appendix to this manual.

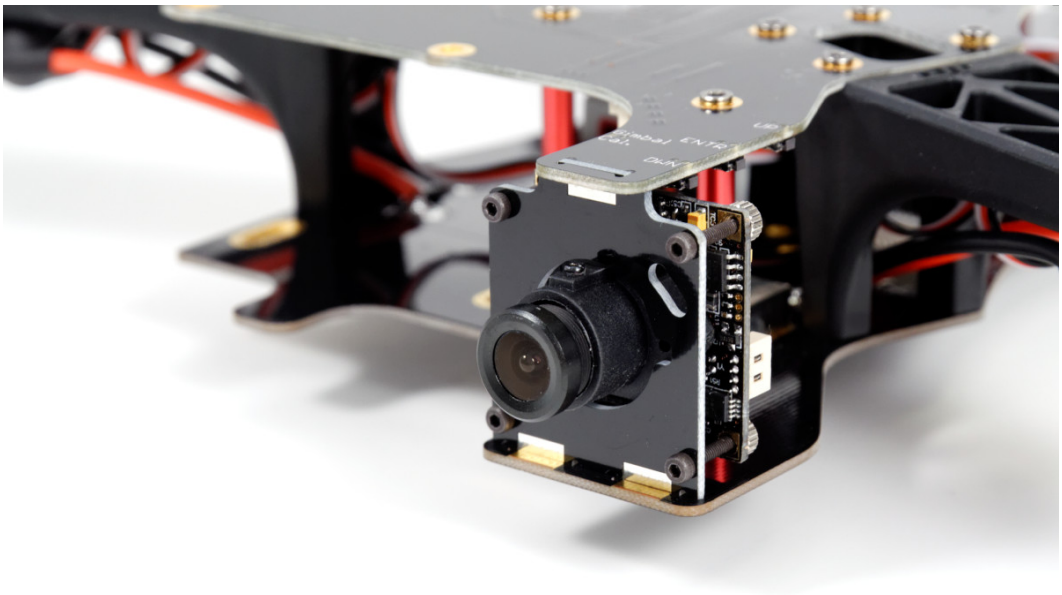
Pilot camera

- Use the supplied camera plate to mount the pilot camera. The mounting pattern is designed to be compatible with most standard 32x32 mm board cameras. You might need to break-away excessive board support. Either use two small zip-ties, rubber bands or four M2x15mm screws and nuts (not supplied) to mount the camera (use threadlock.)

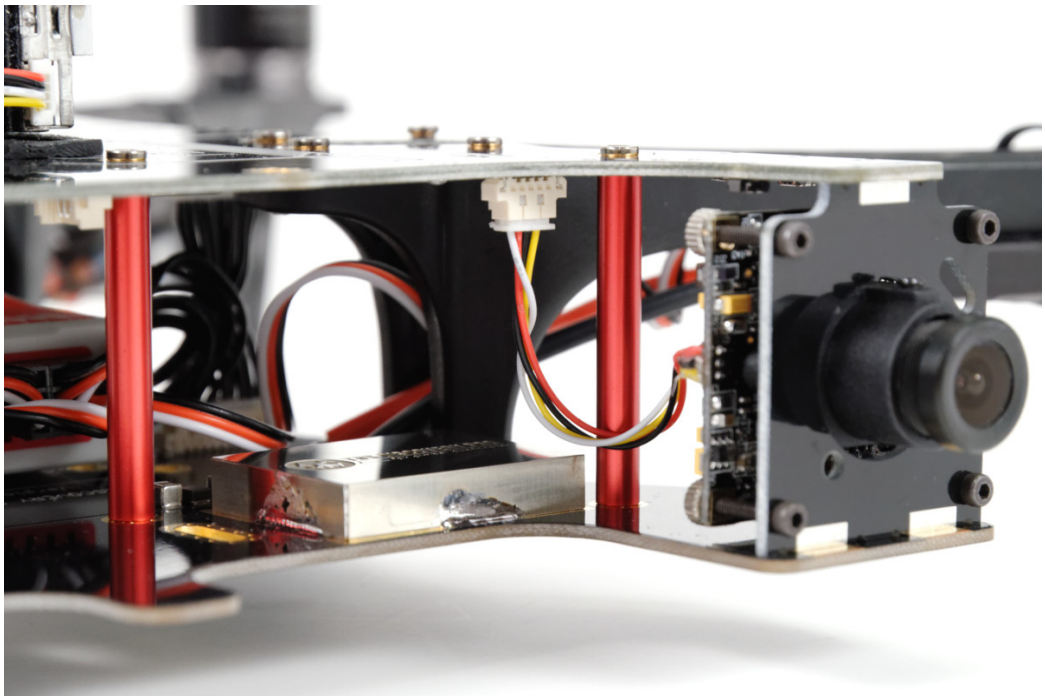


- Plug in the cable connector for the camera and insert the tabs on the top and bottom of the camera frame in the corresponding routed gaps on the frame. For a secure mount, you can add solder to the three exposed solder spots, or leave it for easy hot swapping in the field.



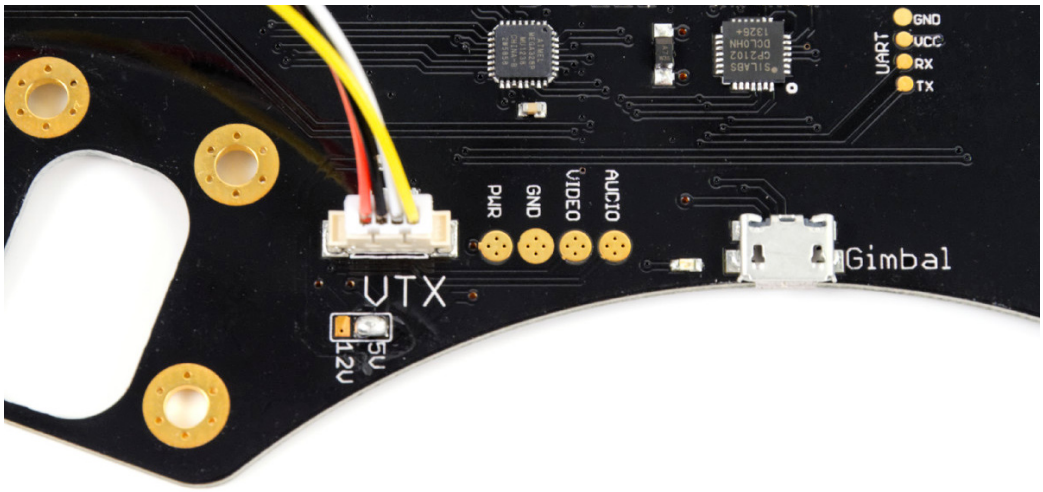


- Decide whether you can use the supplied wires and connector socket on the top frame or connect the camera and video transmitter via the round solder pads. The supplied picoblade Molex cable “5V VTx” are designed to work with the TBS GREENHORN, TBS ROOKIE, Lawmate video transmitters, and the supplied “12V CAM” cable with the TBS59/TBS69 cameras respectively. You can of course modify and solder the wires to suit your specific need. The connector wire color and signal arrangement is shown in the picture previously, where yellow is video, white is audio, red is power and black is ground.

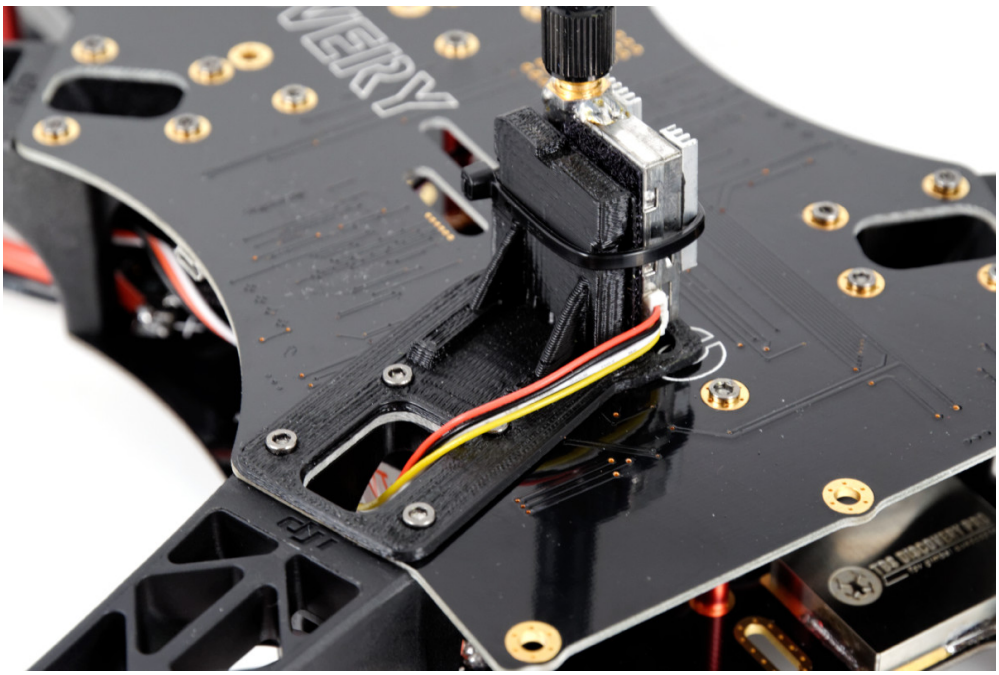


Video transmitter

- Put the video transmitter close to the front on the top plate. Use zip-ties and/or self-adhesive foam pads to fit the transmitter. TBS offers a custom made mounting bracket for easy vertical install over the front-right frame arm. To avoid possible video interference, be sure to use a foam or gel pad between the frame and VTx unit to reduce exposure to vibration.



- The kit includes a small JST cable which is compatible with Lawmate 500mW VTx as well as our TBS GREENHORN and TBS ROOKIE. For FatShark VTx you need to cut the cable and solder your FatShark cable onto it. The connector wire color and signal arrangement is shown in the picture above.

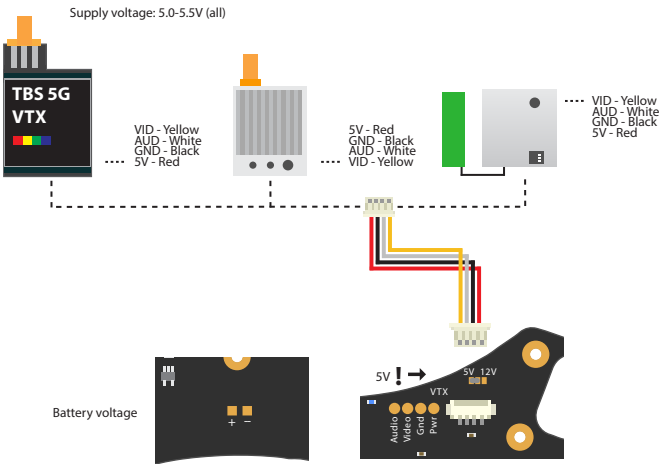


- Powerful video transmitters, such as the ImmersionRC 5.8GHz 600mW or more powerful VTx, must be powered directly from the bottom frame (small +/- pads) to avoid overdriving the CORE. Test this a few minutes on the ground and verify that the CORE does not reboot which indicates a thermal protection shutdown/overcurrent.

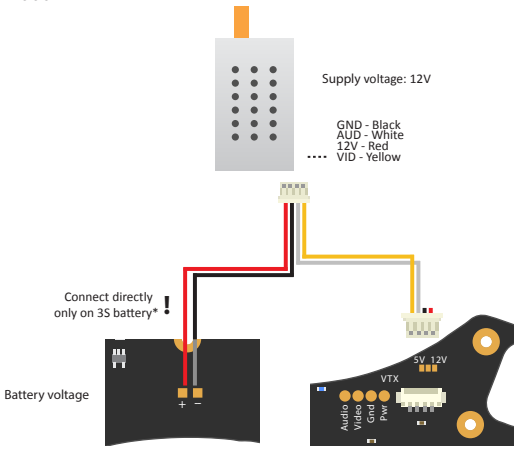
TBS DISCOVERY / DISCOVERY PRO - Video transmitter (VTx) setups

TBS/Lawmate VTx

- 1.2G 500mW
- 2.4G 100mW, 200mW, 500mW
- 5.8G 25mW (TBS Greenhorn), 200mW (TBS Rookie), 500mW (TBS Boss)

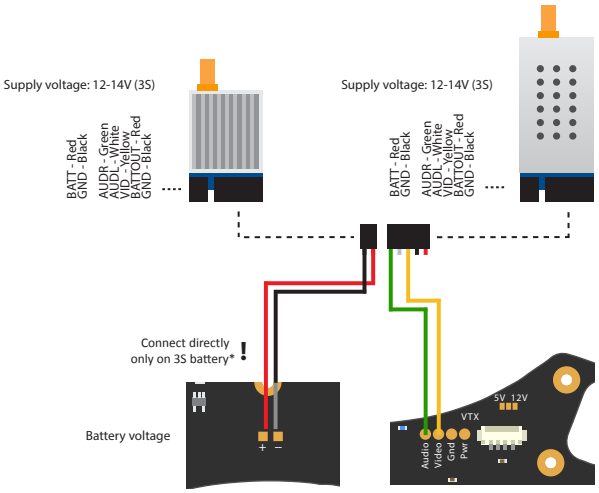


- 1.2G 1000mW
- 2.4G 1000mW



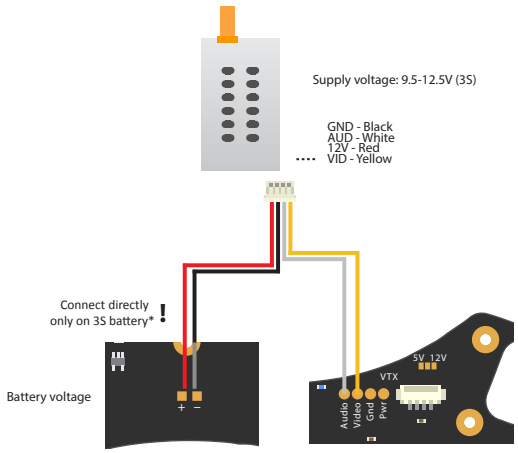
Boscam VTx

- 2.4G 500mW
- 5.8G 200mW, 400mW, 500mW



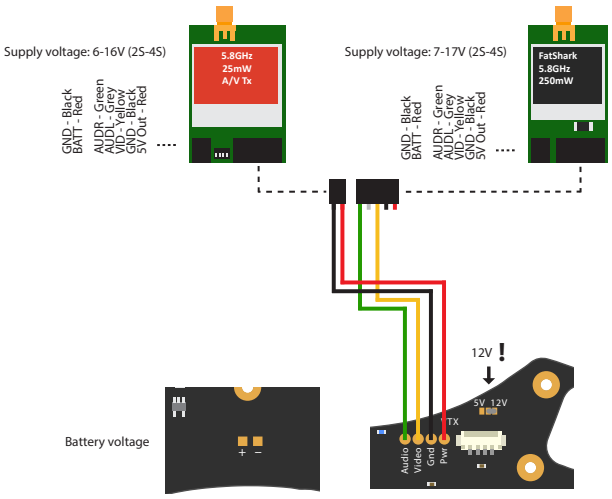
Racewood VTx

- 1.3G 500mW

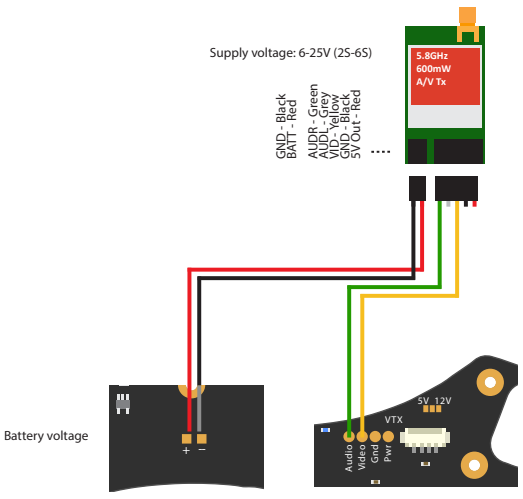


FatShark/ImmersionRC VTx

- 5.8G 25mW, 250mW

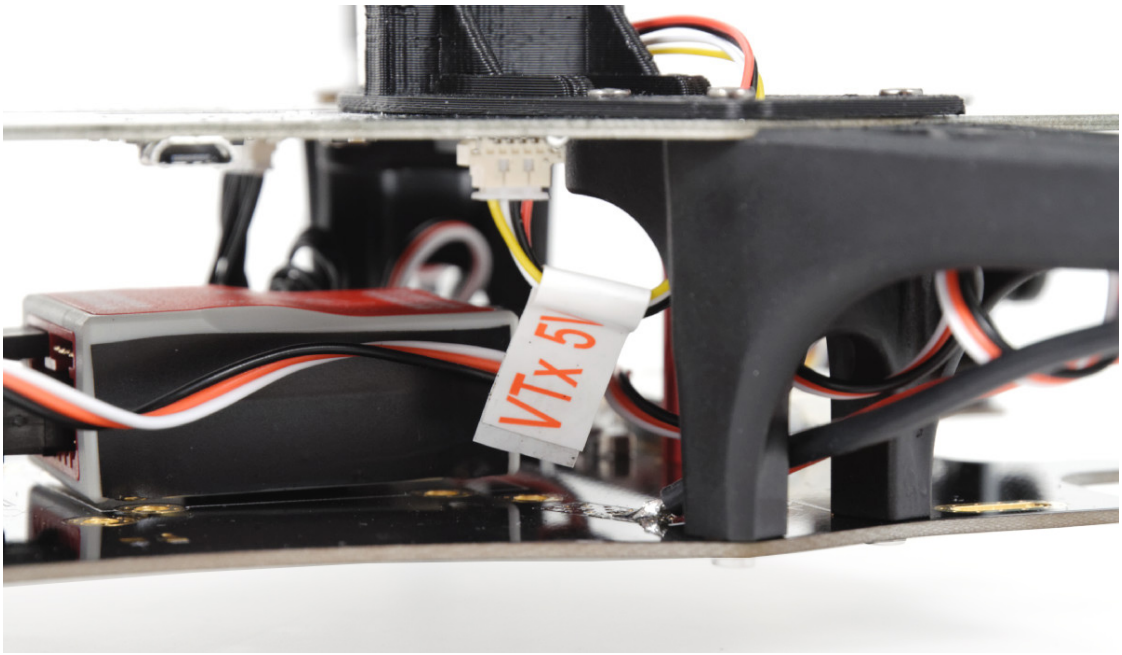


- 5.8G 600mW



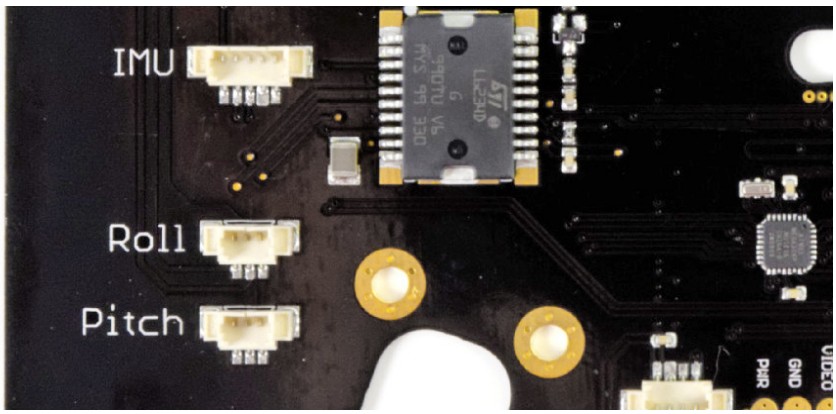
Note: Connecting a video transmitter directly to a shared battery source may induce interference on the video image. Consider adding a filter between the solder pad and video transmitter.

* On 4S+ setups where 12V is not available, consider using a dedicated TBS CORE PNP to supply power to the video transmitter.



Brushless gimbal controller

- Plug in the 3 Molex cables for the pitch- and roll-motors, as well as the IMU board, into the connectors labeled “PITCH”, “ROLL”, and “IMU” located near the front on the top plate.



- The controller comes pre-configured with PID gains which are fine-tuned for use with a GoPro HD Hero3 and no additional accessories (lens protection or housing.) Tuning may be necessary (PID, power) when using an older GoPro model or different add-ons. Also make sure to balance both axis by moving the GoPro back or forth until it stays still independent of how you rotate/leave it.
- Additional configuration can be done using the SimpleBGC software package via the micro USB connector on the right-side of the top frame. The CORE uses dual profile switching (described later in the manual) which means that all essential flight tuning should be done in both profiles.
- The gimbal controller has two dedicated channels (RC_PITCH, RC_ROLL) brought out on the top plate R/C header (channel 5 and 6) which can be used to position the GoPro image. This means that you can assign a knob or slider on the radio to control pitch and roll of the gimbal.

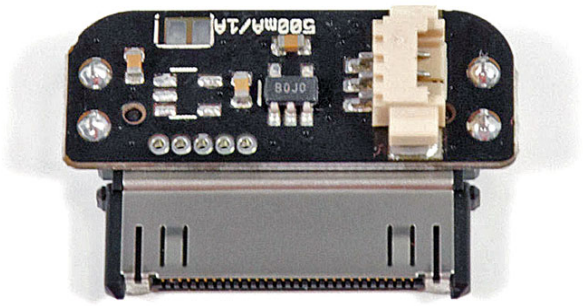
- If the camera gimbal **is not level at start-up**, move the gimbal and quad to a perfectly level position (use a bubble leveler) and press the “GIMBAL CAL.” button on the top plate for 3-5 seconds until the gimbal motors release. Wait for the blue LED to stop blinking and motors to lock again. Ensure that the gimbal is perfectly still and straight during this calibration process.
- If the gimbal still drifts, recalibrate the sensors by turning any UHF or video transmitters, plugging in power, connecting the frame to SimpleBGC, then propping up the gimbal so it stays level and still. Then click “CALIB. ACC”, wait for it to finish, click “WRITE”, and then click “CALIB. GYRO” and “WRITE”.
- To further fine-tune the accelerometer, perform the 4 position calibration by setting both POWER to 0 and clicking “CALIB. ACC” after each time you position the gimbal *face forward*, *face down*, *face up* and *face backwards*. And only at the very end re-enable the POWER settings and commit the calibration data by clicking “WRITE”. See the SimpleBGC manual for further details.
- Gyro calibration is very sensitive. If you are in a skyscraper, considering going to the ground floor for this calibration. Do not use unstable surfaces, such as lightweight tables or wooden floors for calibration. You only need to do this once in a while or when moving to an entirely new geographical location. The calibration directly influences how well the gimbal performs.
- The gimbal controller is PPM compatible (no S.BUS support) and the channel 1 trace on the top plate is integrated directly to the controller chip. To enable PPM gimbal, you need to close the solder pads labeled “PPM GIMBAL” on the top plate, enable “PPM-Sum” and assign the right channels via the SimpleBCG software. Remember to remove any servo-cables between the receiver and the header channel 5 and 6, as any PWM signal would cause conflict.
- Note that in PPM mode, the CORE can not switch profiles because it relies on the gimbal controller to be PWM configured. We suggest that you use a channel on your radio to switch profiles.

Camera switcher

- Switching video downlink feed is now possible via a dedicated R/C channel on the radio, e.g., a 2-position toggle switch. Connect a servo-cable from the receiver to the R/C header (channel 8). The video switcher will change input when the PWM-period passes the 1520µs center point (50%). No further sub-trim should be necessary. The failsafe setting depends on your receiver configuration.
- To enable the camera switcher functionality (off by default), press the “ENTR” button on the top plate for 4-5 seconds and toggle to the “CAMERA TYPE" menu and select "SWITCH".
- When using PPM for R/C and/or gimbal control, the camera switching still has to be hooked up to PWM. Fortunately, most receivers still output PWM on the remaining receiver pins when in PPM mode. It only requires one additional servo-cable to CAM_SWITCH (ch8) to enable switching.
- Set the GoPro recording mode to match your FPV camera; 25p/50p equals PAL, 30p/60p equals NTSC. This allows for faster transitions and no garbled screen because the viewing device (display, goggles) does not need to switch video format.
- The GoPro jumper selector called “GP OUT SEL” is by default set to camera switcher and no further soldering is necessary. For more information, refer to dual-pilot support later (advanced.)

GoPro link

- With video switching now possible on the DISCOVERY PRO, the kit includes a small adaptor which plugs into the GoPro 30-pin bus connector to provide video output and the possibility to charge the GoPro while in flight.
- After assembling the camera gimbal frame, plug in the 3-pin molex connector from the GoPro adaptor to the gimbal IMU board. The IMU board just passes the video signal straight through to the CORE/video switcher input, in an uncluttered fashion.



- (Advanced users only) There is even a component you can add on the board to be able to change the charging rate from 0.5A to 1A continuous. To enable faster charging, solder a dab on the two pads on the back-side labeled “500mA/1A” and order the IC NCP380HSN05AAT1G from Mouser or Digi-Key. Solder the IC to the unoccupied pads on the adaptor board (adequate soldering skills needed.)

OSD (On Screen Display)

- You can use the integrated OSD to get live readout on screen about the battery voltage (V), current draw (A), total current consumption (mAh), receiver signal strength (%) and flight time (minutes:seconds). This gives an essential overview of the system vitals while in flight.

- The OSD is enabled by default, to disable it completely hook up video and press the “ENTR” button on the top plate for 4-5 seconds, toggle to the “OSD" menu and select "OSD OFF".

- In the picture above the video feed is switched to the GoPro camera. Notice how the OSD adapts to the GoPro margins. The EzUHF RSSI Link was used here, allowing additional details to be showing of the R/C uplink.
- As a side note, as soon as the RSSI figures get towards -90 or the link quality drops below 80%, it is a good time to turn around (whichever comes first.)
- To read the R/C receiver signal strength (RSSI), connect a servo-cable between the receiver and the designated RSSI_ANALOG header on the top plate. All major FPV R/C system vendors support either analog or digital (PWM) RSSI output. For EzUHF owners, the CORE also supports “OSD Link”. Enter the CORE menu to select the right RSSI type for your receiver and calibrate the max. (radio on) and min. (radio off) value.
- The bottom plate includes an on-board current sensor in-line with the battery supply. Configure the CORE to use the 50A current sensor. The sensor can also be tuned (in % increments) to more accurately display current consumption (mAh), i.e. at the end of a flight if it was 1% too high, adjust it down 1%. The same kind of adjustments can be made for the battery voltage (in 0.1V increments.) The current sensor output is compatible with similar OSD systems. (Advanced users only) Limited instructions on how to install the TBS EzOSD on the PRO can be found later in this manual.
- Coupling current sensor and RSSI input directly on-board makes for a clutter-free OSD setup and clean build. A full menu layout of the CORE is available as an appendix to the manual.
- Lastly, when all the R/C and FPV gear is installed connect the 9-pin top-bottom link cable and close the frame. Use the remaining spacer and frame arm screws to secure the frame.

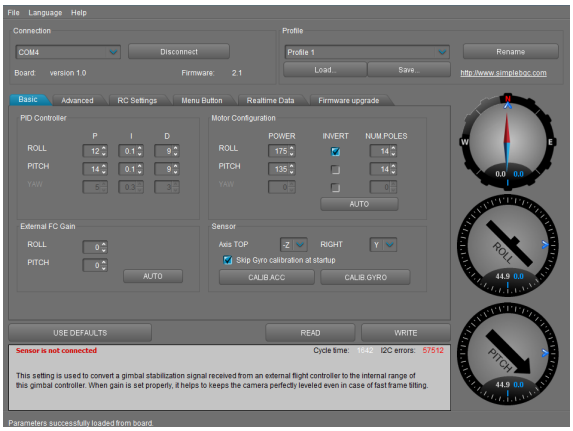
Note: Digital RSSI and Camera switch share the source pin with each other. If you use the Camera switch you can only use analog RSSI or the link input from EzUHF receiver.

Brushless gimbal stabilization

Integrated gimbal controller

Setting up a gimbal the right way can be a daunting task, fortunately we licensed the SimpleBGC firmware (AlexMos) and the SimpleBGC hardware layout from Viacopter. The controller has all the parameters pre-set and gains tuned by TBS for a great out-of-the-box experience.

The gimbal controller is fully embedded into the frame (a world's first), no soldering or software configuration required. Just plug in the motors and IMU, and you are good to go. The on-board USB port connects to your PC for future firmware upgrades and custom configuration.



If you want to apply updates and make adjustments to the gimbal, download the SimpleBGC and SiLabs CP210x driver package (www.simplebgc.com), plug in battery power, and connect the DISCOVERY PRO to a Windows computer via a micro USB cable (e.g., from the NAZA-M or a mobile phone.) Extensive details of the brushless controller is available in the SimpleBGC manual.

DISCOVERY PRO utilizes two profiles, one silent profile (Profile 1), to keep the gimbal quiet while on ground and one noisy profile (Profile 2). The CORE MCU will detect when main motor starts (current consumption >3A) and switch from the silent to noisy profile automatically. If you change something in SimpleBGC you have to **do the change on both profiles**. If you want to change your in-flight values you have to do this on Profile 2.

The following table shows the suggested PID and power controller gains for a GoPro HD Hero3&3+ mounted on the gimbal. Download the factory settings from bit.ly/tbsprosettings.

Axis	P	I	D	Power	Poles	Inverted	FC Gain
Roll	12	0.1	9	175	14	Yes	0
Pitch	14	0.1	9	173	14	No	0

Other essential settings: Axis TOP to -Z, RIGHT to Y, skip gyro calibration at startup CHECK, gyro trust 100, and PWM frequency to HIGH (silent) for Profile 1 and LOW for Profile 2, ROLL to RC_ROLL, PITCH to RC_PITCH, CMD to EXT_ROLL, RC control ROLL to -30/30/CHECK/3/UNCHECK/10/0% and PITCH to -90/90/CHECK/3/UNCHECK/10/0%.

HD camera

The GoPro HD Hero camera is the most commonly used HD recording camera (as of writing) for sport purposes, thanks to its wonderful high-quality picture and compact size. The TBS DISCOVERY PRO was designed around the GoPro to take advantage of its great features.

Consider using the GoPro settings in the tables below for “no-prop-in-view” footage. Adding a ND filter to the front of the GoPro will also help slowing down the shutter speed and reduce “jello”.

GoPro HD Hero1:

Video format:	NTSC (or PAL to match pilot camera)	to get 30fps
Video resolution:	1080p 30fps (medium angle)	for 10x5-inch props
	720p 30fps (wide angle)	for 9x5-inch props

GoPro HD Hero2:

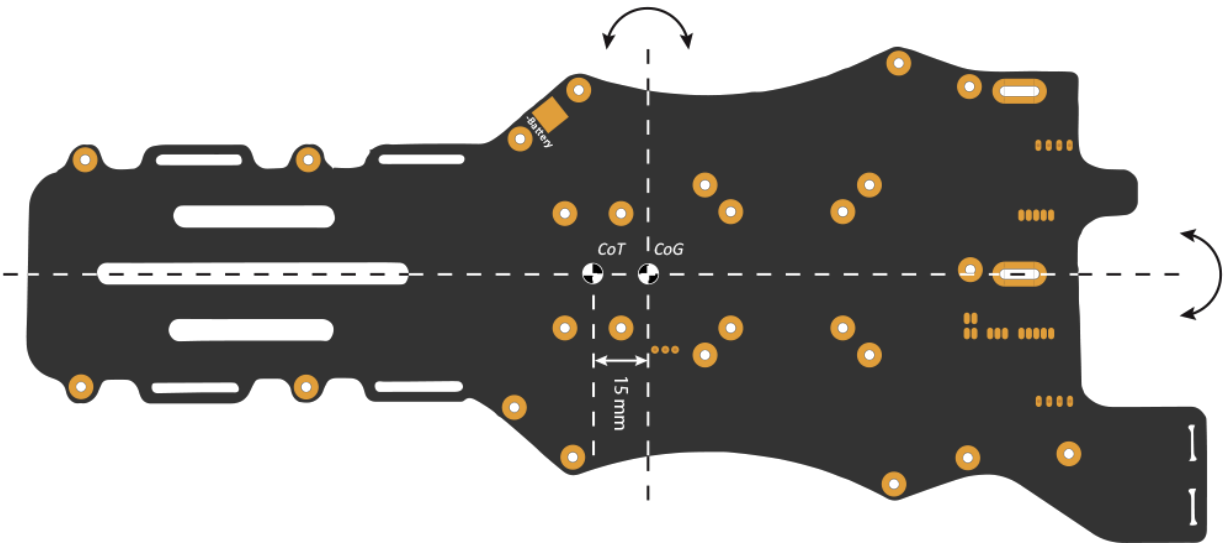
Video format:	NTSC (or PAL to match pilot camera)	to get 30fps
Video resolution:	1080p 30fps	high quality video
Video angle:	Medium (127 degrees)	for 10x5-inch props
	Wide (170 degrees)	for 9x5-inch props

GoPro HD Hero3/3+:

Video format:	NTSC (or PAL to match pilot camera)	to get 30/60fps
Video resolution:	1080p 60fps (or 30fps)	less chance of “jello”
Video angle:	Medium (127 degrees)	for 10x5-inch props
	Wide (170 degrees)	for 9x5-inch props

Center of Gravity optimization

- A properly balanced multirotor will distributing the weight (mass) equally over the four motors. The mark on the bottom plate is the Center of Thrust (CT, CoT) mark and the Center of Gravity (CG, CoG) spot is 15mm forward of this mark. When holding the frame in the air at the CG spot it should ideally be level and not dip to either side.
- After completing the build and loading up the frame, adjust the CG over the lateral (pitch) axis by primarily moving the battery pack forward or backward. You might need to move the middle two frame spacers to accommodate the battery. The CG over the longitudinal (roll) axis should be in the center of the frame front-to-back and should only need slight adjustments.
- When the frame is out of balance some motors are going to have to work harder than others and you will have less authority in a given axis due to the fact that one or more motors are already working more than normally required. Small balance variations are countered very well by the flight controller and should not cause any problems.
- If the quadcopter is too nose heavy it will bob up and down in forward flight and if it is too tail heavy it will get very twitchy and hard to fly.
- As a side note, the flight controller does not need to be over the CG spot. It should be mounted in the center of the white rectangular lines on bottom plate.

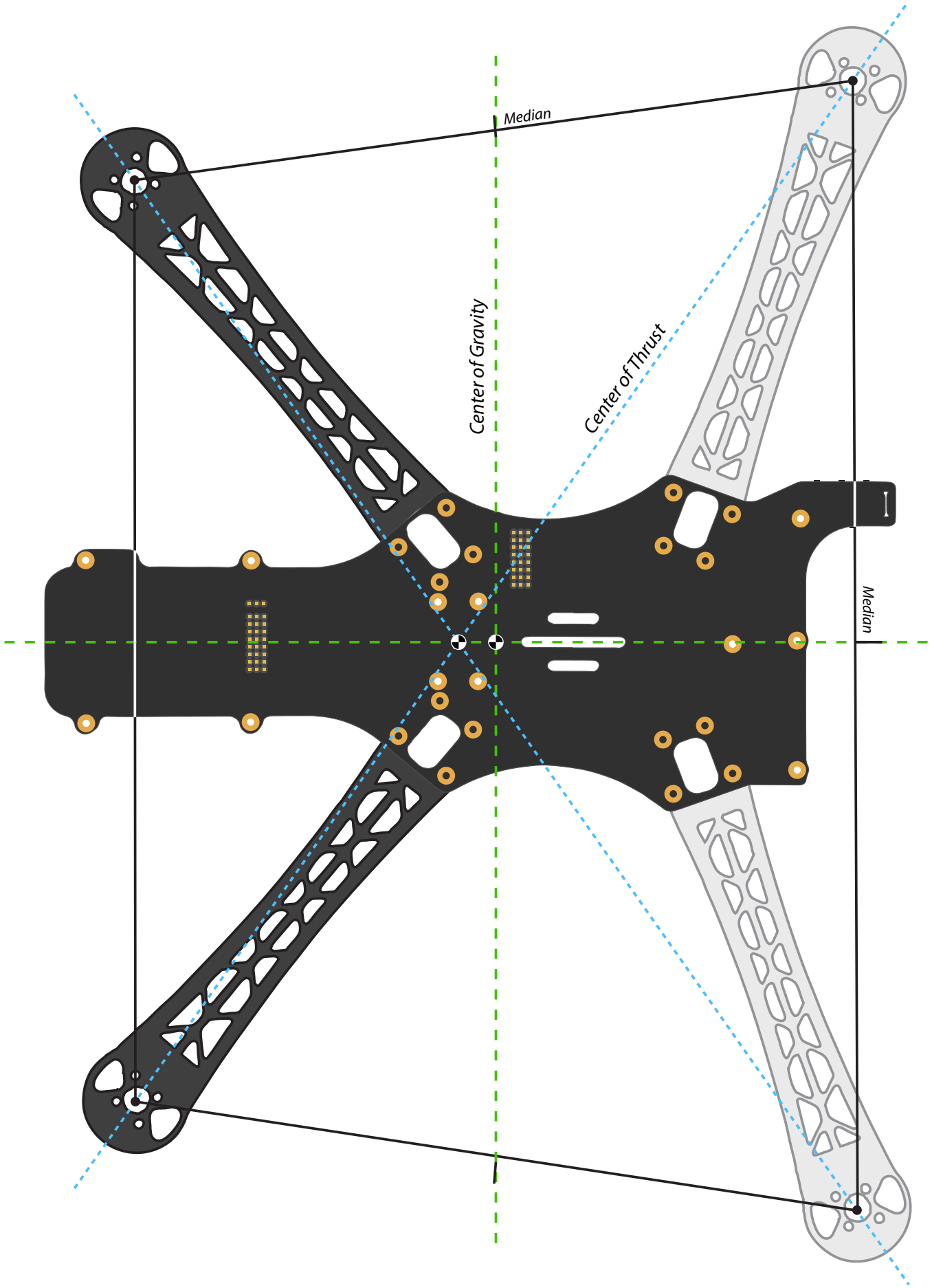


TBS DISCOVERY PRO

fpv gimbal quadcopter

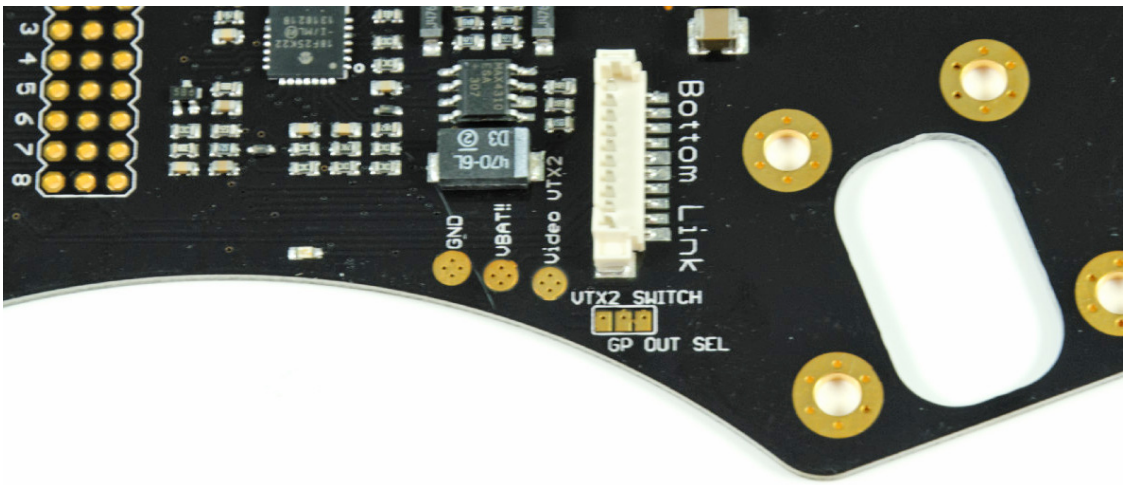
Center of Gravity diagram

rev. 08. 2013 - by ivc.no/tbs



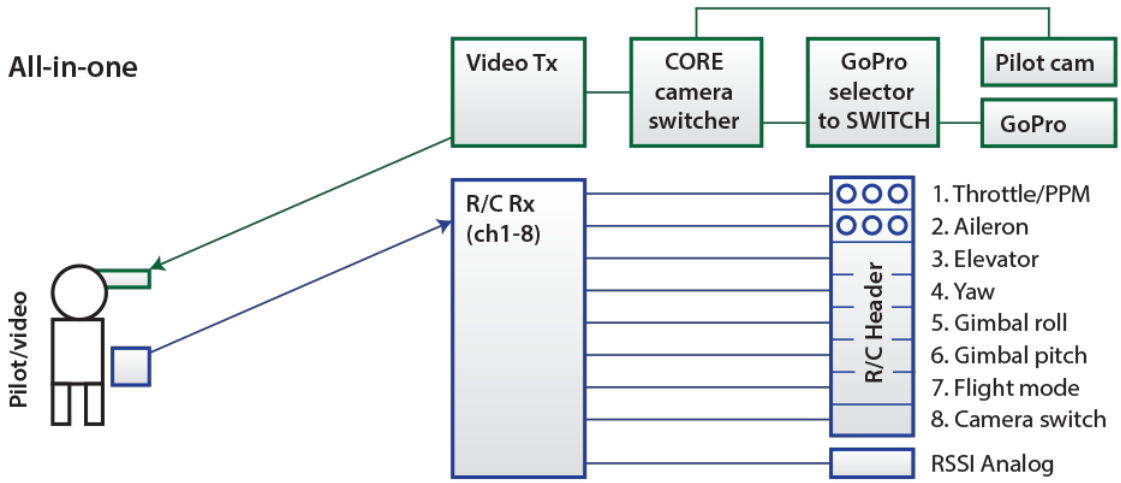
Dual-pilot support (ADVANCED USERS ONLY!)

Split dual-pilot support is possible in situations where a separate operator for piloting the quad and camera is preferred. Extra equipment is needed for the extra video link and R/C control uplink (2-axis gimbal and yaw adjustments.) Installation of the video transmitter and R/C receiver follows the same basic setup principles described previously.

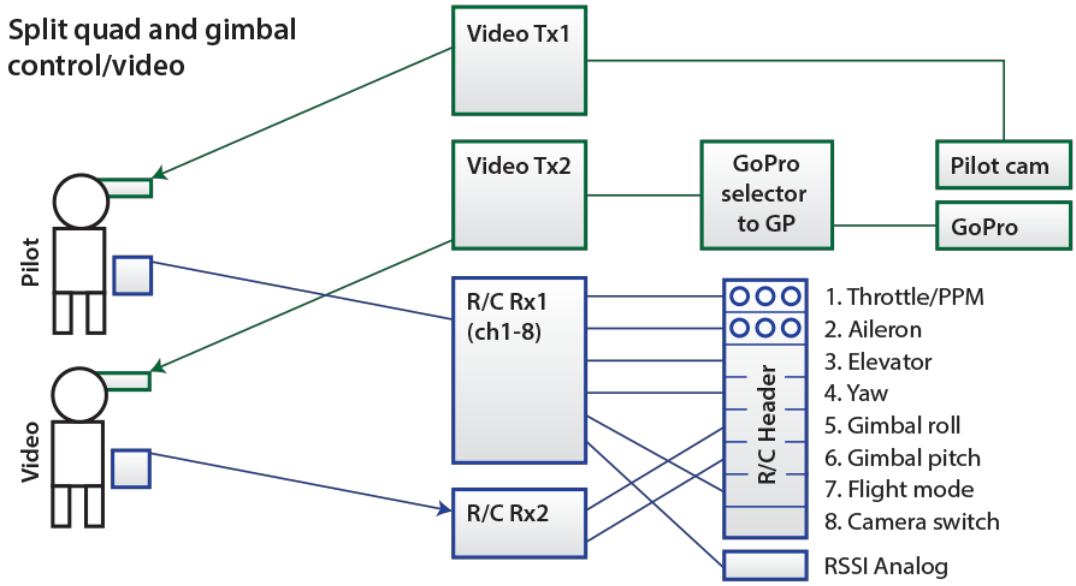


Connect the second video transmitter to location labeled VTX2 (GND, VBatt!!, Video.) The GoPro output selector jumper works like this; the middle and right pads are connected by default from the factory, transferring the Gopro image to the camera switcher. To use a second transmitter, cut the trace in between the two pads. This can be done with a sharp knife. Use a multimeter to verify that the two pads are entirely separated. Now connect the left and middle pad with a dab of solder, this diverts the GoPro image to the Video pad.

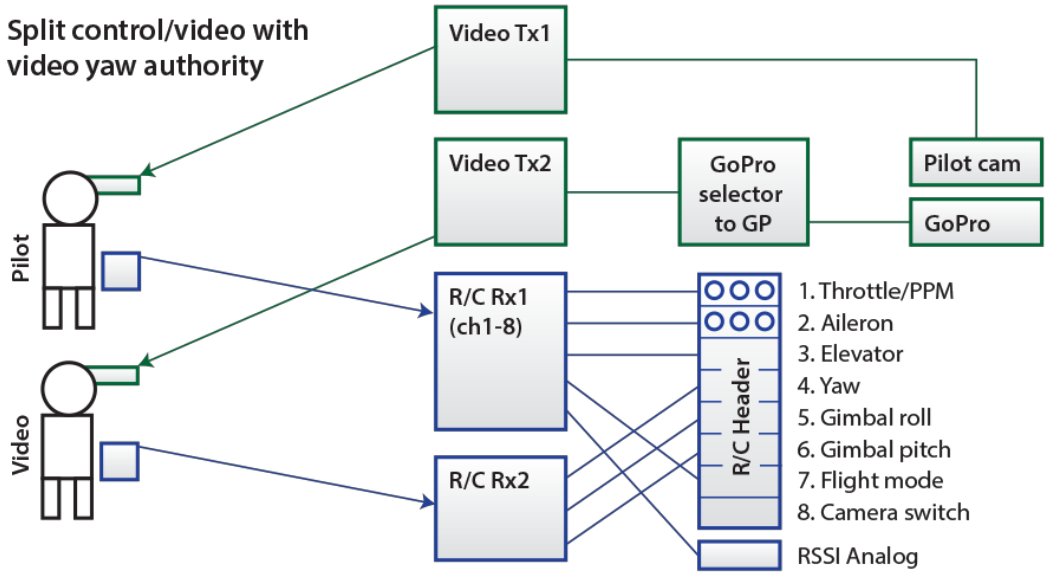
- **Single operator** - For reference, the following diagram shows the normal “all-in-one” setup where one operator maneuvers quad and controls video positioning.



- **Dual operator** - Introducing a separate video operator for the gimbal roll and tilt control requires one additional video transmitter and R/C receiver. Disable the video switcher, cut the trace between the two “GP OUT SEL” jumper pads and solder the left pad to the middle.

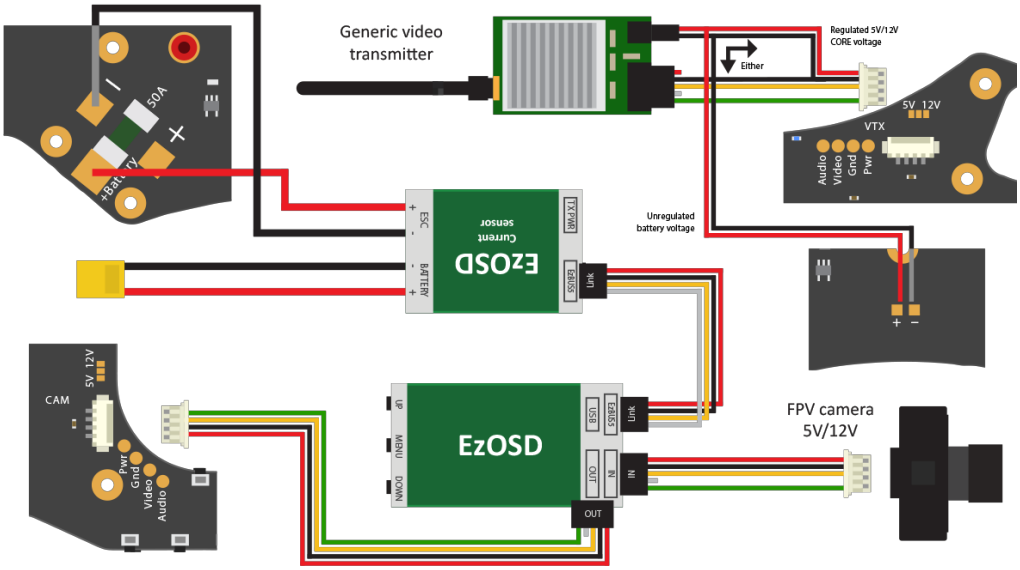


- **Dual operator with yaw authority** - To give the video operator the ultimate freedom over framing and picture positioning, swap the responsibility for yaw control over to the the video operator. This requires good piloting skills and continuous communications back and forth to practice safe maneuvering and flight.



TBS EzOSD installation (ADVANCED USERS ONLY!)

The TBS EzOSD/IMRC EzOSD is not officially supported, but it can be installed by users understanding who understand the risks and void of warranty.



- Following these instructions will give you EzOSD on-screen while viewing the FPV camera and a clear uncluttered picture when switching to the GoPro camera.
- First, enter the CORE menu via the buttons and set CAM TYPE to SWITCH and OSD to OSD OFF.
- Connect the GoPro as normal to the top plate. Connect the FPV camera to the IN port of the EzOSD (PWR, GND, VID, AUDR - *if you want audio*) and connect the OUT port to the CAM connector (PWR, GND, VID, AUDR) on the DISCO PRO frame.
- Then, you need to connect the video transmitter (VTx) to DISCO PRO VTX port (PWR, GND VID, AUD) as you normally would. If the VTx is high power and has an on-board regulator, power it from the unregulated points on the bottom plate (+/- pads), otherwise use the regulated CORE 5V/12V directly from the VTX frame connector.
- For the EzOSD current sensor you need to add an extension from the current sensor's "BAT" input to the battery. You will not be able to use the standard pigtail as that will be too short. From the “ESC” (+) output you will need to solder to the “BATTERY” (+) input on the PRO. From the “ESC” (-) output you can go to the “BATTERY” (-) input (bottom side of the frame) or solder directly to one of the ESC's (-) pads on the PRO. This essentially keeps the battery pigtail nicely in place, puts the current sensor (positive lead) in-line with the battery and the powers the 5V regulator (negative lead) for the EzOSD and unregulated TX power out of the current sensor.
- Install the OSD Link 4-pin EzBUS5 cable between the EzOSD and EzOSD Current Sensor, and optionally to the EzUHF OSD Link port via a split Y-cable (no ground connected.)
- Removing the shunt practically disables the CORE automatic gimbal profile switching (no CORE current sensing available) and all gimbal tuning should be done on Profile 1 from now on.

Flight

First flight

Check that the flight battery and transmitter battery is fully charged. Make sure all the screws on the frame and the propellers are secured, and that the battery strapped down. Balance the quadcopter around the Center of Gravity (CG) spot by repositioning the battery. Make sure the gimbal is positioned perfectly level and flat against the frame. It has to be calibrated at least once to get good level reference.

Find an wide open location free from obstacles, dust and distractions (e.g., garden or park.) The flight conditions should be calm with only a light breeze. Flip the flight mode switch to “Attitude” mode and execute the stick combination to arm the flight controller (e.g., for NAZA left stick to bottom-left and right stick to bottom-right.) Slowly raise the throttle stick and when the propellers start to spin, make sure they rotate in the right direction and the propeller type is correct (right-hand or left-hand turn.)

Takeoff

With all the essentials checked, stand behind the quadcopter with the gimbal facing away from you. Raise the throttle to about 50% where the quadcopter should start to lift-off and hover. Control the hover by primarily using the aileron and elevator sticks. Remember, only small stick movements. If the stick works in the opposite direction than expected, invert the channel and watch the flight controller monitor to confirm.

Let go of the sticks and observe if it drifts in either direction. Compensate by adding 2 or 3 clicks of trim on the radio in the opposite direction. If the quadcopter still drifts, land, put the frame on a level surface, balance the frame and cycle the power to the flight controller to re-initialize the gyro calibration.

FPV

After the quadcopter has been tweaked to stay still in a hover and fly true, turn on the FPV equipment and do a range test to verify that the video link is reliable. Visual inspect the area to pick out noteworthy landmarks and use these to orient yourself once your are in the air. Get a friend or assistant to be your spotter during the entire session.

While still flying line of sight (LOS), takeoff and hover the quadcopter as normal, attain reasonable altitude, and with the video goggles ready on your head, put them on (or turn to the display) to engage in FPV flight. If the picture gradually weakens (noise blends in) or video suddenly drops, increase altitude and return to home, as this normally indicates that you fly at the edge of the video range or behind obstacles, respectively.

Good practices

We have compiled a list of all of the things that have been tried and tested in countless environments and situations by TBS crew and other experienced FPV pilots.

Follow these simple rules, even if rumors on the internet suggest otherwise, and you will have success in FPV.

- Start with the bare essentials and add equipment one step at a time, after each new equipment was added to proper range- and stress tests.
- Do not fly with a video system that is capable of outperforming your R/C system in terms of range.
- Do not fly with a R/C frequency higher than the video frequency (e.g. 2.4GHz R/C, 900MHz video).
- Monitor the vitals of your plane (R/C link and battery). Flying with a digital R/C link without RSSI is dangerous.
- Do not use 2.4GHz R/C unless you fly well within its range limits, in noise-free environments and always within LOS. Since this is most likely never the case, it is recommended to not use 2.4GHz R/C systems for longer range FPV.
- Do not fly at the limits of video, if you see noise in your picture, turn around and buy a higher-gain receiver antenna before going out further.
- Shielded wires or twisted cables only, anything else picks up RF noise and can cause problems.
- When using powerful R/C transmitters, make sure your ground station equipment is properly shielded.
- Adding Return-To-Home (RTH) to an unreliable system does not increase the chances of getting your plane back. Work on making your system reliable without RTH first, then add RTH as an additional safety measure if you must.
- Avoid powering the VTx directly from battery, step-up or step-down the voltage and provide a constant level of power to your VTx. Make sure your VTx runs until your battery dies.
- Do not power your camera directly unless it works along the complete voltage range of your battery. Step-up or step-down the voltage and provide a constant level of power to your camera. Make sure your camera runs until your battery dies.
- A single battery system is safer than using two dedicated batteries for R/C and FPV. Two batteries in parallel even further mitigate sources of failure.
- For maximum video range and “law compatibility”, use 2.4GHz video with high-gain antennas.
- When flying with R/C buddies that fly on 2.4GHz, or when flying in cities, it is perfectly possible to use 2.4GHz video provided you stick to the channels that do not lie in their band (CH5 to CH8 for Lawmate systems, available from TBS).
- Do not use diversity video receivers as a replacement for pointing your antennas, diversity should be used to mitigate polarization issues.
- Improving the antenna gain on the receiver end is better than increasing the output power (except in RF-noisy areas). More tx power causes more issues with RF on your plane. 500mW is plenty of power!

- Try to achieve as much separation of the VTx and R/C receiver as possible to lower the RF noise floor and EMI interference.
- Do not buy the cheapest equipment unless it is proven to work reliably (e.g. parts falling off, multitudes of bug fix firmware updates, community hacks and mods are a good indicator of poor quality and something you do NOT want to buy for a safe system). Do due diligence and some research before sending your aircraft skyward.

Troubleshooting

- **Issue: Horizontal lines in pilot video downlink**
  Solution: If there are lines in the video during flight that disappear as soon as you land, your video transmitter is exposed to too much vibrations. Memory foam in conjunction with the Flame Wheel VTx mount will take out the vibrations in an instant and give you crystal-clear video.

- **Issue: Motor(s) doesn't start**
  Solution: It is probably a lazy start syndrome, some information on that is available here: bit.ly/15wNLk4. You should calibrate your ESC throttle endpoints, details on how to perform this: bit.ly/110deyX. We have a calibration cable available which speeds up the process. Please remember to remove the props before doing that.

- **Issue: Can the TBS EzOSD be installed on the DISCOVERY PRO?**
  Solution: It requires taking the VTx output and feeding it to the EzOSD and removing the shunt resistor. For instructions, look at this post: bit.ly/1a2r6xg.

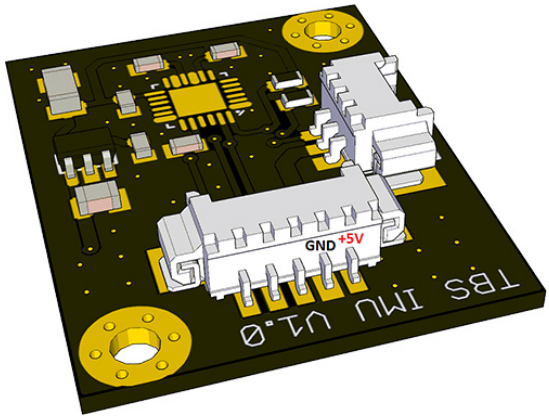
- **Issue: Can the GoPro camera be charged from the frame?**
  Solution: If you don't use the internal power supply from the TBS CORE for your VTx (e.g. a VTx with an included power supply) there is enough 5V power available to charge the GoPro. In this case TBS has conveniently located a soldering pad to activate the charging feature.

- **Issue: After switching video from GoPro to pilot camera, video is rolling and desynced**
  Solution: Set the GoPro recording mode to match your FPV camera. 25p if you are using PAL, 30p if you are using NTSC. This allows faster transitions between the two cameras because the viewing device does not need to switch between PAL and NTSC.

- **Issue: I can't connect to the Gimbal using the SimpleBGC software**
  Solution: Ensure that the SiLabs CP210x drivers are installed, download them from bit.ly/bi3or4.

- **Issue: The gimbal motor does not feel securely tightened or spins freely without any movement on the gimbal (tilt axis)**
  Solution: Pull off the bell and roughen the motor shaft with a low grit sand paper or a file to cause a rough surface. Add a drop of Loctite or CA glue to the shaft and slide the motor bell back on. Let the glue dry.

- **Issue: Gimbal controller displays a blue light and motors not engaging**
  Solution: Try to connect your PRO to the SimpleBGC UI software and check what message you get there. There is possibly a bad connection between the top plate and the gimbal IMU. Check the connection by verifying the voltage at the IMU when everything is plugged in:



- **Issue: The gimbal drifts or doesn't center properly**
  Solution: Install the SimpleBGC Software (www.simplebgc.com), level the gimbal on a heavy and sturdy table and fix it using a thin book or similar. Turn off any UHF transmitters and disconnect any video transmission devices. Ensure there are no vibrations on the table. Remove the camera and strap from the Gimbal, as it simplifies levelling the gimbal. Connect the battery. The gimbal will try to "fight" - do not worry about this it will not overheat the motors unless being kept running for extended periods of time. Connect the micro USB to the top plate, and select "Connect" in the software. Now select "Acc. Calibration" and wait for the motors to regain power. Then select "Gyro calibration". If these steps have been done correctly, the gimbal will now lock dead center. You can remove whatever you used to support the Gimbal and it will hold its position.

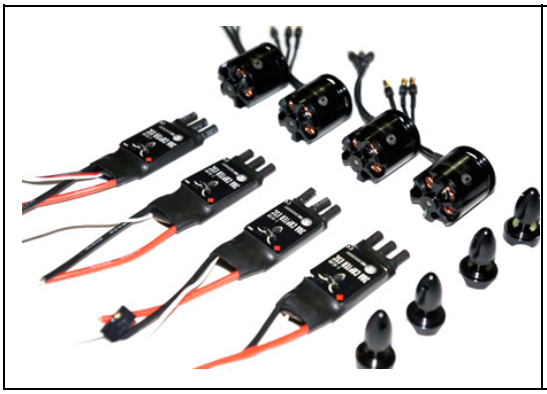
- **Issue: The gimbal stutters or moves in jerky motion**
  Solution 1: Has the USB port been plugged in while the battery was disconnected? Unplug the USB, then plug in the battery, and subsequently connect the USB plug again.
  Solution 2: The IMU may be under tension, which prevents the gimbal from rotating freely. Loosen the zip-ties of the IMU cable and give them some “play”, especially around the ball-bearing area.

- **Issue: Video signal resets every few seconds**
  Solution: Too much current is being drawn from the CORE causing it to go into shutdown mode. The video transmitter should be powered from a separate power source. Use a 5V or 12V BEC and connect it to the + and - pads on the bottom plate.

Recommended parts

Below is a list of compatible R/C and FPV gear for the TBS DISCOVERY PRO quadrotor. This will hopefully make it easier to pick up spare parts and upgrades.

Power sets

	**TBS 900kV2 Motor / ESC Combo** For the more sophisticated, agile-flight loving pilot or for those requiring super-vibration-resistant and high quality motors. • 4x TBS BULLETPROOF 30A ESC (flashed with SimonK Firmware) • 4x TBS 900kV2 Motor with M5 prop mount hubs

Individual parts

Motors

- TBS 900KV2 or Tiger Motors MT2216-10/11 900KV brushless motor (5mm shaft)
- DJI 2212 920KV brushless motor (8mm shaft)
- Sunnysky 2216-12 800KV brushless motor

Speed controllers

- TBS 30A Multicopter SimonK firmware speed controller
- DJI OPTO 30A no-BEC speed controller
- Tiger Motors 18A BEC speed controller
- HobbyKing F-20A or F-30A BEC programmable ESC with SimonK firmware

Flight controller

- DJI NAZA-M V1/V2/Lite with optional GPS
- OpenPilot CopterControl 3D
- APM2 Arduino-based autopilot controller

R/C Transmitter/Receiver

- Futaba 8FG / 7C with included receiver R6208SB / R617FS
- Graupner MX-12 radio with included GR-6 receiver
- ImmersionRC EzUHF 8ch Diversity receiver
- ImmersionRC EzUHF 8ch Lite receiver

Propellers

- Graupner E-Prop 9x5-inch propellers
- Graupner E-Prop 10x5-inch propellers
- GemFan E-Propeller 10x5 Carbon Fiber propellers
- RCTimer Carbon Fiber 9x5-inch propellers
- RCTimer Carbon Fiber 10x5-inch propellers

Battery

- TBS 4S 3300mAh 30C or KyPOM KT4500/35-4S Lipo pack
- TBS 4S 4500mAh 30C or KyPOM KT3300/35-4S Lipo pack
- Gens Ace 4S 3300mAh 25C Lipo pack
- Zippy Compact 4S 4000mAh 25C Lipo pack
- Zippy Compact 4S 5000mAh 25C Lipo Pack
- Turnigy nano-tech 4S 3300mAh 35C Lipo pack

FPV transmitter

- Lawmate TM-240500-LM 2.4GHz 500mW transmitter
- TBS ROOKIE 5.8GHz 200mW transmitter
- TBS GREENHORN 5.8GHz 25mW transmitter
- BosCam TS-353 5.8GHz 400mW transmitter

FPV camera

- TBS69 or TBS59 FPV camera
- TBS ChipChip FPV camera
- Security Camera 2000 PZ0420 or CMQ1993X (IR blocked) 600TVL camera

Spare parts

You can either get spare parts directly from us (team-blacksheep.com) or from one of our distributors and retailers near you.

Our ever-growing list of retailers is published on the left at team-blacksheep.com/shop.

Appendix

- Frame assembly diagram
- Gimbal assembly diagram
- Electronics installation diagram
- Common R/C receiver setups
- Video transmitter installation diagram
- CORE menu layout
- Center of Gravity diagram

Manual written and designed by ivc.no in cooperation with TBS.