Pixhawk and other electronics

A primer

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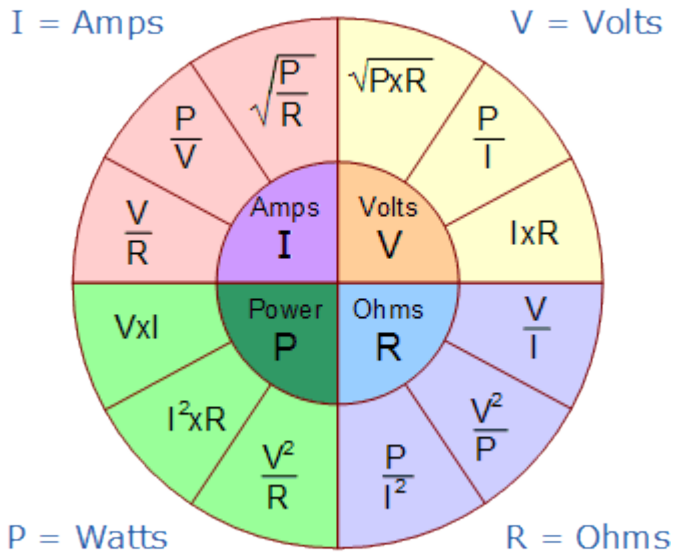
Electrical Units

- Voltage
  - Volts (V)
  - “Flow” potential
  - The *only* supplied value by a battery
- Resistance
  - Ohms (Ω)
  - Characteristic of a circuit
- Current
  - Amps (A)
  - Resultant of potential and resistance
- Power
  - Watts (W)
  - 1 *J/s*

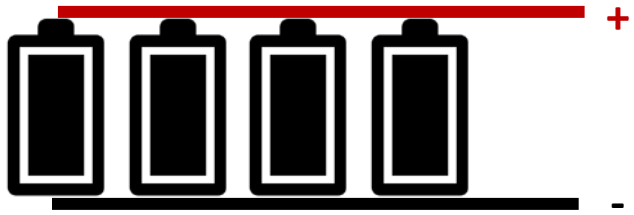


Series and Parallel

- Ex: AA batteries, nominal 1.5 V, 2000 mAh capacity per cell 

  - (Just a regular alkaline battery, NOT LiPo)
- *Series* connections increase voltage
  - If we put 4 AAs in Series, what is the resulting voltage of the pack? The capacity?

  - Voltage: 6V Capacity: 2000 mAh Total Energy: 12 Wh
- *Parallel* connections increase capacity
  - If we put 4 AAs in Parallel, what is the resulting voltage of the pack? The capacity?



  - Voltage: 1.5V Capacity: 8000 mAh Total Energy: 12 Wh

LiPo Batteries

- Provides an electrical potential → Voltage
- Is constructed of cells of a given capacity (mAh)
  - Capacity is current * time, hence Amps (or milliamps), over an hour
  - Describing a battery by saying “it has 7000 milliamps” is nonsensical, though we can *probably* guess what you mean
- Does not “provide” a set amperage
  - Ex: a 20C 4000 mAh LiPo *can* pump out 80A without damaging the battery, but it will NOT pump out 80A all the time
- Most LiPos are sold as a *n*S1P arrangement, where *n* is the number of cells in series, and there is just that one set of serial cells (i.e. no parallel arrangement)

LiPos – Parallel and Series

- Generally buy a battery with the series arrangement already done
  - Example: You design your propulsion system to use a 4S battery. It is much easier (and probably cheaper) to buy a 4S battery than two 2S batteries and put them in series
- Not unheard of to buy two identical batteries and put them in parallel to double the capacity.
  - Example: You are planning an extremely long mission which will require approximately 16,000 mAh on a 4S battery. You may not be able to find a single 16,000 mAh 4S battery, but you can source two identical 8,000 mAh 4S batteries.
  - Put them in parallel configuration using additional wiring, such as this.
  - Be sure to match connector styles, or plan to convert.

Batteries – Common issues/FAQs

- Voltages for LiPos are given as a nominal voltage, 3.7V, which is the voltage at approximately 50% charge
- Never discharge a LiPo below 3V/cell
  - Example: Absolute minimum on a 4S would be 12.0V
  - “We just want to fly another minute” is a bad excuse
- “The wires for this battery are huge, but I want to solder on an XT60.”
  - You probably purchased a high-discharge rated battery than can handle 120+ amps…there is a good reason the wires are large. Solder on an XT90 and then make or buy a XT90 to XT60 adapter.
- “How do we know how much battery we used?”
  - Most chargers will read out the mAh charged back into the battery
  - Log the mAh consumed within your Pixhawk, the save out the log file

Pixhawk/PX4/Ardupilot

- "Pixhawk" refers to the physical hardware
  - Current models
    - Pixhawk 2.1 (*The Cube*)
    - Pixhawk 4
    - Pixhawk 4 mini
- "PX4" and "Ardupilot" refers to the software (firmware) running onboard
  - QGroundControl software can install PX4 or Ardupilot
  - Mission Planner software can only install Ardupilot
- ***PX4 ≠ Pixhawk 4***

Powering your Pixhawk

- Different models have slightly different power connectors, but should come with the correct items to connect to a LiPo battery
  - Pixhawk 2 has a “power module” that sits between your LiPo and your ESC
    - Comes pre-installed with XT60s
    - Also measures battery voltage and current draw
      - Nice to monitor for mission duration and battery health

  - Pixhawk 4 has options
    1. A huge, annoying power distribution/IO board that is great for quad- and octo-copters
    2. In-line power module and compact IO breakout (please buy this)

Pixhawk – Common issues/FAQs

- The connectors are delicate – be nice
- Be mindful of board orientation and mounting
- Remember that wires take up space
  - And have non-zero weight
- Purchase 915 MHz radios, not 433 MHz
- “The GCS says the battery is too low.”
  - Make sure the power module is properly set up in your GCS
- “There is no signal to the servos.”
  - Make sure the safety switch has been pressed (aka vehicle is “unsafe”)
  - Make sure the servos are plugged in to the right location
  - Make sure the flight mode is set to your desired mode

Servos

- Defining specification is torque
  - Determining your torque requirement is not straightforward
    - Depends on aerodynamic loads, hinge axis alignment, manufacturing errors, etc.
- LOTS of manufacturers to choose from
- Lots of shapes and sizes
  - Thin servos might be nice for wings, but probably costs more than a similarly-torque-spec'd "standard" looking model
- Make sure their required voltage is being met
  - More and more "HV" or High Voltage servos on the market that require more than 6 volts, which is the highest that many ESC-borne BECs will do
  - Too low of a voltage can lead to an odd twitch

Powering your servos

- Servos do not get powered by the Pixhawk directly
- Voltage must be provided by one of three ways
  - Standalone battery pack (4.8V NiMH packs, aka receiver packs can be used)
  - BEC that is built-in to your ESC (Most common for this project)
    - Note that if your ESC says “opto” or “opto-isolated”, then there is no BEC
  - Standalone BEC
    - Could be on a separate LiPo as a safety mechanism for running your propulsion battery figuratively into the ground, or be similar to the Pixhawk Power Module (a passthrough)

Powering your servos, example

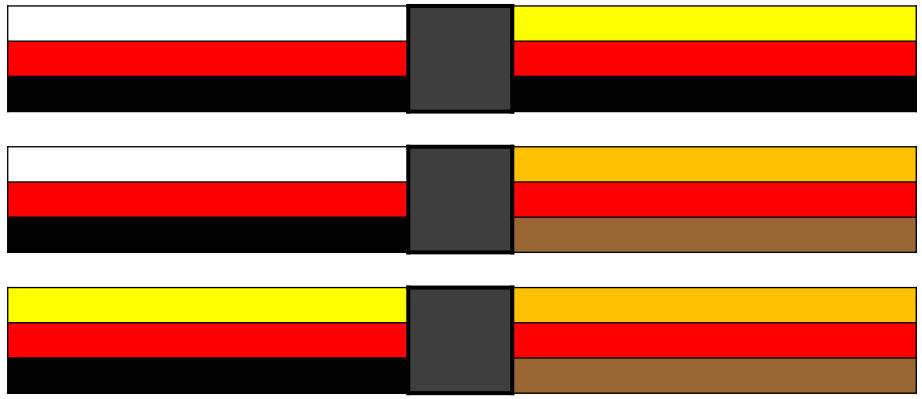
- Must make sure that current rating of BEC (or battery) is greater than all your servos' max current draw (with some margin, maybe 25%)

	Aileron, Elevator Servos	Rudder Servo	Total
Make/Model	Hitec HS-322HD	Hitec HS-125MG	
Quantity	3	1	
Max current (each)	800 mA	1200 mA	
Voltage required	4.8 – 6.0	4.8 – 6.0	
Simultaneous max current	2.4 A	1.2 A	3.6 A

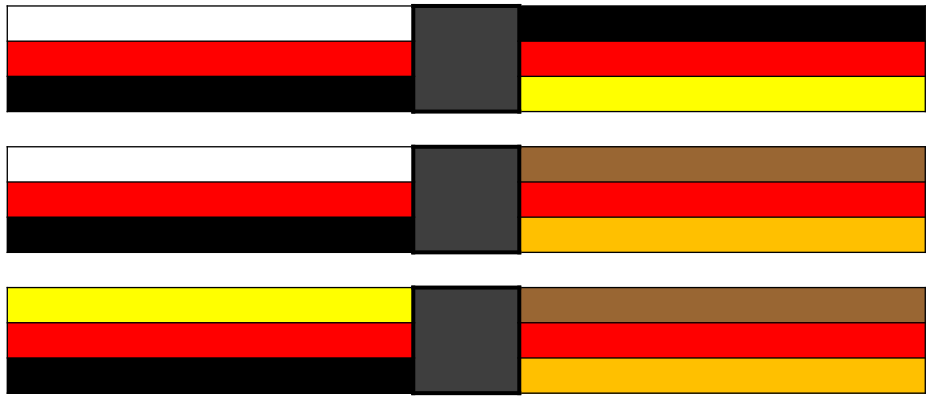
Positive, Negative, and Signal

White/Yellow/Orange: PWM Signal Red: +VDC Black/Brown: -VDC

RIGHT



WRONG



Servo signal: Pulse Width Modulation

- 0% deflection: 1100 µs (Note, this can sometimes be reduced to 1000 µs)
- 50% deflection (“centered”): 1500 µs
- 100% deflection: 1900 µs (Note, this can sometimes be increased to 2000 µs)

PWM Signals

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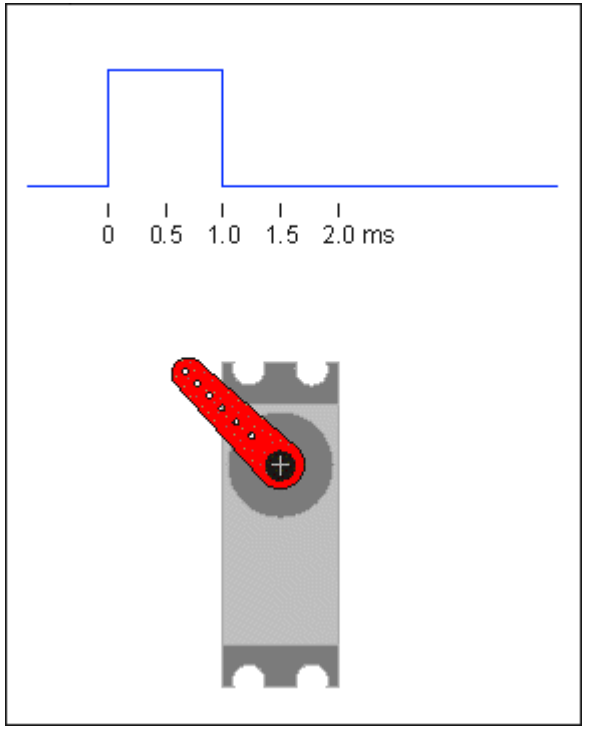

Throttle signal: Still PWM

- Read your ESC’s manual to find the required range (1100-1900 µs? 1000-2000 µs?) of your signal

Controls Mixing

- Can “mix” transmitter controls to do more complex tasks automatically
  - Examples
    - Deflect elevator up when flaps deployed
    - Add right rudder when throttle increased
    - Add elevator up when throttle increased (for planes with high-mounted motor)
    - Add left/right rudder to counteract adverse yaw in left/right bank
- Reduces pilot workload
- May be absolutely required in a situation such as a v-tail
- Note that when moving to automated flight modes, the mixing will probably be ignored, but compensated for by the autopilot anyhow

Controls Mixing – RC Transmitter (Tx)

- Read each transmitter's instructions
  - Example: Spektrum radios; Enter menu → Mixing → Set mixes 1 – 3
    - Flaps mixes (e.g. to deflect elevator) done in the Flaps System menu
    - This image shows a transmitter with a 3-position switch used for flaps (normal)
  - Make sure deflections are in the correct direction
    - Don't want elevator down when flaps deploy, or else you're going down REALLY fast

- For V-tail
  - Glider this fall (no Pixhawk); Set up the Tx with native v-tail mixing (usually in wing/tail setup menu or similar) or use a standalone v-tail mixer.
  - With Pixhawk; Do not use Tx v-tail mixing. Re-assign servo outputs for elevator/rudder as left and right v-tails

Servos – Common issues/FAQs

- Make sure your servos are being powered by an appropriate source
  - Example of good setup: 5V, 5A BEC powering normal-sized servos
  - Example of bad setup: 5V, 2A BEC powering normal sized servos
    - Leads to voltage sag, possibly brown-outs
- Make sure your servos are centered when installing them
  - Example: You take servos straight out of the box, put a servo horn perpendicular to the flat side, and put it in your wing. You power on the servo, and send it a 1500 µs signal. It deflects 45°, and now you must uninstall the servo, move the horn, and reinstall the servo.
- "My servo is deflecting the wrong way." (Looking like flaps instead of ailerons)
  - More of an issue when using a servo "Y" cable and a low-channel receiver
  - If plugged into its own channel in the Pixhawk, reverse that output
  - Some digital servos can be reversed on the servo, but analog servos can not.

Servos – Common issues/FAQs

- “My servo isn’t moving at all.”
  - 90% of the time a servo wire is hooked up incorrectly
  - Check your GCS servo output page to see if a signal is being sent
  - Make sure the servo is powered (battery, BEC, etc) powering the servo rail
- “The servo is all jittery.”
  - Servo rail voltage may be too high/low
  - Sometimes servos have a tiny bit of jitter because of their dead band circuitry
    - Usually goes away under load
- “Why is the servo getting so hot?”
  - May be overloaded (more torque than the servo can handle)
  - Servo rail voltage may be too high/low

Suggestions

- Read your product manuals
  - Or at least skim the important parts
  - Valuable tidbits like “How to hook everything up”

- Set up an “iron bird”
  - Basic testbed for your electronics, mounted to one piece of material so you can carry it around
  - Can include Pixhawk, servos, batteries, GPS, etc.
  - Can make it in 5 minutes out of foamboard and tape – it need not be pretty
- Try to have access to a digital multimeter
  - Best basic electrical troubleshooting tool
    - Voltage testing
    - Continuity testing

Suggestions

- List out all electrical connections before you purchase components
  - Figure out if you need to replace a battery, ESC connector, etc.
  - Figure out if you need to buy different size bullet connectors for your motor/ESC
- Build an electrical budget (for power draw, not $$)
  - Investigate whether any additional systems will require separate power sources due to voltage differences or system architecture reasons
- Produce a nice (high quality) and easy-to-follow electrical diagram
  - Include cable and connector types, peripherals, what power is going where, etc.
  - Does not need to be analogous to the aircraft layout, but it can be

Example

- Not perfect
- It is CLEAR
- It includes all components
  - Except connectors…
- It breaks down the complex system
  - Pixhawk wiring separate from payload system
  - Shows the interconnectivity between the two

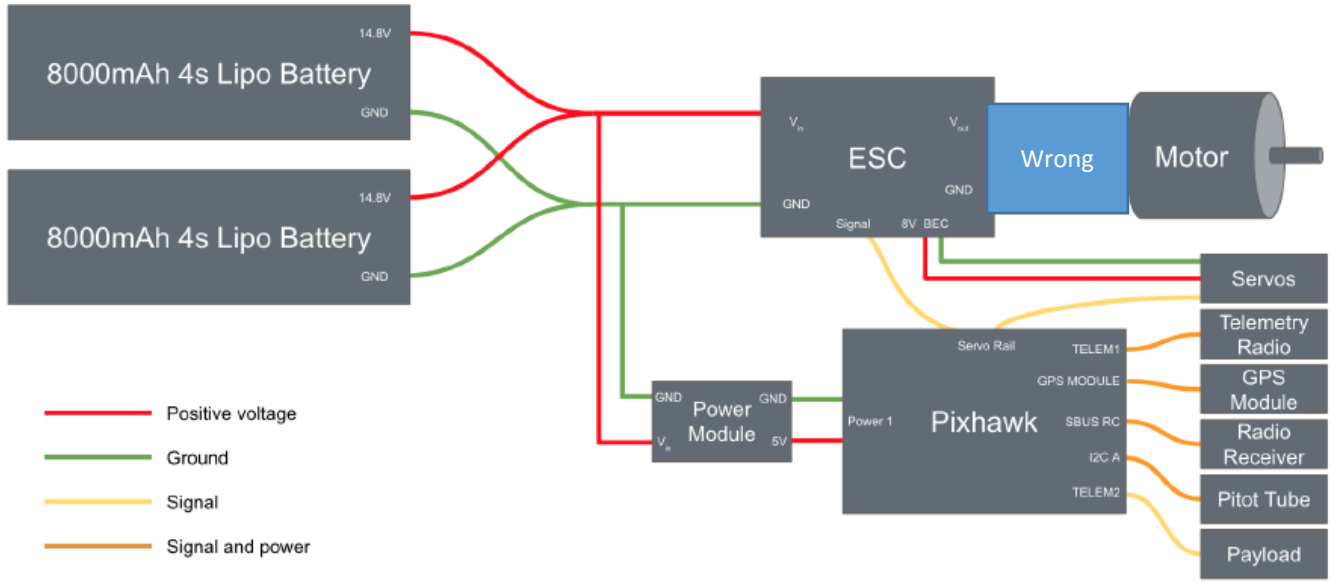

Fig. 56 Wiring diagram of avionics

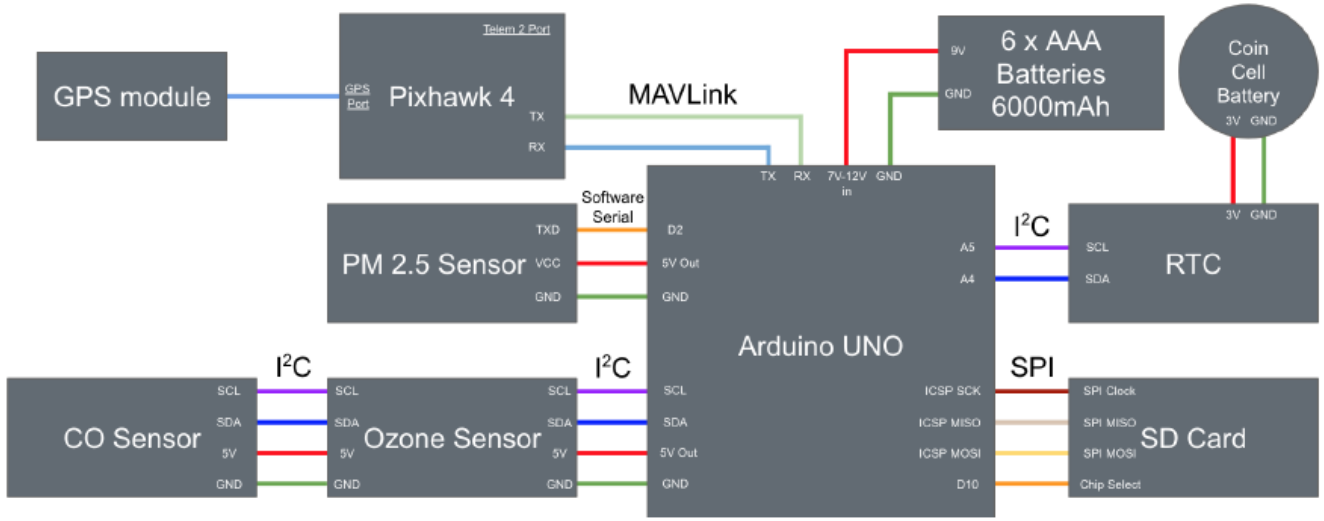

Fig. 57 Wiring diagram of payload