Xflight Technologies LLC

Servo Selection and Installation Guide

Version 1.2

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Xflighttech.com

A. Terms, Conditions and Warranty

This guide is provided for information purposes only to aid the builder in identifying and installing suitable PWM servos for the Xflight Autopilot product range.

See Appendix A for details

Disclaimer: Xflight Technologies LLC is not qualified in aeronautical design engineering, and this guide is not intended to provide design advise. It is simply a guide to servo selection, identifying the areas that need to be considered when selecting a trim tab servo. A qualified aeronautical engineer should be consulted for any specific design considerations.

B. Types of Servos

PWM servos are controlled by a Pulse-Width Modulated (PWM) signal. Typically, a pulse is sent to the servo every 20ms, so its position is updated 50 times per second. Depending on the width of the pulse, the servo will move to a new position. A pulse width of 1500μS is center, and minimum and maximum ranges are typically 1000 μS and 2000 μS respectively.

The two main types are digital and analog. Both work with PWM signals, however the servo motor is driven differently. Here is a brief overview of each:

Analog Servo

The analog servo motor is driven at the same frequency as the PWM voltage pulses, so the longer the pulse the faster the servo motor turns to its desired position. The drawback of analog servos is that with pulses every 20ms (50Hz), this does not allow them to move particularly fast, or to develop a lot of torque; important if you are counteracting a high load.

Digital Servo

Digital servos drive their motors via a micro controller which processes the PWM pulses into much higher frequency voltage pulses for the motor, in the order of 300 per second (300Hz) or higher. Digital servos therefore are more reactive, have a much faster and smoother response, and are much better at holding position against a load. In order to achieve this performance, they will draw more power.

For our purposes, digital servos are recommended.

C. Servo Construction

There are many aspects to a servo's construction, however since we are considering high torque servos, any reputable manufacturer will use the required materials to deliver the torque specified, and so we will not consider all aspects of its construction here.

Gears

For our purposes we need high torque servos with a strong, rugged construction and are looking for servos with metal (steel or titanium) or Karbonite gears.

Bearings

Bearings are also important and there are typically only two choices – bushings or ball bearings on the output shaft. Ball bearings (the more the better) are preferable as there is a lower tendency for them to wear out, and therefore less "play".

Case

It is best to have an aluminum servo case, as opposed to plastic as this will also act as a good heatsink.

Splines

Servos have splined shafts so the servo arm cannot slip out of position when properly secured. The most common spline count is 25, referred to at 25T (25 teeth). This needs to match the servo arm.

D. Servo Specifications

Servos come in many different sizes, e.g. nano, micro, standard, large, etc. For our purposes we are interested in the standard to large range.

The main metrics to look for when selecting a servo are size/weight, torque and speed, as well as operating voltage.

Torque

The torque rating specifies how much force the servo can apply at right angles to a servo arm and is measured in ounce-inches (oz-in) or kilogram-centimeters (kg-cm). Below is an example for a 400 oz-in torque rated servo, and the loads it could handle at 1" and 2" from the servo shaft.
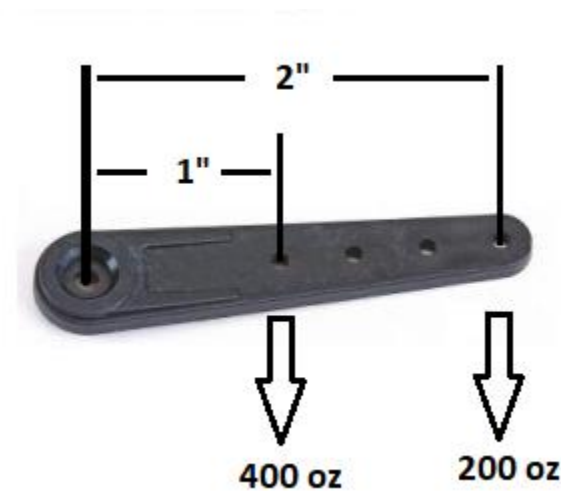
Calculators are readily available on-line to convert between oz-in and kg-cm.

Torque is often quoted at different voltages, with higher servo voltages providing higher torque, within the servo operating voltage range.

Required torque values for trim tab applications, in the LSA aircraft category are typically in the 300 to 500 oz-in range, depending on trim tab size, maximum airspeed and other factors (see section on Selection and Installation below).

Secondary control surface applications, in the LSA aircraft category, again depend on size, maximum airspeed and other factors and typically require torques of 700 oz-in and above, however since these can vary so much, they will not be considered further here.

<u>Speed</u>

Speed rating is simply the time it takes in seconds for a servo to rotate a certain number of degrees, typically quoted as 60 degrees, without load. A speed of about 0.2s or less is good for our purposes.

Speed is often quoted at different voltages, with higher servo voltages providing faster response, within the servo operating voltage range.

A typical Speed specification: **0.20sec@6v~0.18sec@7.4v**

<u>Rotation</u>

Rotation angle indicates the maximum rotation capability of the servo

Maximum rotation should be 180 degrees (mechanically), in practice around 100 degrees for 1000 μS and 2000 μS pulses. Beware of large rotation angle servos, e.g. 270 – 360 degrees, or continuous rotation servos

Typical Specification Sheet

This is a typical PWM servo specification sheet, with the main areas of interest highlighted:

Features:
- Full metal case
- Fantastic torque (40kg@7.4V)
- Coreless motor
- Metal geared
- Twin ball bearings
- Perfect for RC cars and other high demand uses
- Robust construction
- Complete mounting hardware pack

Specs:
Model: **TGY-20C**
Operating Voltage: **6~7.4v**
Torque: **35kg@6v~40kg@7.4v**
Speed: **0.20sec@6v~0.18sec@7.4v**
Dimensions: **40.5x21x42mm**
Weight: **78g**
Working Frequency: **1520/333Hz 900us-2100us**
Motor: **Coreless**
Ball Bearing: **2BB**
Gears: **Metal**
Servo Plug: **JR type**
Sevo Lead Length: **330mm**
Spline Count: **25**

E. Selection and Installation Notes

Assuming you have selected a digital servo, rather than analog, the next primary consideration is identifying the maximum load it needs to handle. We will only consider trim tab applications here.

The size and torque requirements of the servo will primarily depend on the size of the trim tab, trim tab/servo maximum deflection angles and the airflow load the trim tab will be subjected to, as well as other consideration like air density, etc. along with a good degree of margin. The calculations are complex and beyond the scope of this guide. An aeronautical engineer would need to be consulted for specific applications, however, here is an example of an elevator trim tab installation for the experimental Hummel H5 (LSA class) aircraft:

H5 trim tab servo mounted within the elevator control surface

Example - Hummel H5 Elevator Trim Tab	
Trim tab average chord	3.5" (9cm)
Trim tab average length	12" (30.5cm)
Maximum airspeed	120mph (VNE 150mph)
Control Surface angle from neutral	30%
Servo arm angle from neutral	30%

The servo used for this was the TGY-20C high-torque servo with a rating of 550 oz-in (or 40 kg-cm).

Once the torque rating has been selected, make sure the response time is good with a speed rating of 0.2 seconds per 60 degrees or better and ensure the servo has metal gears, ball bearings and preferably a metal case too.

You will then need to look at the size and weight and make sure it fits into the enclosure you have in mind. Since trim tabs are typically located on movable primary control surfaces (i.e. elevator and aileron), they will either be mounted inside the primary control surface, as per the elevator example above, or can be mounted externally on the primary control surface.

Finally select a servo arm (metal recommended) with a good shaft coupling (e.g. retaining screw), and long enough to provide good clearance from your control surface and has a matching spline count to the servo shaft.

F. Servo Power Supply

Servos will need to be provided power according to their rated voltage. The maximum rated voltage will provide the maximum available torque. In order to step down the battery voltage from 12 or 24 Volts, a regulator will be required, these are often referred to as BEC's (battery elimination circuits. The name comes from the RC (radio controlled) world, were servo power is often provided from the motor power unit or electronic speed controller, therefore eliminating the need for an additional servo battery).

There are two types:

Linear

Linear Regulators generate less interference or electromagnetic noise than the Switching Regulator, but typically draw more current. (Linear Regulators are available at Xflightech.com).

Switching

Switching Regulators reduce voltage by switching the supply on and off several thousand times per second, generating electromagnetic noise. They are more efficient and draw less current.

G. Installation tips:

- The control surface should be neutrally balanced to begin with. For example, an elevator spring could be used to hold the elevator at the neutral position

- Install servos such that they do not interfere with primary control surface operation. Even if servos get stuck fully extended, you should still have full manual control of the aircraft

- Make sure the secondary / trim flight control surfaces move smoothly from max up to max down deflection across a good portion of the servo full range rotation. I.e. do not have them be so sensitive that the servo only moves through a small rotation for full deflection or moves through a large rotation for a very small deflection

- Make sure there is no possibility of the servos being driven beyond the control surface hard stops. You can define end points in the Autopilot flight controller settings

- Ensure the servo torque rating is sufficient for the loads required (as discussed above).

- Ensure you provide a regulated power source for the servos as specified by the manufacturer for maximum torque and install this as close as you can to the servo.

- If your servos jitter and are constantly moving to remain stationary when in use, you may have to upgrade to larger servos, or check your **P I D** values (see Autopilot user guide) Continuous servo jitter will cause them to get very hot, and possibly fail

- It is strongly recommended to use shielded cable (shield connected to ground, Belden 8451 shielded 22 AWG or similar) for all servo wires, and to use differential drivers for cable runs greater than 10 feet (available at xflighttech.com)

Example Installation:

For the Hummel H5 elevator trim, the servo was mounted inside the control surface as shown below. It was mounted to 2 square aluminum tubing pieces with wooden dowel glued inside, with the servo screwed into the wood, and then the tubing pieces riveted to the elevator control surface from underneath.

A slot allows the servo arm to come out with sufficient clearance (about 1.5 inches in this case) to connect via a control rod to the trim tab horn.

H5 trim tab servo mounted to 2 square aluminum tubing pieces with wooden dowel glued inside. These are then riveted to the control surface from underneath

Slot allows the servo arm to come out and connect via a control rod to the trim tab horn.
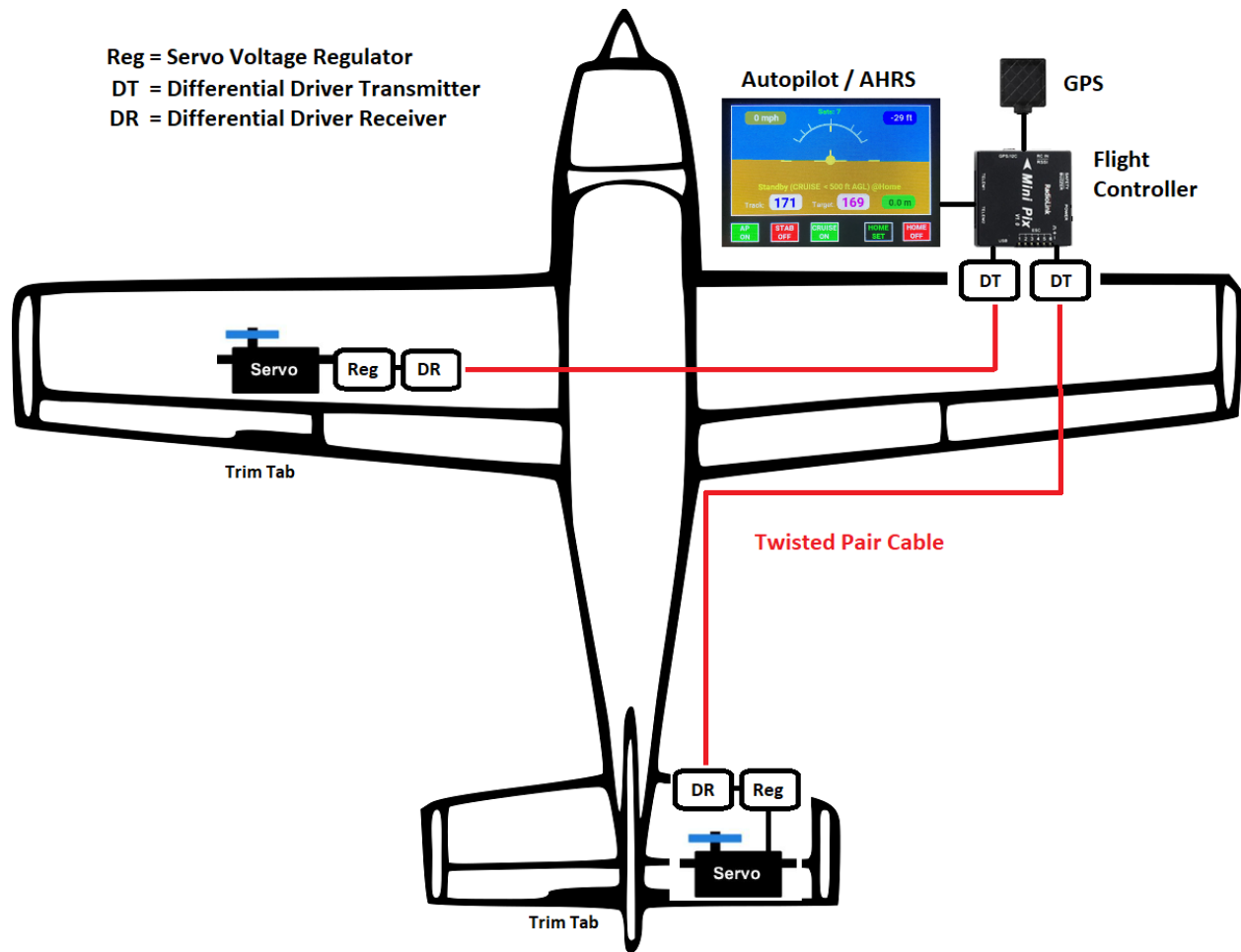
H5 trim tab with servo access panel on elevator control surface

*Another example of a trim tab riveted to the trailing edge of a control surface
with servo control rod and horn*

If there is not sufficient room inside the control surface, it is also possible to mount the servo on the outside.

H. Overall Layout

Reg = Servo Voltage Regulator
DT = Differential Driver Transmitter
DR = Differential Driver Receiver

Autopilot / AHRS

GPS

Flight Controller

Mini Pix

DT   DT

Servo   Reg   DR

Trim Tab

Twisted Pair Cable

DR   Reg

Servo

Trim Tab

Recommended cable:

Signal: **Belden 8451 shielded 22 AWG or similar**

Power: **20 AWG to 22 AWG Electrical cable**

Appendix A.

Xflight Technologies LLC Terms, Conditions and Warranty

1. **PARTIES.** This Contract represents the terms and conditions of sale of Xflight Technologies Products by and between Xflight Technologies LLC, of 1982 State Rd 44, New Smyrna Beach, Florida 32168, USA ("Seller"), and Buyer ("Buyer").

2. **ITEMS PURCHASED**. Seller agrees to sell, and Buyer agrees to buy, one or more of the following products (the "Goods") in accordance with the terms and conditions of this Contract:

Products
Xflight AutoPilot and related sub-components
Xflight AHRS and related sub-components

3. **FLIGHT CONTROLLER.** Note that the use of the Ardupilot opensource firmware, as used in 3rd party Flight Controllers, in this application is contrary to Ardupilot's Code of Conduct for use in Manned Vehicles, for more info see**: https://firmware.ardupilot.org/**

4. **INTELLECTUAL PROPERTY.** Intellectual property created, made, or originated by the officers, employees, or contractors of Seller shall remain the sole and exclusive property of Seller. Any intellectual property associated with Goods, specifically the software, shall remain the property of Seller. Seller retains all rights to its pre-existing intellectual property and any intellectual property it creates in connection with the development and manufacturing of the Goods of this agreement. Parties agree that Seller will retain ownership of all rights in any invention and work product developed pursuant to the agreement and acknowledges that all materials created by the Seller pursuant to and related to the agreement belong to the Seller under United States intellectual property laws.

5. **WARRANTIES.** The Goods are sold on an "AS IS" basis. SELLER SHALL IN NO EVENT BE LIABLE FOR ANY INCIDENTAL, SPECIAL, OR CONSEQUENTIAL DAMAGES OF ANY NATURE, EVEN IF SELLER HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. Seller's liability, if any, for defective Goods, is limited to replacement, repair or refund of the defective Goods, at Seller's option for up to 30 days from date of purchase.

6. **PERSONAL USE**. Buyer agrees to limit the operation and use of purchased Goods to personal recreational use. Buyer agrees to not develop or resell Goods, its components, or documentation to another party without Seller's written authorization.

7. **PRODUCT RISKS**. Buyer acknowledges that the ownership and operation of newly developed autopilot and AHRS products, including the subject Goods contemplated by

this contract, comes with many unforeseeable risks and potential hazards. Buyer has reviewed the risks, safety hazards and recommendations provided by Seller in the User Guide. Buyer has considered these risks and represents himself as a consumer with a sophisticated understanding of aircraft operation and mechanics, vehicle physics, flying safety protocols, and the concepts underlying the Goods' design. Buyer accepts all foreseeable and unforeseeable risks associated with the ownership and operation of the Goods, components, and related equipment.

8. **INDEMNIFICATION.** Buyer shall defend, indemnify, and hold harmless Seller, including its officers and agents, from any and all actual or alleged claims, demands, causes of action, liability, loss, damage and/or injury (to property or persons, including without limitation wrongful death), associated with the ownership and operation of the Goods of this contract. This indemnity shall apply in all actions, whether brought by an individual or other entity, or imposed by a court of law or by administrative action of any federal, state, or local governmental body or agency, arising out of or incident to any acts, omissions, negligence, or willful misconduct of Buyer, its personnel, employees, agents, contractors, or volunteers in connection with or arising out of Buyer's actions. This indemnification applies to and includes, without limitation, the payment of all penalties, fines, judgments, awards, decrees, attorneys' fees, and related costs or expenses, and any reimbursements to Seller for all legal expenses and costs incurred by it.

9. **REMEDIES ON DEFAULT.** In addition to any and all other rights a party may have available according to law, if a party defaults by failing to substantially perform any provision, term or condition of this Contract (including without limitation the failure to make a monetary payment when due), the other party may terminate the Contract by providing written notice to the defaulting party. This notice shall describe with sufficient detail the nature of the default. The party receiving such notice shall have 30 days from the effective date of such notice to cure the default(s). Unless waived by a party providing notice, the failure to cure the default(s) within such time period shall result in the automatic termination of this Contract.

10. **ARBITRATION**. Any controversies or disputes arising out of or relating to this Contract shall be resolved by binding arbitration in accordance with the then-current Commercial Arbitration Rules of the American Arbitration Association. The parties shall select a mutually acceptable arbitrator knowledgeable about issues relating to the subject matter of this Contract. In the event the parties are unable to agree to such a selection, each party will select an arbitrator and the two arbitrators in turn shall select a third arbitrator, all three of whom shall preside jointly over the matter. The arbitration shall take place at a location that is reasonably centrally located between the parties, or otherwise mutually agreed upon by the parties. All documents, materials, and information in the possession of each party that are in any way relevant to the dispute shall be made available to the other party for review and copying no later than 30 days

after the notice of arbitration is served. The arbitrator(s) shall not have the authority to modify any provision of this Contract or to award punitive damages. The arbitrator(s) shall have the power to issue mandatory orders and restraint orders in connection with the arbitration. The decision rendered by the arbitrator(s) shall be final and binding on the parties, and judgment may be entered in conformity with the decision in any court having jurisdiction. The agreement to arbitration shall be specifically enforceable under the prevailing arbitration law. During the continuance of any arbitration proceeding, the parties shall continue to perform their respective obligations under this Contract.

11. **NOTICE.** Any notice or communication required or permitted under this Contract shall be sufficiently given if delivered in person or by certified mail, return receipt requested, to the addresses listed above or to such other address as one party may have furnished to the other in writing. The notice shall be deemed received when delivered or signed for, or on the third day after mailing if not signed for.

12. **ASSIGNMENT.** Neither party may assign or transfer this Contract without prior written consent of the other party, which consent shall not be unreasonably withheld.

13. **ENTIRE CONTRACT.** This Contract contains the entire agreement of the parties regarding the subject matter of this Contract, and there are no other promises or conditions in any other agreement whether oral or written. This Contract supersedes any prior written or oral agreements between the parties.

14. **SEVERABILITY.** If any provision of this Contract shall be held to be invalid or unenforceable for any reason, the remaining provisions shall continue to be valid and enforceable. If a court finds that any provision of this Contract is invalid or unenforceable, but that by limiting such provision it would become valid and enforceable, then such provision shall be deemed to be written, construed, and enforced as so limited.

15. **WAIVER OF CONTRACTUAL RIGHT.** The failure of either party to enforce any provision of this Contract shall not be construed as a waiver or limitation of that party's right to subsequently enforce and compel strict compliance with every provision of this Contract.

16. **APPLICABLE LAW.** This Contract shall be governed by the laws of the State of Florida in the USA.

EXCHANGE OF GOODS

The following provisions relate to the physical exchange of Goods and payment forming the transaction of this agreement.

17. **TITLE/RISK OF LOSS.** Title to and risk of loss of goods shall pass to the buyer upon delivery F.O.B. at the seller's place of home or business to an agent of the buyer including a common carrier, notwithstanding any prepayment or allowance of freight by the seller.

18. **INSPECTION.** Buyer, upon receiving possession of Goods, shall have a reasonable opportunity to inspect the Goods to determine if the Goods conform to the requirements of this Contract. If Buyer, in good faith, determines that all or a portion of the Goods are non-conforming, Buyer may return the Goods to Seller at Buyer's expense. Buyer agrees to securely mail the goods back to buyer with electronic tracking to the address listed above.

19. **PAYMENT.** Payment due shall be made to Xflight Technologies LLC by cash, bank transfer, credit card or PayPal prior to shipment of Goods. If an invoice is not paid when due, seller will not ship Goods to Buyer. In addition to any other right or remedy provided by law, if Buyer fails to pay for the Goods when due or reverses credit card charges after shipment of Goods, Seller has the option to treat such failure to pay as a material breach of this Contract, and may cancel this Contract and/or seek legal remedies.

20. **PAYMENT OF TAXES.** Buyer agrees to pay all taxes of every description, country, federal, state, and municipal, that arise as a result of this sale, excluding income taxes.