# Autopilot — Installation Manual

Kanardia d.o.o.

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A lot of useful and recent information can be also found on the Internet. See `http://www.kanardia.eu` for more details.

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Some open source code is used in the Nesis software:

- https://angusj.com/clipper2/
- https://flatbuffers.dev/

 

- https://www.oberhumer.com/opensource/lzo/
- https://rapidxml.sourceforge.net/
- https://www.sqlite.org/index.html
- https://www.nayuki.io/page/free-small-fft-in-multiple-languages
- https://rapidjson.org/
- https://design.ubuntu.com/font

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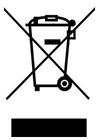


Disposal of Waste Electrical and Electronic Equipment. This electrical item cannot be disposed of in normal waste. Check with your local authority for kerbside collection, or recycle them at a recycling centre.

## Revision History

The following table shows the revision history of this document.

| Rev. | Date | Description |
|---|---|---|
| 2.7 | Mar 2026 | Updated for changes in 4.1 software. |
| 2.6 | Nov 2025 | Maintenance section with checklists was added, some clarifications. |
| 2.5 | Jun 2025 | Bench test clarification was added. |
| 2.4 | Mar 2025 | Updated for changes in Seru v2 and software version 3.12. |
| 2.3 | Jul 2024 | Clarifications for gear reduction ratio and vertical speed D-term. |
| 2.2 | Jan 2021 | Updated for changes in software version 3.9. |
| 2.1 | Nov 2020 | Updated for changes in software version 3.8, Amigo and Nesis windows. |
| 2.0 | Feb 2020 | Complete Manual rework. |
| 1.2 | Jul 2016 | Tuning table expanded. |
| 1.1 | Maj 2016 | Tuning notes were added. |
| 1.0 | Aug 2015 | Initial release. |

# Contents

# 1 Introduction

First of all, we would like to thank you for purchasing our product.

This chapter describes the basic principle on which autopilot operates. After reading it, you will be familiar with basic knowledge you will need to properly install and tune the autopilot.

Be aware that this manual is intended for the new SERU v2 (shown on the cover page). For SERU v1, refer to the Autopilot_Installation_Manual_R2.3.pdf.

| CAUTION: The autopilot is not TSO approved as a flight instrument. |
|---|

## 1.1 Designations

A few icons appear on the side of the manual, which have special meanings:

This icon denotes information that needs to be taken with special attention.

This icon denotes background information about the subject.

This icon denotes a tip.

In the text, `Shall & Should` appear frequently.

**Shall** ...the use of this term indicates a requirement!

**Should** ...the use of this term indicates a characteristics that is not required, but it is highly recommended.

## 1.2 Intended Use

The autopilot is designed to help a pilot in stable, controllable flight conditions during cruising. If such conditions are met, the autopilot can be engaged to take some relief from the pilot, who can perhaps focus a bit more on ATC communication or to do some navigation task. Nevertheless, it is still pilot's responsibility to monitor the autopilot and airplane behavior all the time.

## 1.3 Operation Limitations

Always respect the following limitations.

- Always expect that autopilot can disengage at any time – you must be able to take over the commands at any time.
- Make sure that aircraft is trimmed properly to prevent abrupt change of pitch/roll in the case of sudden autopilot disconnect.
- After every change in the autopilot system, perform the ground test.
- The autopilot shall be only used in VFR (Visual Flying Rules) conditions.
- Information from the Aircraft Operating Handbook always supersedes information given in this manual.
- The autopilot is designed to be used in cruising conditions only. It will not work at low and high speeds. It can't fly approaches and departures and it can't do takeoffs and landings.
- The autopilot shall not be used in turbulence.
- Do not use the autopilot with flaps extended.
- In any case of abnormal activity, the autopilot must be deactivated and the pilot must take over the commands immediately. Never wait for autopilot to deactivate itself automatically.
- Autopilot does not use any information from Magu (magnetic compass).

## 1.4 Minimal Configuration

Most modern light airplanes can be controlled during a stable flight by controlling elevator and aileron only. An autopilot function can be achieved using the following minimum configuration:

- Two servo motors that are mechanically connected with the airplane command system. One motor controls elevator and the other controls aileron.

- An AD-AHRS-GPS device which consists of many sensors and provides crucial information required by the autopilot system (airspeed, rate of climb, pitch, roll, position, direction, altitude, etc.) Such device is inside one of our PDF instruments, for example, Nesis PFD, Nesis lite PFD or Horis PFD.

- A display unit takes pilot inputs like required altitude and direction. It is also used to enter configuration parameters required to properly setup the autopilot system.

- A servo motor controller. It monitors the pilot instructions and information obtained from the sensors and controls the servo motor accordingly.

- A communication system that connects all devices and allow information exchange in real time.

In Kanardia autopilot case, there are two different solutions for an autopilot minimal system.

### 1.4.1 Nesis Based Minimal System

When Nesis or Nesis lite is used as a base, the following minimal equipment is required for a fully functional autopilot:

- Two SERU servo motors. SERU consists of a servo motor and an integrated controlling unit, which serves as a motor driver. One SERU controls elevator and the other controls aileron.

- Nesis III or Nesis IV PFD (also Lite versions). The display has integrated AD-AHRS-GPS device, which provides all sensor data. The display has several buttons and a knob that allow pilot control over the system. In addition, touch screen can be also used on Nesis III.

- Simple RJ45 cables (a.k.a. Ethernet cables) are needed to connect them together. The devices are communicating using the CAN bus system, which is integral part of almost all Kanardia devices.

In this combination Amigo is optional, but recomended nevertheless.

### 1.4.2 Horis Based Minimal System

When Horis is used as a base, the following minimal equipment is required for a functional autopilot:

- Two SERU servo motors. SERU consists of a servo motor and an integrated controlling unit, which serves as a motor driver. One SERU controls elevator and the other controls aileron.
- Horis 80/57 PFD unit with integrated AD-AHRS-GPS device, which provides all sensor data.
- Amigo display, which acts as a command panel for the autopilot.
- Simple RJ45 cables (a.k.a. Ethernet cables) are needed to connect them together. The devices are communicating using the CAN bus system, which is integral part of almost all Kanardia devices.

In this combination, Amigo is essential.

## 1.5 Principle of Operation

When autopilot is active, pilot selects requested altitude, direction and rate of climb or descend. AD-AHRS-GPS device provides current values for almost all flight parameters. Controller units compare the requested values with actual values and give appropriate commands to the servo motors. The PID controller principle is used together with the cascade control system.

The autopilot drives two separate controls: aileron and elevator. In general these two controls are independent, though minor dependency may exists.

Each control has multiple control loops[1]. Elevator control has pitch, vertical speed and altitude loop. The loops are regulated in cascade. This means that requested altitude sets wanted vertical speed and the vertical speed loop sets wanted pitch. The pitch loop then controls the elevator by minimizing the difference between requested and actual pitch.

Aileron works in a similar way. Requested direction sets the required roll angle and the roll loop controls the aileron trying to minimize the difference between requested and actual roll angle.

[1] The control loop is basic term from control theory. In simple terms – the control loop tries to move the actuator in such a way that difference between WANTED and ACTUAL value becomes minimal.

Loops must be properly tuned to achieve requested autopilot operation. Various experimental values in the form of tuning parameters are provided at the end of the document. These values represent good starting point for first autopilot tests.

# 2 Mechanical Installation

This section provides information about the installation of autopilot servo motors (the SERU device) into an airplane. It contains important rules which must be obeyed to have a working and safe autopilot system. The installation information in this section is extremely important and must be clearly understood by the installer.

Important: SERU is not water-resistant. Ensure that it cannot come into contact with water. Take into account scenarios involving excessive rain or other conditions that might allow water to enter the aircraft and potentially reach the SERU.

Improper servo installation or failure to observe and diagnose installation problems prior to flight can result in extremely serious consequences, including loss of ability to control the aircraft. If there are any questions on the part of the installer it is mandatory to resolve these questions prior to flight of the aircraft.

CAUTION: Improper installation could result in lost aircraft controls, injury or death!

## 2.1 Servo Motor

The servo motor must be installed in a fixed position. It must be attached with all four mounting screws. The motor mount should be provided by aircraft manufacturer and has to be adapted to specific airplane model. The motor should be oriented parallel with longer edge regarding control rod connected to the servo arm. The servo schematics is given in Figure 1. It defines three important elements:

1. Safety pin,
2. Arm movement limiter,

(3) Arm.

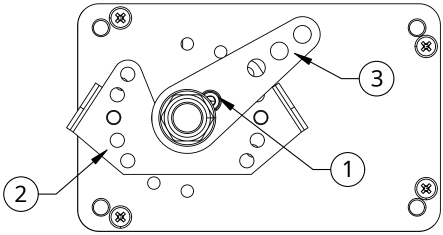



Figure 1: Safety pin, limiter and arm.

## 2.2 Servo Arm

Servo arm has multiple holes for mounting control rod, Figure 2. Choose the hole which maximize the arm rotation. The hole center radius are 28, 34 and 40 mm from the rotation center. Assuming ideal arm rotation of -60°to +60°with neutral position at 0°, this allows for 48.5, 58.9 and 69.3 mm of ideal command rod travel respectively. In practice, command rod travel will be shorter. Namely, ideal mounting position is usually not ideal and full arm rotation is seldom achievable. Some experimentation is required.

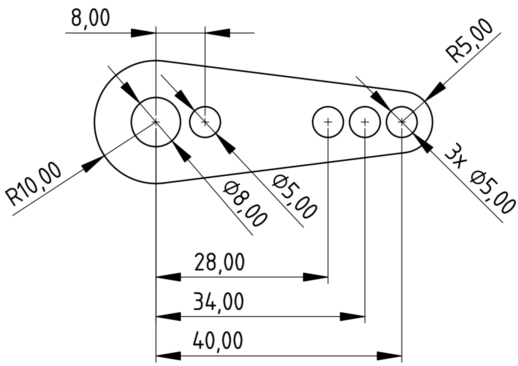



Figure 2: Position of holes.

Servo arm should not be removed or replaced without Kanardia advise. The removal of servo arm includes removal of safety pin. Please contact Kanardia before replacing safety pin for latest instructions.

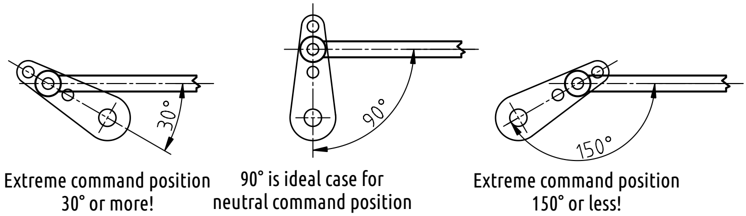



Figure 3: Main servo dimensions.

Figure 3 illustrates valid relative positions between command rod and servo arm. When command is in neutral position, the angle between rod and arm shall be 90° or at least very close to this ideal case. When command is in its extreme position the angle between the command rod and the arm must never be more than 150° or less then 30°.

Under no circumstances the servo arm is allowed to come into position called *over center* – the position at which the primary aircraft control would lock up and will result in a fatal crash. A mechanical stop must be applied to prevent this to happening. Mechanical stops must limit the arm movement at least 30° before the over center situation.

## 2.3 Servo Arm Limiter

To protect against control lock up, a mechanical arm limiter is supplied with servo. The limiter is drilled so that it can be mounted at different angles as required (18° intervals).

The limiter must not prevent aircraft command movements. Always make sure that the controls can have their full travel and they never reach the servo limiter.

## 2.4 Servo Arm Safety Pin

Safety pin is a safety mechanism which prevents blocking of the aircraft command system for the case of blocked servo motor. If servo blocks the command system, pilot must apply high force on the command stick. This force will break the pin and release the servo from command system. Once the pin is broken, the autopilot system is not operational until the pin is replaced.

If safety pin is broken or it gets slack the whole autopilot system must be checked. Only after the cause of the problem was found and corrected, safety pin can be replaced with a new pin. Always use original safety pin.

The safety pin is made from high grade steel (metric grade 12.9) and it is intentionally weaken to break at specific torque applied on servo arm. The pin should sustain 10 Nm occasional torque without any pin damage. This is slightly above the max torque of 8 Nm provided by the servo motor v2 (or 6/3 Nm for the v1 big/small version). The nominal break torque is estimated at 14.3 Nm, the plastic deformation torque is estimated at 12.9 Nm (permanent damage in the pin).

The airplane command system must be capable to withstand the forces in the command system required to break the safety pin.

# 3 Electrical Installation

Servo motor has two electrical connections. The first one provides power for the electrical motor and the second one connects controlling device with the CAN bus. (The controlling device is hidden inside the servo motor).

## 3.1 Electrical Power

The autopilot servo motor must be connected to a 12 V DC standard aircraft power source. It is also possible to use 24 V DC power. The maximum current consumption for one servo motor is 5 A (at 12 V). Always protect servos with an automatic/replaceable fuse and a switch. The fuse protects against over-current and the switch allows quick disconnect by taking power from the motor. Figure 4 shows typical connection.

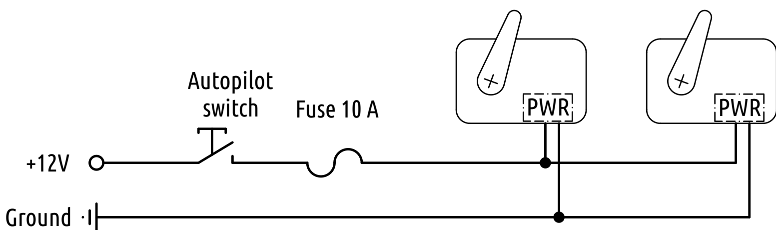



Figure 4: Typical connection of servo motor electrical power.

The *autopilot switch* must be easily accessible by the pilot. The pilot must be able to reach it in any moment.

## 3.2 CAN Bus

Servo motor must also be connected to the CAN bus. The controller module is built in the servo housing. The controller exchanges the information over the CAN bus. In addition, CAN bus is also used to power the controller. This means that controller works even when servo motors are without power.

Figure 5 shows CAN bus connections for the minimal autopilot configuration. In reality more devices can be connected to the CAN bus. The CAN bus goes trough Nesis or Nesis lite, where it is internally connected to AD-AHRS-GPS module, then continues to one servo, the other servo, and beyond if there are any other devices further along.

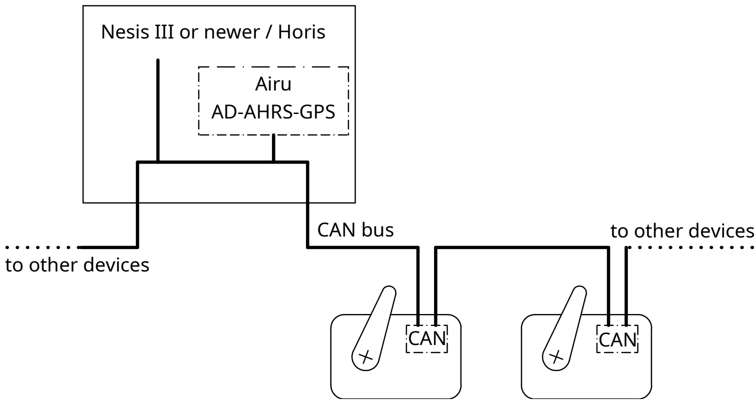



Figure 5: Typical CAN bus connection for Nesis based minimal autopilot configuration.

Please note that CAN bus must be terminated with a 120 Ohm terminator on both ends of the main line. Terminators are not shown on Figure 5.

## 3.3 External Push Button

It is advisable to install an external push button, which allows for quick autopilot disconnect and level commands. The push button shall be installed on the command stick, where it is easily accessed by pilot. Two wires from the push button must be connected to the Nesis service port or to Amigo auxiliary port. The connection details are given in the Nesis installation or in Amigo manual, see the *External Push Button* section.

### 3.3.1 Autopilot Quick Disconnect

Nesis/Nesis lite should be then configured to react on the push button event. When the button is pushed, the autopilot disconnect command is sent via CAN bus to both servo controllers, which will cut power of both servo motors.

In the case of Amigo, no configuration is necessary.

### 3.3.2 Autopilot Level

The same button can be used also used for the autopilot level command. This command will activate Track Hold mode for aileron and Altitude Hold mode for elevator.

In the case of Nesis/Nesis lite, this function must be configured. In the case of Amigo, it is activated by a long press on the external button. No configuration is necessary.

## 3.4 Joyu Command Stick

Alternatively, Joyu command stick can be also used. Joyu has multiple programmable buttons and one or more of its buttons can be assigned to operate the autopilot.

Short press on the button should be used for autopilot disconnect and long press for the autopilot level function.

Please see the Joyu manual for more details.

# 4 Configuration

For the autopilot to operate properly, controllers inside the servo motors must be configured. Once the configuration is complete, the whole system must be also tuned. In general, tuning is needed for every airplane. In most cases airplanes of the same type may use the same autopilot configuration if autopilot mechanical installation is identical.

Any accidental change of any of parameters in this section and subsections may result of autopilot being inoperative.

## 4.1 Overview

These configuration and tuning can be done either with Nesis/Nesis lite or with Amigo. This section includes several figures. Each figure illustrates Nesis solution on the left and Amigo solution in the right.

If you have both Nesis and Amigo, do not use the Autopilot configuration or tuning on both instruments at the same time. Use either Nesis or Amigo.

Next steps reveal typical workflow:

1. In case of v1 servo motors configure both servos. Each servo has several parameters that must be set properly.

2. Perform ground test. Swap functions or reverse axis. Elevator and ailerons must move in correct directions.

3. Set autopilot operation limits. They define an envelope of values, which must be met for AP to operate. This is a very important safety feature.

4. Set autopilot controller parameters. Most of them can be set on the ground, but some must be adjusted during flight tests.

5. Tune autopilot. This is the most difficult part. This can be performed only in flight. Several controller values must be determined.

First three steps shall be set on the ground. Most of the fourth step can be also set on the ground, but may be necessary to change some of parameters during the flight test. Final step can be only done in flight.

Section 7 reveals the workflow for airplanes where autopilot parameters are already known.

## 4.2 Autopilot Settings

Please refer also to the Nesis or Amigo manual.

In Nesis, the settings are accessible from `Service options` page in the display. Special password (provided with the instrument) must be entered to access the Service options page. The password can be also found under the `Info` icon.

In Amigo, press and hold the ALT knob and then select the `Autopilot` from the menu.

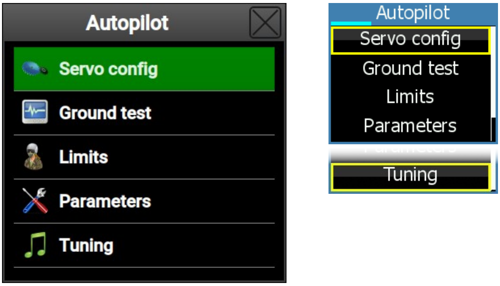



Figure 6: Main autopilot settings menu.

Figure 6 shows the main autopilot settings menu. Nesis version is on the left and the Amigo version is on the right. This pattern repeats throughout this section.

The menu items follow the logic from the workflow:

**Servo config** is used to configure servo motors. Section 4.2.1 reveals the details. This option is present only if any of the Seru units is v1.

**Ground test** is used to make sure that servos are correctly moving the controls. See section 4.2.2.

**Limits** is used to define valid operation envelope of the autopilot, section 4.2.3.

**Parameters** is used to define various controller parameters, section 4.2.4.

**Tuning** is an in-flight operation used to setup PID terms of the controller loops for the elevator and aileron. See section 5.5.

### 4.2.1 Servo Configuration

This option is present and necessary only with v1 version of Seru units.

When setting up an autopilot, configuring the servos is the first step. Two servos are required: one for elevator and the other for ailerons. A servo can perform either role. Each servo has its own serial number.

During the mechanical installation, write down the serial number of the servo which was connected to aileron and the serial number of the servo used for elevator.

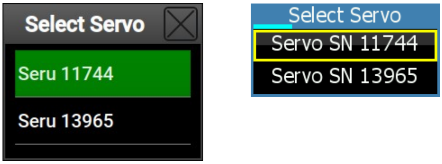



Figure 7: An example of servo selection based on serial number.

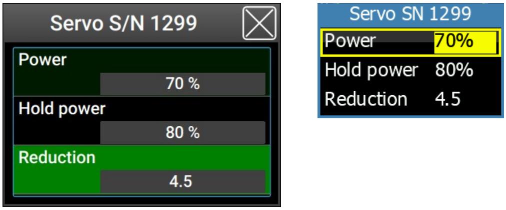



Figure 8: An example of servo settings window.

Select the servo to configure. A selection example is shown on Figure 7. Once serial number is selected a window with servo details opens, Figure 8. The servo configuration window defines following parameters:

**Power** defines how much power (=torque) shall be used by servo when moving its arm. 100% means total servo capacity. Try to avoid using more than 90% due to possible servo overheating. This also depends where and how servo is installed. In long term, try to find the lowest value, which still provides enough torque.

**Holding power** defines how much power is used when motor is not moving. This value depends on the power value above. If it is set to 50% this means that motor will use 50% of the torque set with the power parameter. For example, if power is set to 70% and holding power is set to 50%, the motor will use 35% of maximal power (torque) at standstill.

**Reduction** is the gearbox reduction factor between the arm and stepper motor. (This factor is 4.57 for recent servos. But factors between 4 and 5 are also in use.) This is servo motor characteristics and shall not be changed. Note: In Amigo you can approximate this value in 0.05 steps. This may introduce a minor error, which is negligable.

In general, `Reduction` shall not be changed and original value (4.5) shall be kept. Change them only if Kanardia support team approves the changes.

### 4.2.2 Ground Test

The ground test is used to check and configure correct servo motor movement. Figure 9 illustrates available options. First test movements and modify by swaping functions or reversing appropriate one.

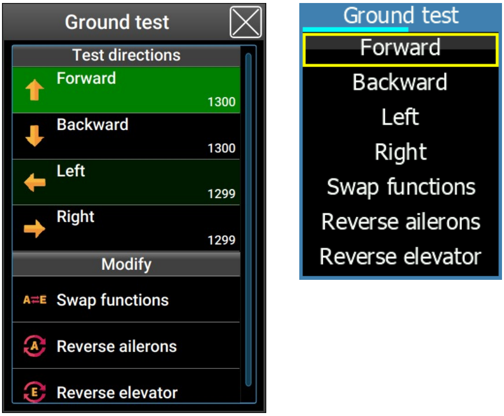



Figure 9: Ground test movement options.

**Forward** shall move the command stick slightly forward (nose down). Make sure that command stick is not fully forward before this command is issued.

**Backward** shall move the command stick slightly backward.

**Left** shall move command stick slightly to the left.

**Right** shall move command stick slightly to the right.

**Swap functions** swaps the function between servo motors. The motor which is controling elevator now controls aileron and vide-versa.

**Reverse aileron** reverses motor direction for aileron.

**Reverse elevator** reverses motor direction for elevator.

You can issue the same command several times in the row.

In many cases the weight of elevator control pulls stick forward on the ground. Servo is probably not strong enough to overcome this weight. In this case, hold the stick gently in the neutral position and execute the `Forward/Backward` commands. You will feel servo movement in your hand.

If a movement appears in wrong direction, reverse appropriate function.

If servo moves a wrong command, swap the functions.

Do not start with the tuning process until you are 100% sure that ground test works correctly.

When performing test on a bench of version 2 motor (Seru v2), make sure the servo lever does not move freely. Hold the servo lever fixed with one hand while engaging the servo. If you want to repeat test several times, the best solution is to fix some push-pull spring to the servo lever, which prevents free lever movements in both directions.

### 4.2.3 Operation Limits

Autopilot is allowed to operate only when the airplane is within operating limits of approved autopilot use.

The limits shall be defined by the airplane producer. These autopilot limits are much, much stricter than airplane capabilities. The limits are set around stable, coordinated flight at the economy cruise speed.

As soon as any parameter goes out of the limits, autopilot will be disabled.

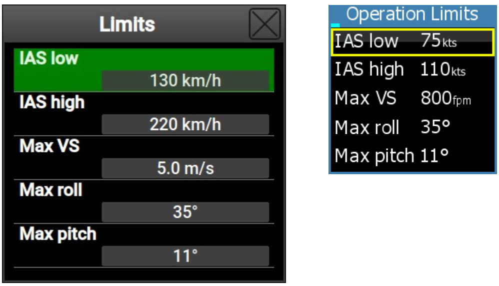



Figure 10: An example of autopilot operation limits.

The following limits must be set:

**IAS low** . . . set this slightly below the economy cruising speed. This shall be significantly more that the stall speed. In fact, this should be set above VFE.

**IAS high** ...set this slightly above the economy cruising speed. This shall be significantly less than VNE.

**Max VS** ...set maximal allowed rate of climb or descent.

**Max roll** ...maximal allowed roll for autopilot operation. Set this to 35° or less.

**Max pitch** ...maximal allowed pitch for autopilot operation. Set this to 12° or less.

All limits must be checked with a flight test after the tuning has been completed. The limits must be set conservatively. Make any adjustments with great care.

Flying with the autopilot at a slow speeds is not allowed. It would be extremely dangerous. The dynamic characteristics of the airplane at low speed can be completely different from the characteristics at cruising speed.

Flying with the autopilot at high speeds is not allowed. It would be extremely dangerous. The dynamic characteristics of the airplane at high speed can be completely different from the characteristics at cruising speed.

### 4.2.4 Controller Parameters

This window defines various parameters that are required for optimal operation. Some of these values can be only determined during flight test. Figure 11 illustrates an example.

**Strategy** Controls which control strategy is autopilot using. Changing strategy is usually not needed and almost always it requires re-tuning of controler parameters. Use default strategy *A2*.

**Pitch backlash** Controls how much rotation is added to motor movement when reversing the direction. This nulls free movement between servo main shaft and command system. For pitch this is ussually not needed because the there is always some aerodynamic force present on the elevator.

**Pitch target** this is the maximal pitch angle that controller will require for a climb or a descent. This angle shall be smaller than max pitch from the limits, section 4.2.3.

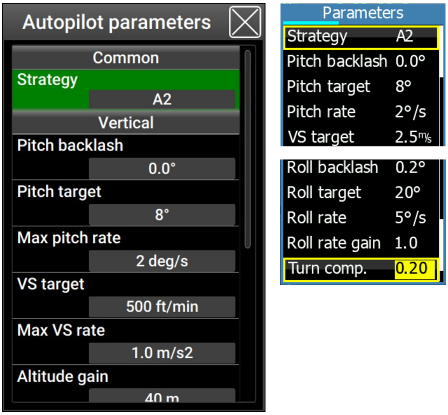



Figure 11: An example of autopilot parameters.

**Max pitch rate** tells how quickly pitch reference can change. Controller loops are calculated several times per second and they change their *desired* pitch all the time. If the outer loop – vertical speed control loop asks for a quick change in pitch, the controller will limit the speed of change to the value entered here. The airplane will therefore make a smooth transition.

**VS target** is the target vertical speed, when change in the elevation is required. This speed shall be smaller than max vertical speed from the limits, section 4.2.3.

**Max VS rate** is the rate of change of the target vertical speed (it has dimension of acceleration). Similar as above, but now for vertical speed.

**Altitude gain** controls how much altitude difference from setpoint is needed to command VS target. Leave default 40m for most planes.

**Roll backlash** Controls how much rotation is added to motor movement when reversing the direction. This nulls free movement between servo main shaft and command system. You can adjust this value also when tuning roll loop.

**Roll target** is the maximal roll that can autopilot require in order to change direction. This angle shall be smaller than max roll from the limits, section 4.2.3.

**Max roll rate** tells how quickly roll reference can change. Same as above, but now for the roll angle. If the outer loop - heading control loop asks for a quick change in roll, the controller will limit the speed of change to the value entered here. The airplane will therefore make a smooth transition.

**Roll rate gain** controls how much the deviation from target roll angle directs roll rate controller. Setting this to 1 means that 3 degree angle deviation will direct 3 deg/s roll rate. Minimal value is special and it means that Roll rate gain mode is disabled.

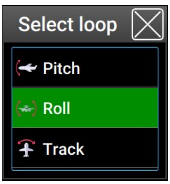
**Turn comp** defines amount of elevator compensation that is required when airplane is executing a turn. Pitch will be slightly increased during the turn. The increase grows with the roll angle.

### 4.2.5 Tuning

Tuning is a in-flight operation. This operation is quite complex and is based on *trial and error*. Here only window description is given. Please refer to the section 5.5 for details about the tuning procedure.

conducted on a clear, VFR day. Before commencing the flight test, ensure that you have adequate altitude, enough fuel, clear weather, no traffic, no obstructions in the flight path, great visibility, no airspace conflicts, etc.

When the `Tuning` option is selected from the Autopilot menu, a window illustrated on Figure 12 appears. Select one of four autopilot control loops to tune.



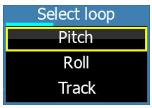
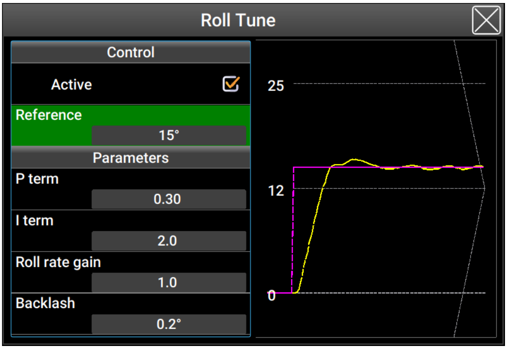




Figure 12: Selection of an autopilot control loop.

Once loop was selected, a tune window appears. This window allows changing the PID controller parameters and observing the response at the same time. Figure 13 illustrates the example.

The `Ref.` represents the loop target value. The target value is changed and airplane response is observed in the chart. The target is drawn in magenta color and the response is in yellow.



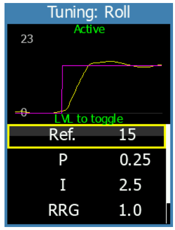




Figure 13: An example of roll loop tuning window.

P, I and D terms are controller terms. The controller tries to reduce an error between a target (magenta) value and an actual value (yellow). Error is a difference between target and actual value.

**P term** defines controller's proportional (gain) part.

**I term** defines controller's integral (cumulative) part. Only present on some loops.

**D term** defines controller's derivative (rate of change) part. Only present on pitch and track loops.

**Rate gain** defines controller gain to calculate desired rate for the loop. Only present on roll loop if roll rate gain mode is active.

**Backlash** defines servo movement when reversing direction. It is the same parameter as in Controller parameter. It is listed here for convinience.

# 5 Tuning

Each autopilot must be taught how to fly a plane. This is done during tuning procedure. The following section provides you with a necessary knowledge how to properly tune the aircraft autopilot.

The tuning of the autopilot is based on trial and error method. The operator has to gain knowledge and experience. It will take time and it is possible that more than one flight is needed to complete this task properly.

## 5.1 Controller

The controller is a system which monitors the process and calculate the required output of the actuator to keep the process variable within a set range. Autopilot actuators are motors which moves aircraft control surfaces and process is aircraft which is monitored with multiple different sensors.

### 5.1.1 PID controller

The Kanardia autopilot is using standard `PID` controllers. A `PID` controller is control loop mechanism employing feedback of controlling parameter. A `PID` controller continuously calculates an error value as the difference between a desired reference and a measured process variable (roll, pitch, VS and heading). It applies a correction based on proportional, integral, and derivative terms (denoted `P`, `I`, and `D` respectively). During tuning the operator is searching for optimal terms inside each loop: roll, pitch, vertical speed and heading.

**P term** or *gain* defines controller's proportional part. For example, if error is large and positive, the controller output will be also proportionately large and positive.

Unfortunately the P term is bad in removing small errors and here `I-term` comes into play.

**I term** is the integration time of the controller. It tells how fast the controller is trying to eliminate the steady-state error. The more error persists, the larger will be its time integral and consequently, the larger will be integral contribution.

**D term** is an estimate of the future trend of the error. It is based on the rate of error change. The more rapid the error change, the greater the controlling or dampening effect.

Typical block representation of the controller with feedback is shown on figure 14. The input to `PID` controller is the difference between reference and measured process value. Output of the controller must control the process to reduce the difference. Controller performance depends heavily on the accuracy of the sensed process variable and the precision of the actuator.

If you are interested in PID controller, a good start may be the Wikipedia article, `https://en.wikipedia.org/wiki/PID_controller`.

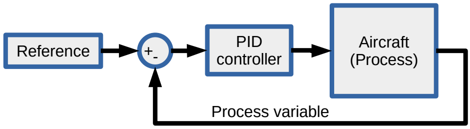



Figure 14: Typical PID controller block diagram.

## 5.2 Step Change and Response

Controller tuning is an iterative process. The operator triggers a step change of the reference value for each loop observing the aircraft response. Based on the aircraft response the terms of the controller are modified to get optimal ones. Analysis of response needs few technical terms which are explained with a figure 15:

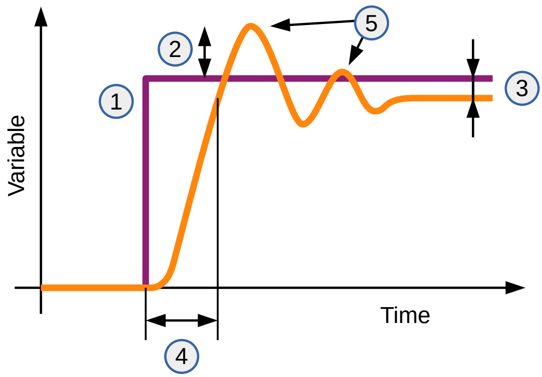



Figure 15: Step response of closed loop system.

1. Reference step change.
2. Overshoot.
3. Steady-state error - remaining error.
4. Response time - 90% of reference step.
5. Oscillations.

## 5.3 Cascade Controller

The main problem of the aircraft control is the fact that the aircraft is a complex process. We have to control at least elevator and ailerons. For each one we are using a cascade control system.

A cascade control involves the use of two controllers. The output of the first controller provides the reference for the second controller.

The example of cascade PID controller for an elevator is shown on figure 16. Note that there are two feedback loops and two controllers. Inner controller is controlling pitch of the aircraft and outer is controlling its vertical speed.

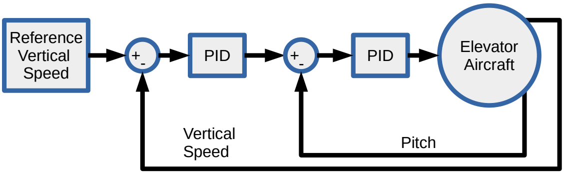



Figure 16: Elevator cascade `PID` controller block diagram.

The important fact of this system is that outer loop response depends on the performance of the inner control loop. This means that inner control must be tuned first and the response of the inside loop must be good enough.

## 5.4 Controller Problems

The `PID` controller is very robust but sometimes the tuning does not provide any usable results. There are two major problems which influence the control loop behavior: mechanical backlash and motor slip.

### 5.4.1 Backlash

is lost motion between the servo motor and the control surface. It has a negative impact on control loop performance. Mainly it results in constant and stable oscillation of aircraft around a problematic axis.

In this case it is best if the backlash in commands is removed. This needs some study where and why the backlash is present. However sometimes this is not doable without serious redesigning the autopilot mechanical linkage. Also it is possible that there is elastic backlash present.

In those cases we provided software backlash compensation. This means that on each servo motor reversal of the direction the motor moves for pre-specified angle. This angle is specified in the servo config dialogue specified in section 4.2.1.

### 5.4.2 Slip

When the momentum on the motor arm is too large the motor will slip. Slipping motor is unable to control the aircraft. Resolve slip issues on either axis before proceeding, either by increasing motor torque, changing hole on control arm or switching to a larger servo. If the motor is slipping there are no software options.

You can notice the slipping as a sudden small jump of the stick. The most common behavior of the aircraft with one of the servos slipping is that aircraft suddenly starts a turn and is unable to correct it.

## 5.5 Tuning Procedure

The tuning of the autopilot requires a ground preparation and a flight testing.

### 5.5.1 On-Ground

Before first flight the operator shall enter appropriate initial values for the autopilot, as described in section 7. The `P-term` of control loops shall be slightly smaller than `P-term` for similar aircraft. `I-term` shall be set to 3.0s for roll and pitch loop. Set `D-term` to 0.0 for appropriate loops.

Conduct the ground motor test.

AD-AHRS unit inside Horis or Nesis (lite) used for autopilot control must be leveled. When in level flight at desired cruising speed it shall show zero bank and pitch angles.

### 5.5.2 In-Flight

The flight test should be conducted on a calm, VFR day. Before commencing the in-flight tuning, ensure that you are at the safe altitude, you have enough fuel, clear weather, no traffic, no obstructions in the flight path, good visibility, no airspace conflicts, etc.

It is highly recommended that you bring someone along on the autopilot test flight. At many points the pilot's attention will be divided between documentation, tuning autopilot, and maintaining situational awareness. An extra pair of eyes looking out is very helpful.

## 5.6 Tuning Rules

The operator should follow following rules during in-flight tuning and testing the autopilot:

- Make notes during flight.
- Change only one parameter or term at once.
- Make small changes of parameters ot terms.
- Test every parameter change multiple times.
- Always tune `P-term` first, next `I-term`, last `D-term`.
- Keep `D-term` small - max. 1/10th of a `I-term`.
- `I-term` of inner loop shall be smaller than `I-term` of outer loop.

# 6 In-Flight Tuning

Kanardia autopilot system uses two-axis control: elevator and aileron. The tuning of autopilot is divided into two independent tasks. The operator shall tune the elevator control first and then move to aileron control tuning.

Please note that during the tuning of the elevator the pilot is responsible to maintain roll angle of the aircraft and take care for direction as well. When tuning ailerons the autopilot will already keep control over elevator. Therefore it is a bit more difficult to tune the elevator.

## 6.1 Elevator

Elevator control consist of two cascaded control loops: pitch and vertical speed. The operator has to tune the pitch loop only.

During in-flight tuning the elevator will be controlled by the autopilot servo. The pilot shall maintain aircraft leveled with ailerons during the elevator tuning but it shall not move the elevator control.

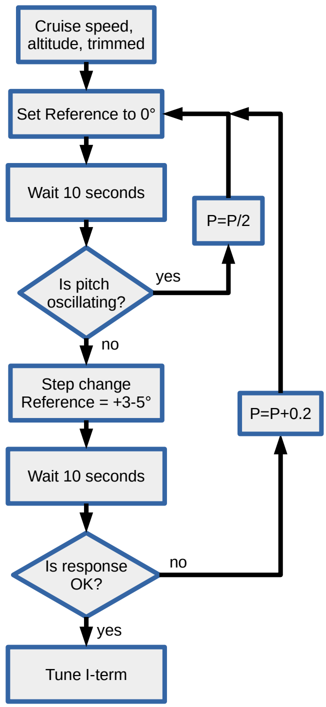
### 6.1.1 Pitch tuning

When reaching target altitude and cruising speed make sure the aircraft is trimmed properly for a level flight. The operator shall enter the Tune dialog for pitch loop as shown in figure 13. By default the autopilot servo motor is in disabled state. The autopilot is enabled by clicking Active menu item on Nesis or by press LVL button on Amigo.

We provided a real tuning procedure example on figure 17. We choose 0.5 for initial `P-term`. Then we gradually increased the `P-term` by 0.2 until we reach satisfactory response. There should be small overshoot present and the servo motor should quickly react to the pitch reference change. Before every step change set reference to 0° and wait for the aircraft to stabilize. Follow provided flow charts for tuning each controller term.

**P-term** shall be tuned following flow chart shown in figure 6.1.1. Start with low `P-term` and then gradually increasing it, until you reach satisfactory response.

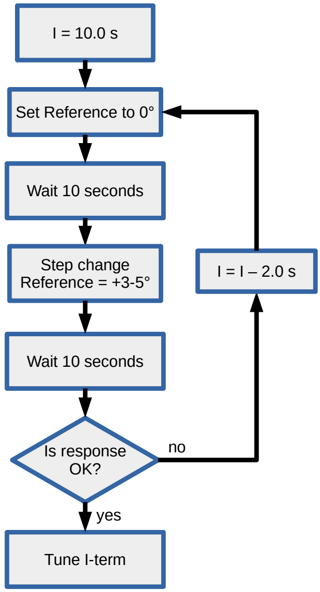
1. Set 0 degrees reference angle.
2. Steady state - Wait enough time for controller to stabilize. Around 10 seconds usually is enough.
3. Step change - Change reference angle by 3-5 degrees. This depends on aircraft. In our example we choose 4 degrees.
4. Observe - Wait 10-15 seconds.
5. P-term - Depending on the aircraft response we have to modify the `P-term`. Please see example tuning on figure 17 for example responses and appropriate actions.
6. Repeat - Go back to step 1.



**I-term** shall be set to start value. Tune it following flow chart shown in figure 6.1.1. Start with high `I-term` and then gradually decrease it, until you reach satisfactory response.

I-term will add some oscillations, do not worry about this for now. The `D-term` should damp it enough. If you get too much overshoot or too much oscillations it is possible that you have basic control loop problems as described in 5.4.

1. Set 0 degrees reference angle.
2. Steady state - Wait enough time for controller to stabilize. Around 10 seconds usually is enough.
3. Step change - Change reference angle by 3-5 degrees. This depends on aircraft. In our example we choose 4 degrees.
4. Observe the response - Wait approx. 10-15 seconds.
5. Modify the `I-term` according on the aircraft response. Please see example tuning on figure 17 for example responses and appropriate actions. If you would like to decrease the response time `I-term` should be decreased.
6. Repeat - Go back to step 1.

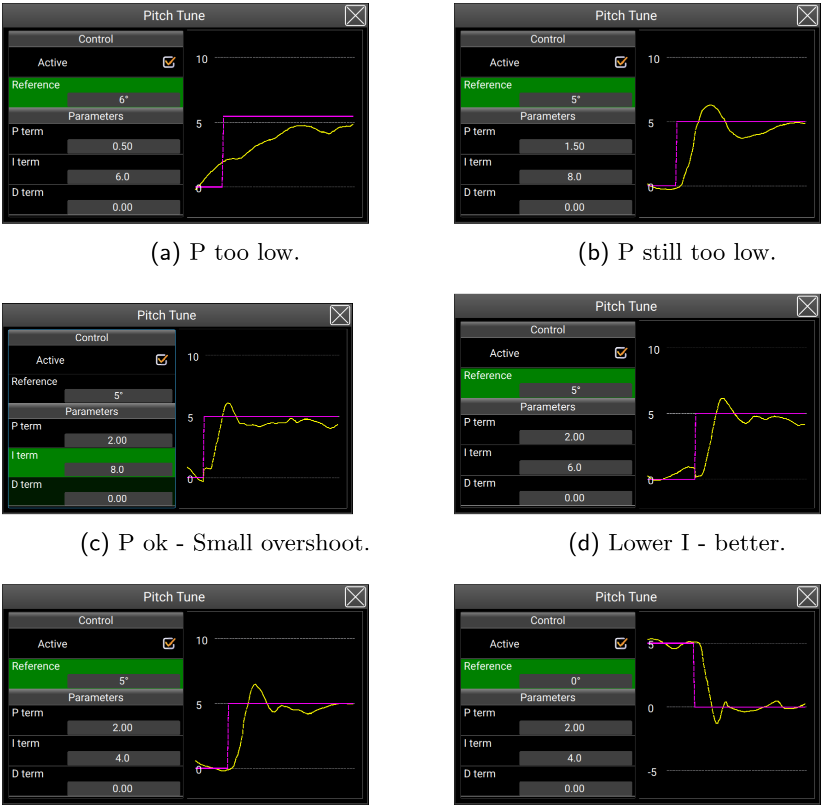



**D-term** should be set to 0.0

**Testing** After successful tuning of pitch loop the operator shall test the pitch loop with different reference angles. The aircraft response shall be with small overshoot and without oscillations.

Be aware that setting excessive reference pitch angle values will cause that aircraft will pitch up or down quickly. Depending on the aerodynamics of the aircraft the airspeed can change quickly. Keep the aircraft within safe limits.



(a) P too low.

(b) P still too low.

(c) P ok - Small overshoot.

(d) Lower I - better.

(e) Lower I - even better.

(f) Test also in minus

Figure 17: Example of pitch tuning process.

## 6.2 Aileron tune

With properly operating elevator autopilot it is much easier to tune the remaining aileron axis. For aileron axis we have to tune two control loops: roll and heading.

### 6.2.1 Roll tune

There are two major operating modes for roll loop. From software version 4.1 the only officially supported mode whith Roll rate gain paramater enabled.

The old mode is kept for compatibility only and should not be used on new airplanes. In this manual we will describe only the tuning with the roll rate controller.

**P-term** in roll loop tuning is the gain of roll rate controller. Dashed lines in tuning dialog marks the selected Maximum Roll Rate parameter. Before first tuning we should set this parameter to the default safe value of 5°/s.

We start tuning with a low value for `P-term`. On our example on Figure 18 we started with `P-term` of 0.5. The `P-term` is then gradually increased to obtain fast enough response without oscillations.

**I-term** When tuning the `I-term` the starting value should be around 3-4s. After setting the `P-term` we can try to gradually decrease `I-term` to improve response, but if you get a response with oscillations `I-term` shall be increased by at least 1.0s.

**Roll rate gain** tells controller the factor to calculate the desired roll rate from the roll angle error. If this parameter is set to 1.0 this means that autopilot will try to correct the error of 5° with an roll rate of 5°/s. For start it should be set to 1.0. This value is fine for most installations.

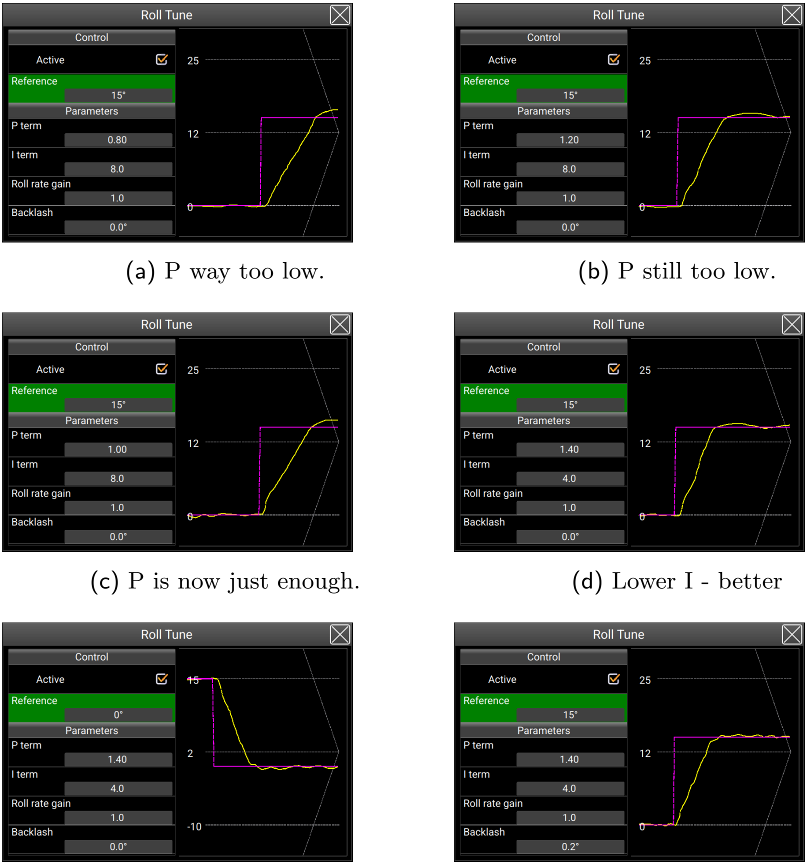
**Backlash** If overshoot occurs during autopilot operation, the most probable cause is backlash in the control commands. Gradually increase the backlash parameter in small increments of about 0.2-0.5 degrees per step. After each adjustment, test system response and evaluate whether the overshoot condition is reduced. Continue increasing the backlash value until stable system response is achieved without overshoot.

### 6.2.2 Heading tune

If the roll control loop is operating properly the tuning of the heading loop is usually simple. However the operator must check that response of the aircraft is good enough under operating all conditions. The starting values for `P-term` shall be 1.0 and `I-term` 25.0s. The step angle for testing the controller response should be 10° larger than selected *Target Roll Angle*.

**P-term** should be set to 1.0 as a starting point. After step change it should be increased if the response of the aircraft heading is too slow. The usual `P-term` values range from 1.0 to 1.8.




(a) P way too low.

(b) P still too low.

(c) P is now just enough.

(d) Lower I - better

(e) Test into other direction.

(f) Set backlash - lower overshoot.

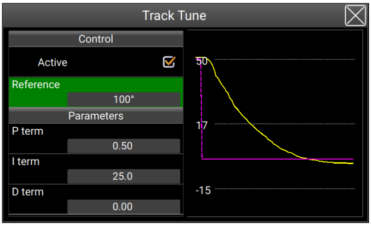
Figure 18: Example of roll rate tuning process.

**I-term** shall be set to 25.0s.

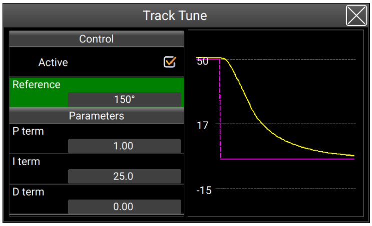
**D-term** shall be set to 0.0.

## 6.3 Fine tuning

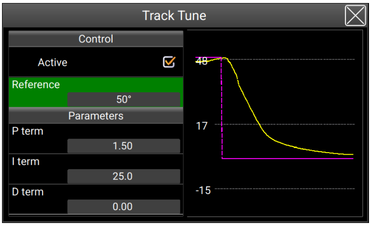
There are some parameters that should be adjusted after the basic tuning is done. This parameters will improve autopilot performance.



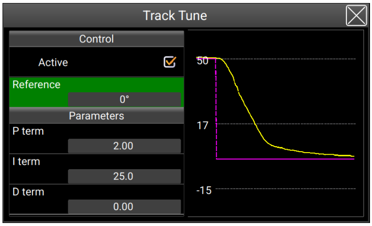

(a) P = 0.5.




(b) P = 1.0.




(c) P = 1.5.




(d) P = 2.0.

Figure 19: Example of heading tuning process.

### 6.3.1 Roll feed forward

This parameter sets how much the elevator control is pulled or pushed during the turn. When initiating the turn observe the pitch of the aircraft. If it dives when initiating turn and climbs when finishing it you have to increase Roll feed forward parameter. For most ultra-light aircraft's it should be around 0.2 and 0.3.

For start it should be set to 0.1. Now with autopilot in level mode change autopilot heading. If the aircraft still dives when initiating turn you should increase the this parameter by 0.1 and re test. Repeat this two steps until you find a value which is applicable for your aircraft.

### 6.3.2 Motor power

Only in the case of v1 servo motor.

If the stick is very hard to overcome the torque of the motor the torque of the appropriate axis should be lowered. This will reduce the current consumption of the motor and it will reduce the motor heating. Also the pilot will be able to override the autopilot with more appropriate force.

# 7 Quick Configuration

This is a quick guide for Nesis operations required to configure the autopilot system for a know airplane.

## 7.1 Configure Servos

Options ⇒Service Mode ⇒Autopilot ⇒Servo config

Only if using v1 version of servo motor. Configure torque and holding torque to a reasonable values which allows overriding the commands.

## 7.2 Direction Test

Options ⇒Service Mode ⇒Autopilot ⇒Ground test

Press move forward, backward, left, right. The yoke/stick should move in the correct direction. If the movement is opposite, change the `Reversed` parameter in Servo Configuration.

## 7.3 Operating Limits

Options ⇒Service Mode ⇒Autopilot ⇒Limits

- Minimum IAS: 140 km/h
- Maximum IAS: 200 km/h
- Maximum vario: 6 m/s
- Maximum Roll: 30°
- Maximum Pitch: 12°

Values shown above are given for example only – use appropriate limits for your airplane. If the aircraft exceeds this limits the autopilot will disengage immediately and the reason will be shown on the display.

## 7.4 Parameters

Options ⇒Service Mode ⇒Autopilot ⇒Parameters
Use appropriate parameters for your airplane.

## 7.5 Tuning

Options ⇒Service Mode ⇒Autopilot ⇒Tuning
Enter values from tables given in section C for all loops

- Pitch
- Roll
- Heading

Please fill the report from appendinx A once the installation and tuning is complete and send the form to Kanardia. The form is needed for future references and maintenance purposes.

# 8 Safety Measures

> Autopilot system is not terrain or traffic aware and it will not make any avoidance action or issue any terrain warning!

The autopilot is directly linked with aircraft commands thus it presents high risk if something fails or goes wrong. Kanardia autopilot is using following safety measures in order to reduce this risk to a minimum.

- Automatic disable when aircraft is outside safe operating limits.
- Multiple Manual disable options.
- Servo power switch immediately cuts the power of servo motors.
- Servo v2 has internal clutch which disconnects output shaft to internal gearbox and motor.

- Servo v1 can be safely overridden, but commands are stiffer and jerky.
- Safety pin will break if the motor or gears inside are mechanically blocked.
- Plastic internal gear will fail if the motor or gears inside are mechanically blocked.
- Mechanical limiter limits the movement of the motor lever preventing mechanical lock-up.

Only v1 servo motors are designed to be over-driven with external force from command stick with no damage in enabled state. Do not override the controls with engaged servo motor v2. There is a posibility that internal gear or shear pin will be damaged.

## 8.1 Automatic Disconnect

The Autopilot will disconnect automatically and immediately when any of the following values is out of the range:

- minimum autopilot IAS,
- maximum autopilot IAS,
- maximum autopilot vertical speed,
- maximum autopilot roll angle,
- maximum autopilot pitch angle.

These values must be configured correctly and they depend on the type and performance of the aircraft. See section 4.2.3 for limit details.

## 8.2 Manual Disconnect

The following ways may be used to disconnect autopilot system manually:

1. Select the *Disconnect* option from the autopilot menu of Nesis.
2. On Nesis, press the *User* button when the autopilot menu is active (double click on user button).

3. On Nesis, make a long press on the *User* button – the long press function must be properly configured.

4. When an external push button is installed on a command stick, press the button to disconnect the autopilot. Nesis or Amigo must be properly configured.

5. When *Joyu* is connected to the CAN bus and its buttons are properly configured, press (or long press) the corresponding button on Joyu.

6. When *Amigo* is connected to the CAN bus, press the top knob to disconnect aileron servo and bottom knob to disconnect the elevator servo.

7. On Nesis only, make a long touch on autopilot status window.

## 8.3 Power Disconnect

The autopilot motors are disconnected as soon as power supply is removed. Therefore it is essential that the power to the servo motors can be cut with removable fuse or with a separate switch. See section 3.1 for more details.

## 8.4 Out-of-Trim Disconnect

When the autopilot servos use excessive force to counter an out-of-trim condition, the autopilot may automatically disconnect. Initially, the system increases servo torque to maintain control, but once the required torque exceeds its limit, it can no longer compensate and may disengage abruptly. This sudden and unpredictable disconnect presents a hazard.

## 8.5 Mechanical Disconnect

Safety pin is the inserted between the servo arm and the servo motor shaft. In the very unlikely case of blocked motor or blocked gears, pilot can use force on the command stick, which will break the pin and release servo motor shaft from the command system. In case safety pin does not break last internal gear on output shaft is made from plastic and it will break at slightly larger force that safety pin.

# 9 Maintenance

This section provides general guidance on autopilot servo maintenance. These are recommendations only — always follow the aircraft manufacturer's POH (Pilot's Operating Handbook) instructions, as they take precedence.

## 9.1 Preventive Schedule

The autopilot installation shall be check periodically for optimal performance and safety.

- `50-100h` – Visual servo inspection & wiring check.
- `200h or annually` – Clean and more detailed check, ground test.

## 9.2 Ground Checklist

Below is a recommended checklist to be followed:

1. Preparation
   - Aircraft is secured and powered off.
   - Circuit breakers for the autopilot are pulled / deactivated.
   - Tools and supplies are ready.
2. Access & Inspection
   - Open servo access panel or remove necessary interior panels.
   - Visual inspection checklist:
     - Servo unit securely mounted, no loose screws.
     - No visible corrosion, moisture, oil, or debris.
     - Control cables or pushrods attached and safety-wired.
     - Wiring harness intact, no chafing or loose connectors.
     - Clevis pins (if any) / control linkages secure and free of play.
3. Electrical & Mechanical Checks
   - Electrical connector
     - Check for corrosion on pins/sockets.

    - Clean with approved contact cleaner if required.
  - Arm movement test
    - Gently rotate control surface or servo arm by hand — ensure smooth resistance (not binding or slipping excessively).
  - Linkage free play
    - Make sure there is not excessive play in the system.

4. Functional Test (After Reconnection & Power-On)
   Only after all covers are back in place, no tools left inside, and aircraft power is safe to use.
   - Restore power / push autopilot circuit breaker back in.
   - Engage autopilot in test mode or hold mode.
   - Verify:
     - Controls move smoothly when autopilot is not activated.
     - Servo turns on and applies pressure.
     - No abnormal noise (grinding, buzzing).
     - Servo arms move in correct direction during the direction test.
   - Test abrupt autopilot disconnect: during direction test, remove the autopilot circuit breaker - all servos must disconnect.

## 9.3 In-Flight Checklist

The following in-flight functional checks shall be made. Always remain ready to take over the controls. Make sure you know how to emergency disconnect the autopilot.

Before autopilot is activated or any autopilot command is given - aircraft must be trimmed to stable flight.

1. Activation & Basic Control
   - Trim the aircraft.
   - Activate the autopilot in the `LVL` mode.
   - Verify:
     - Smooth engagement (no sudden control inputs).
     - No oscillations.

  - Track (direction) is hold within 2-3 degrees.
  - Altitude is hold within 50 feet.

2. Tracking Mode

   - Select tracking mode. Set target tracking 20 or 30 degrees left or right.
     - Check correct bank angle and turn rate.
     - Smooth roll in and roll out on selected tracking.

3. Altitude Mode

   - Check engine power settings. Be prepared to apply or reduce power as needed.
   - Set target altitude 1000 feet higher or lower then current altitude.
   - Verify:
     - Smooth transition for climb/descend.
     - Observed climb/descend rate is close to target climb/descend rate.
     - Once altitude is reached, smooth transition to target altitude.

4. Disconnect by Command
   Always remain alert for a potential out-of-trim condition, which may result in unexpected and abrupt change in pitch or roll.

   - Activate the LVL mode. Wait a few moments.
   - Hold commands and disconnect autopilot by pressing the disconnect button.
   - Verify:
     - Autopilot servos must disconnect – move commands slightly to check.
     - Check visual warning about autopilot disconnect.
     - Check audio warning about autopilot disconnect.
   - If there are more options to disconnect, check them all by repeating the process.

5. Disconnect by Power Cut (Emergency Disconnect)
   Always remain alert for a potential out-of-trim condition, which may result in unexpected and abrupt change in pitch or roll.

- Activate the LVL mode. Wait a few moments.
- Hold commands and deactivate autopilot by pulling the autopilot power fuse.
- Verify:
  - Autopilot servos must disconnect – move commands slightly to check.
  - Check visual warning about autopilot disconnect.
  - Check audio warning about autopilot disconnect.

6. Disconnect by Applied Force
   Always remain alert for a potential out-of-trim condition, which may result in unexpected and abrupt change in pitch or roll.

   - Activate the LVL mode. Wait a few moments.
   - Pull or push the command stick. Autopilot will fight against your input. Slowly and steadily increase the applied force. Once enough force is applied for some period of time, autopilot will disconnect the servo.
   - Repeat the test for the other axis.

7. Disconnect by Out-of-trim
   Dangerous: This procedure will place the aircraft in an out-of-trim condition, which will cause sudden and unexpected control forces. Be prepared and maintain a firm hold on the controls.

   - Activate the LVL mode. Wait a few moments.
   - Hold controls.
   - Slowly trim forward (or backward) so that airplane is more and more out-of-trim. Once enough force is applied to the servo it shall disconnect.
   - Verify:
     - Once out-of-trim, first yellow and later red arrow shall appear on the trim indicator (Nesis display) or on the middle of Amigo display.
     - If the out-of-trim condition is worsened or if it persists for a long time (red arrow), autopilot will disconnect.
   - Repeat the test for the other axis when applicable.

# A Autopilot Installation And Tuning Form

| | | | |
|---|---|---|---|
| Date | | Airplane/Type | |
| Customer | | Registration | |
| Performed by | | Signature | |

Servo motor settings

| Setting | Elevator | Aileron |
|---|---|---|
| Lever hole | | |

Operating limits

| | | | |
|---|---|---|---|
| Max IAS | | Max roll | |
| Min IAS | | Max pitch | |
| Max VS | | - | |

Configuration parameters

| | | | |
|---|---|---|---|
| Strategy | | Pitch backlash | |
| Pitch target | | Max pitch rate | |
| VS target | | Max VS rate | |
| Altitude gain | | Roll backlash | |
| Roll target | | Max roll rate | |
| Roll rate gain | | Turn comp | |

Tuning parameters

| Parameter | Pitch | Roll | Track |
|---|---|---|---|
| P-term | | | |
| I-term | | | |
| D-term | | | |

# B Recommended default parameters

If you cannot find initial values in appendix C and D please use this default settings for initial autopilot setup.

## B.1 Latest Defaults

Table 1: Default Limits

| | | | |
|---|---|---|---|
| Max IAS | 220 km/h | Max roll | 25° |
| Min IAS | 150 km/h | Max pitch | 15° |
| MAX VS | 5 m/s | | |

Table 2: Default configuration parameters

| | | | |
|---|---|---|---|
| Strategy | A2 | Pitch backlash | 0° |
| Pitch target | 10° | Max pitch rate | 2°/s |
| VS target | 2.5m/s | Max VS rate | $1\text{m/s}^2$ |
| Altitude gain | 40 | Roll backlash | 0° |
| Roll target | 20° | Max roll rate | 5°/s |
| Roll rate gain | 1.0 | Turn comp | 0.1 |

Table 3: Default PID values

| Parameter | Pitch | Roll | Track |
|---|---|---|---|
| P-term | 1.0 | 1.0 | 1.0 |
| I-term | 5.0 | 3.0 | 25.0 |
| D-term | 0.0 | 0.0 | 0.0 |

# C V2 Parameters For Known Airplanes

In this section you will find parameter configurations for some aircrafts. We will be adding more of them gradually.

The values that applied to SERU v1 do not apply directly to SERU v2!

If your installation and aircraft type is identical, then these values should give you a very reasonable autopilot behavior.

However, when the hardware installation is a bit different (usually, it is) or if different servo arm was used or a different hole in the servo arm, etc, then these values may not be completely suitable and re-tuning is necessary.

Some loops given below are using special values. RFF means Roll Feed Forward, VS is Vertical Speed, RRG means Roll Rate Gain.

## C.1 Ellipse Spirit

Table 4: Ellipse Spirit configuration parameters

| | | | |
|---|---|---|---|
| Strategy | A2 | Pitch backlash | 0° |
| Pitch target | 10° | Max pitch rate | 2°/s |
| VS target | 2.5m/s | Max VS rate | $1\text{m/s}^2$ |
| Altitude gain | 40 | Roll backlash | 1.0° |
| Roll target | 15° | Max roll rate | 5°/s |
| Roll rate gain | 1.0 | Turn comp | 0.15 |

Table 5: Ellipse Spirit PID values

| Parameter | Pitch | Roll | Track |
|---|---|---|---|
| P-term | 1.3 | 1.5 | 1.0 |
| I-term | 5.0 | 2.5 | 25.0 |
| D-term | 0.0 | 0.0 | 0.0 |

## C.2 Skyleader 400 J400

Table 6: Skyleader 400 configuration parameters

| | | | |
|---|---|---|---|
| Strategy | A2 | Pitch backlash | 0° |
| Pitch target | 10° | Max pitch rate | 2°/s |
| VS target | 2.5m/s | Max VS rate | $1m/s^2$ |
| Altitude gain | 40 | Roll backlash | 1.0° |
| Roll target | 20° | Max roll rate | 5°/s |
| Roll rate gain | 1.0 | Turn comp | 0.1 |

Table 7: Skyleader 400 PID values

| Parameter | Pitch | Roll | Track |
|---|---|---|---|
| P-term | 1.5 | 1.0 | 0.6 |
| I-term | 9.0 | 3.0 | 25.0 |
| D-term | 0.0 | 0.0 | 0.0 |

# D V1 Parameters For Known Airplanes

In this section parameters for Seru V1 are listed. You can use them for initial tuning of Seru v2.

## D.1 Ekolot Topaz

Table 8: Topaz configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 40° | Max pitch rate | 10°/s |
| Pitch target | 12° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | $1.5\text{m/s}^2$ |
| VS target | 3m/s | Turn comp | 0.0 |
| - | - | Roll rate gain | Disabled |

Table 9: Topaz PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.0 | 0.018 | 0.8 | 0.75 |
| I-term | 14.0 | 19.0 | 10 | 28 |
| D-term | 0.16 | 0.16 | 0.02 | 0.3 |

## D.2 Pipistrel Sinus

Table 10: Sinus configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 40° | Max pitch rate | 5°/s |
| Pitch target | 12° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | $1.5\text{m/s}^2$ |
| VS target | 3m/s | Turn comp | 0.0 |
| - | - | Roll rate gain | disabled |

Table 11: Sinus PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 0.5 | 0.02 | 0.5 | 1.0 |
| I-term | 7.0 | 12.0 | 8.0 | 25 |
| D-term | 0.16 | 0.2 | 0.02 | 0.2 |

## D.3 Aeropilot Legend 540

Table 12: Legend 540 configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 40° | Max pitch rate | 5°/s |
| Pitch target | 10° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | $1.0 m/s^2$ |
| VS target | 3m/s | Turn comp | 0.2 |
| - | - | Roll rate gain | disabled |

Table 13: Legend 540 PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 0.65 | 0.017 | 0.9 | 0.6 |
| I-term | 4.0 | 15.0 | 6 | 26 |
| D-term | 0.2 | 0.32 | 0.16 | 0.2 |

## D.4 Evector Eurostar EV97

Table 14: EV97 configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 40° | Max pitch rate | 2°/s |
| Pitch target | 12° | Max roll rate | 5°/s |
| Roll target | 20° | Max VS rate | $1.5 m/s^2$ |
| VS target | 3m/s | Turn comp | 0.3 |
| - | - | Roll rate gain | disabled |

Table 15: EV97 PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 0.4 | 0.025 | 0.7 | 0.9 |
| I-term | 7.0 | 12.0 | 8 | 26 |
| D-term | 0.0 | 0.2 | 0.2 | 0.2 |

## D.5 Aerospool Dynamic WT9

Table 16: WT9 configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 30° | Max pitch rate | 2°/s |
| Pitch target | 10° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | $1.0 m/s^2$ |
| VS target | 2.5m/s | Turn comp | 0.2 |
| - | - | Roll rate gain | 1.0 |

Table 17: WT9 PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.2 | 0.024 | 0.6 | 1.5 |
| I-term | 6.5 | 15.0 | 4.5 | 26 |
| D-term | 0.5 | 0.3 | 0.4 | 0.14 |

## D.6 Roko Aviation

Table 18: NG6 configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 30° | Max pitch rate | 3°/s |
| Pitch target | 10° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | $1.0m/s^2$ |
| VS target | 2.5m/s | Turn comp | 0.2 |
| - | - | Roll rate gain | disabled |

Table 19: NG6 PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.2 | 0.017 | 0.6 | 0.6 |
| I-term | 6.5 | 15.0 | 4.5 | 26 |
| D-term | 0.52 | 0.32 | 0.4 | 0.2 |

## D.7 Aeroprakt

Table 20: A22 & A32 configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 30° | Max pitch rate | 2°/s |
| Pitch target | 10° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | $1.0m/s^2$ |
| VS target | 2.5m/s | Turn comp | 0.2 |
| - | - | Roll rate gain | 1.0 |

Table 21: A22 & A32 PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.9 | 0.020 | 0.45 | 0.45 |
| I-term | 5.0 | 20.0 | 5.0 | 22 |
| D-term | 0.2 | 0.2 | 0.16 | 0.3 |

## D.8 Direct Fly

Table 22: NG configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 30° | Max pitch rate | 2°/s |
| Pitch target | 10° | Max roll rate | 3°/s |
| Roll target | 15° | Max VS rate | $1.0m/s^2$ |
| VS target | 2.5m/s | Turn comp | 0.2 |
| - | - | Roll rate gain | 1.0 |

Table 23: NG PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.0 | - | 1.2 | 0.6 |
| I-term | 6.0 | - | 3.5 | 26.0 |
| D-term | 0.1 | 2.0 (Comp) | 0.0 | 0.2 |

## D.9 Comco Ikarus

Table 24: C-42C configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 30° | Max pitch rate | 2°/s |
| Pitch target | 10° | Max roll rate | 3°/s |
| Roll target | 15° | Max VS rate | 1.0m/s$^2$ |
| VS target | 2.5m/s | Turn comp | 0.2 |
| - | - | Roll rate gain | 1.0 |

Table 25: C-42C PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.1 | 0.016 | 0.85 | 0.5 |
| I-term | 3.0 | 8.0 | 6.0 | 26.0 |
| D-term | 0.2 | 0.0 | 0.16 | 0.0 |

## D.10 Flight Design CT2K

Table 26: CT2K configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 30° | Max pitch rate | 2°/s |
| Pitch target | 10° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | 1.0m/s$^2$ |
| VS target | 3m/s | Turn comp | 0.15 |
| - | - | Roll rate gain | 1.0 |

Table 27: CT2K PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.0 | - | 0.6 | 1.6 |
| I-term | 5.0 | - | 7.0 | 16.0 |
| D-term | 0.12 | 2.0 (Comp) | 0.2 | 0.1 |

## D.11 FK9 mk II

Table 28: FK9 mk II configuration parameters

| | | | |
|---|---|---|---|
| Max arm mv | 30° | Max pitch rate | 2°/s |
| Pitch target | 8° | Max roll rate | 3°/s |
| Roll target | 20° | Max VS rate | 2.0m/s$^2$ |
| VS target | 2.5m/s | Turn comp | 0.2 |
| - | - | Roll rate gain | 1.0 |

Table 29: FK9 mk II PID values

| Parameter | Pitch | VS | Roll | Track |
|---|---|---|---|---|
| P-term | 1.0 | - | 0.9 | 0.6 |
| I-term | 7.0 | - | 6.0 | 30.0 |
| D-term | 0.1 | Compensated | 0.16 | 0.2 |