MGL Avionics

iEFIS

Integrated Autopilot

User and installation manual

Manual dated 14 November 2014

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General

This manual describes the integrated autopilot functionality built into MGL Avionics iEFIS systems.

Autopilot abilities

External autopilot systems

External autopilot systems can be controlled via NMEA interface (RS232 serial port 2) or ARINC 429 interface (GPSS steering). Note the "Lite" versions do not have ARINC abilities.

Capabilities depend on the external autopilot system.

Internal autopilot systems

The internal autopilot system can be configured as 1, 2 or 3 axis system providing bank, pitch and yaw control in any combination coupled to the EFIS internal or external navigation sources.

Autopilot functionality

The current release of the MGL Avionics integrated autopilot provides a one, two or three axis system intended to control ailerons, rudder and elevator.
Most systems would install a servo connected to ailerons and a second servo connected to elevator. A third servo connected as Yaw stabilizer can be of advantage for some aircraft. The yaw stabilizer can be engaged independent of the remainder of the autopilot system.

It is possible to use an external autopilot connected to the EFIS and use the built in yaw stabilizer at the same time.

Autopilot navigation sources

Available navigation sources are dependent on the type of EFIS and its installation.

Horizontal navigation sources

Horizontal navigation sources include the following:

- Magnetic compass (heading)
- Magnetic or true track derived from a GPS
- Track to a waypoint using GPS
- Track derived from route waypoints and followed by means of a GPS
- VOR radial
- GVOR radial (VOR simulated by a GPS)

- ILS Localizer
- GLS (GPS based localizer)
- Other sources as may be connected to the EFIS

Vertical navigation sources

Vertical navigation sources include the following:
- Altimeter (altitude hold)
- Altimeter (following vertical profile as part of route)
- Glideslope
- GLS (GPS based glide slope)
- Other sources as may be connected to the EFIS

Yaw control sources

Yaw control can be coupled to the following:
- Slip indicator – use yaw control to position the ball (normally center but can be set off center as needed for some aircraft)
- Yaw stabilizer based on turn rate (gyro stabilizer)
- Mixed slip indicator position and yaw stabilizer based on turn rate (gyro stabilizer)

Autopilot requirements

In order for the autopilot to function, the following items are required:

Any iEFIS panel.

SP-6 compass (optional). This is required if magnetic compass heading needs to be followed and no GPS fix is available. In case of a valid GPS fix, magnetic heading is calculated from GPS track for use by the autopilot as this provides a more stable heading signal.

SP-7 AHRS. The AHRS supplies turn rates, bank and pitch angles for use by the autopilot. The AHRS is also required if a yaw servo is to be used. The autopilot will not work without an AHRS. Note: The "Lite" version has an internal AHRS that can be used. An external SP-7 can also be fitted if desired but this is not required in most cases.

1,2 or 3 MGL servos connected to the iEFIS Lite CAN bus or iEFIS iBOX CAN bus. Note the iBOX has two CAN interfaces – you can use either or even mix servos onto the two busses. There is no setup required for this – simply connect as desired, the system will figure it out.

MGL Avionics Digital servo

This servo is based on a powerful stepper motor and provides high control speed and full range of control movement including capstan control. This servo is ideal for full authority control systems such as the MGL autopilot system. With medium power consumption it

provides electronically variable torque and relatively low system drag when not engaged.

The MGL servo provides position information and operational status back to the host system and can be engaged in any position. The MGL servo provides a wear free position feedback mechanism. The MGL servo is also able to measure the forces acting on the servo arm to provide automatic trim correction information or manual trim feedback.

The servo is constructed using a NC machined aluminum housing, double ball bearings on the output shaft and fully integrated electronics. Threaded mounting holes are provided on the servo face as well as sides, allowing simple, bracket-less installation in many cases. This servo is able to be engaged in any position and in any range, the servo arm is not limited to any position or range.

Multiple of these servos are connected to an EFIS system using the CAN interface bus.

Picture of the MGL servo

Other servo systems

MGL provides the "MGL Avionics CAN Servo protocol" document to interested parties allowing special application servos to be constructed or existing servos to be modified to be able to be used with the MGL Avionics autopilot system.

Engaging and disengaging the autopilot

The autopilot can be engaged and disengaged in several ways:

- Via the EFIS keypad or touch screen
- Via autopilot engage/disengage switch (With the "Lite" this requires fitting of an extender).
- Remotely on a regular iEFIS via Wifi

The autopilot will refuse to engage if:

- A digital servo is used and it reports a fault
- A digital servo is used and no information is received (RX fault)
- Selected navigation source does not have valid solution
- No AHRS is connected

The autopilot will disengage if:

- The disengage function on the EFIS keypad is activated
- Engage/disengage switch is pressed (switch connected to IBox or Extender)
- A digital servo reports torque overdrive for 1 second
- Active navigation source has been lost
- Power is removed from a digital servo (causes RX fault)

Preflight check of the autopilot installation

The Menu provides a preflight check function.

Each servo (excluding power control) will be moved to its extreme control limits and when complete left it its neutral position. At the same time, the display will show the action taken so servo direction can be verified.

Note: This function will not be available if an active flight has been detected. Airspeed must read below 30mph. In addition, a confirmation will need to be acknowledged before this function will commence. Under no circumstances should this function be activated in flight. The function can exited by pressing any key on the EFIS which will also disengage the servos.

During the servo preflight check, verify the correct directional operation of each servo. The controls must not bind and the servos must not slip in any position. With the servos disengaged, verify that full manual control is present.

If a yaw control servo is being used, the pre-flight check will confirm if you would like the Yaw servo to be activated as part of the pre-flight. If your yaw servo is connected to a nose gear

steering system, the combined force required to control the yaw may exceed the ability of the servo. If this is the case with your installation, select to not engage the yaw servo.

The yaw servo should be periodically tested on the ground with offending drag removed if required. On smaller aircraft this could be achieved by lifting the nose gear during the test.

Installation

Installation of the autopilot system consists of four steps:

- Obtain information from suitable sources as to best or recommended location and means for servo installation – if this is not possible, perform a test flight as outlined in the next chapter to determine suitability of the aircraft for installation of an autopilot.

- Physical installation of the servos, electrical and mechanical connections

- Ground based configuration of the autopilot system

- Test flight based calibration of the autopilot system

Physical installation of the servos

This phase starts with the identification of a suitable location for each servo. In many cases the aircraft manufacturer may have predetermined a suitable location and control linkage. Installation of the servo should be carried out by a suitably qualified aircraft technician.

- The servo needs to be installed on a rigid platform. It must not move under any expected mechanical load.

- Control linkages must be installed such that there is no play between servo bell crank and controls. Any play introduced here can seriously affect the autopilots ability to fly the aircraft properly.

- Electrical wiring should be installed to aircraft standards using suitably dimensioned cable. Please consult with the servo manufacturer for recommended wire types and core dimensions.

- Servo power must be routed via a circuit breaker or switch easily accessible to the pilot. Servos will disengage if power to them is removed.

Post installation checks:

DO NOT FLY THE AIRCAFT UNTIL THE FOLLOWING POST INSTALLATION CHECKS HAVE BEEN CARRIED OUT AND FULL AND CORRECT FUNTIONS HAVE BEEN OBSERVED:

- Verify that no controls are binding during any position of the flight controls

- Verify that the servos when not engaged will not restrict movement of any flight controls including maximum limits of the flight controls

- Verify that the servos, once engaged, have as close to zero tolerance as possible when moving the control surfaces. VERIFY THIS. With the autopilot engaged, move the control surfaces by hand and ensure that there is no significant play. If any play is

found, recheck your control linkages and install better or more suitable parts if required. Control linkage play may seriously limit the autopilots ability to control your aircraft, in particular where pitch control is concerned.

Pre-installation test flight

Unless a suitable, known good servo installation is used (for example a series built aircraft with existing autopilot installations), it is recommended to test fly the aircraft before installation as follows here. Please note that this is a guide only and may need modification to suit the particular aircraft.

The main aim is to fly the aircraft manually in exactly the same fashion that the autopilot would. If you are installing a two-axis system and want to use aileron and elevator controls without pilot assisted rudder and power input, ensure that your aircraft can actually be flown that way. If you cannot, the autopilot will not be able to do so either !

Using the above example, fly the aircraft to a stable, straight and level condition, then move your feet off the rudder pedals and refrain from adjusting power. Attempt to keep the aircraft on your current heading or ground track and exactly on your current altitude using aileron and elevator control only. Important: Use only small control corrections and feed these in gently, emulating a servo as best you can. If you find you can control your aircraft this way in moderate turbulence while keeping the speed relatively constant proceed to the next step:

Intercept a new heading 90 degrees from your current heading using only aileron and elevator, use a turn rate that you feel comfortable with – we suggest around 2 to 3 seconds per degree (approximately rate one turn). If you find you can perform this maneuver fine with gentle control inputs proceed to the next step:

From a straight and level position, attempt a climb to a new altitude (perhaps 500 feet above where you are now). Take note of your climb rate (feet per minute) and airspeed. Decide on a climb rate that results in best climb and a good speed without you needing to adjust power. Note down your result as you will be entering this in the autopilot pitch setup.
Now repeat the same for a descent. Again, take note of your speed and descent rate and choose a combination that is most suitable for your aircraft without power adjustment. Remember these values for the pitch setup.

It is acceptable to climb and descend with manual power adjustments. If you choose to operate the autopilot this way, use appropriate power settings and note your climb and decent rates. You will used these as target vertical speed settings for the autopilot pitch control.

Possible issues and suggested solutions:

If your aircraft does not turn well without rudder input, try turning it with rudder only – will the ailerons self-center due to aerodynamic forces ? If you find you can turn your aircraft well without active aileron input you may be able to connect the bank servo to the rudder rather than the ailerons.

Difficulty holding altitude due to engine power effects. This can be a bothersome issue and may be related to the amount of power your engine produces at various propeller loads coupled with an uneven torque curve of the engine. Here is a typical scenario based on a

particular aircraft we used during the autopilot development:

You start off with a low power setting (economy cruise) and you are holding altitude. The aircraft ascends a bit and you correct by a slight nose down attitude change. The engine now has a slightly lower load and RPM increases, the engine produces more power and instead of descending back to your target altitude your speed and lift increases so you ascend even more. More nose down worsens the effect. Eventually you find some equilibrium where you can hold altitude but only at a much higher speed where drag starts to help you from increasing speed.
The reverse is also true – pitch up the nose and you slow down, more engine load – slower RPM, less engine power and you might find you start descending in a nose high attitude at slow speed rather than gaining altitude, the effect you had hoped for.
The above scenario is often related to two stroke engines but can also affect four stroke engines that are "lugged" by a propeller with a too high pitch.

If your aircraft behaves as above, it may not be possible for a two axis autopilot to even hold altitude properly, never mind climb and descend. In this case you may need to control power manually to assist the autopilot – a control you may find you need to do even when flying without autopilot to remain within target speed and altitude.

As an alternative, you need to install an automatic power/RPM control (governor) or select a autopilot characteristic that includes throttle control.

Issues related to aircraft stability:

Traditional capture and track autopilots can only be used with any measure of success on aircraft that are neutrally stable. If you aircraft is subject to a yawing moment when proceeding through the yaw-neutral position or a pitch moment when proceeding through pitch-neutral or significant stick force reversal based on angle-of-attack or speed changes, it is unlikely that you will be able to use this type of autopilot with any satisfaction.
Aircraft like this can still be flown using an autopilot but tend to need full authority systems using fast servos that can instantly and proportionally correct any attitude deviation. Often, autopilots for these types of aircraft are purpose-build and designed for a particular aircraft. Example: B2 Stealth bomber.

Ground based configuration of the autopilot system

During this phase you select the autopilot character and individual servo configurations.
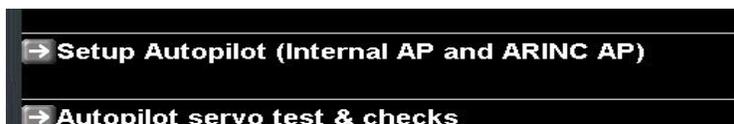
The autopilot setup menu is accessible via the setup menu. Please note that some functions in this menu cannot be selected if a flight is active or airspeed shows above 30 mph.

For each servo select the servo type and electrical connection source.

MGL Avionics servos on "iEFIS" systems must be connected to the CAN interface.
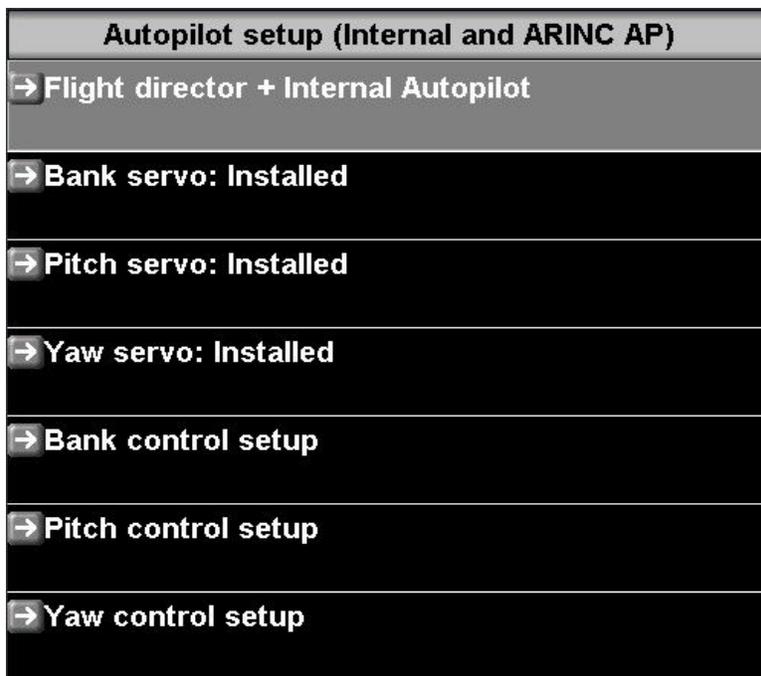
Select each servo that you have installed to gain the relevant setup menu for that servo.

Identifying a MGL servo

If MGL servos are selected, you will enable functions that will allow you to "identify" the servos. The servos need to be configured so they know what function they are assigned to.

You can identify a servo if the autopilot is not engaged and no flight is active (check that airspeed is reading "0").

In order to identify a servo (assign its function), **only one servo is allowed to be connected**. Please temporarily disconnect all other servos. Once you have a single servo connected you can use the "identify bank, pitch or yaw servo" functions.

Example: You have the bank servo connected and powered. You then send the "Identify bank servo" command by selecting the relevant function.

You will receive a confirmation message. If you are satisfied that all is well, press "1" to continue.
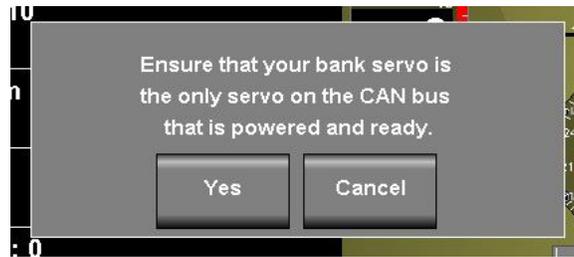
After a few seconds you will be shown a message either confirming that the servo has been successfully configured or that no data has been received. If the procedure is not successful, please check your power supply and signal wiring from the EFIS to the servo.

Once successful, you can proceed with the pitch or yaw servo in similar fashion.

Before you can use the MGL servos you must identify them using the procedure described here.

You can repeat this procedure and reassign servos as needed.

If you change servos or re-assign servos you must perform the identification procedure and select servo positions. Servos are unique and internal position numbers vary between servos.

Configuring the roll (bank) servo

MGL Avionics servo setup

Bank servo direction

Not used for MGL servo.

Here you select the servo rotation direction. This depends on your installation. The direction is identified as CW (clockwise) or CCW (counter clockwise) as specified by the servo manufacturer to achieve a right bank.

The servo direction in usually selected after performing the servo preflight test and noting the control movement vs. the intended movement. If the preflight screen is showing a left bank and your controls are moving for a right bank, change this setting.

Target rate of turn

Select your desired target rate of turn when capturing a new heading.

Typical turn rates range from 2.0 to 3.0 degrees per second. A rate of 3.0 degrees per second corresponds to a rate one turn (360 degrees in two minutes).
This value is used for large heading errors, for smaller errors this value is suitably scaled down to ensure smooth track intercept and hold.
For fast aircraft, it is recommended to choose lower rates of turn to avoid the bank angle from getting too steep.

Bank servo torque

This entry will only show if you have the MGL Avionics servo selected. Here you select the maximum torque the servo will be able to hold before slipping. 100% is the maximum possible torque. Lower this number if you need the servo to slip at a lower torque setting. You should select a setting that allows an easy override of the servo by the pilot but it should remain high enough so it will not slip during higher control force loads that may be experienced during turbulence or out-of-trim conditions.

Bank servo Magnitude

This setting selects the amount of servo movement for a given bank angle error (the error between desired bank angle and actual bank angle). This value is selected during a test flight (next chapter). Set this value to "10" before the first flight. A higher value produces more servo movement. The aim is to find a value that results in rapid correction of an error without over-correction. Typical values are from 10 to 30.

Heading control:...

This entry is also available if the external ARINC autopilot has been selected (Odyssey, Voyager or Explorer).

Using this setting you select the amount of bank angle to apply to correct a given track error. This allows you to select a "gentle" or "forceful" intercept.
Select: Slow, Medium or Fast to best suit your aircraft.

Bank autotrim

If you have a SP-10 connected and configured as bank trim controller, then checking this option will enable the autopilot to control the bank trim. For this to work the servo torque must not be set higher than 80% (a higher setting prevents the servo from measuring stick forces).

Bank left limit / Bank right limit

You cannot use or test the MGL Avionics servos until you have completed the following procedure:

These entries show if you have a MGL servo selected.
These functions are used to set the left and right limits as well as the required servo direction. Move the stick to the maxiumum left bank position you would like the autopilot to fly (this may be slightly less than the maximum left bank position that can be flown). You should see the current position shown in the range of 0 to 4095 as you move the stick. Select the function when you have reached the desired position. This will copy the current position into the limit field. Repeat this procedure for the right bank position. It does not matter which side you do first and you can do this as many times as needed.

Note: You need to exit all menus to permanently store these settings.

If you do not see the current position field number changing with servo arm position, please check that the servo is powered and that the serial communications link has been connected correctly. Also ensure that you have selected the correct port on the COM Extender for this

servo.

Recommended first settings:

Target rate of Turn: Slower aircraft: 3.0, faster aircraft: 2.0
Bank Servo torque: As needed to ensure pilots ability to override servo.
Bank Servo magnitude: 10
Heading control: Medium

Configuring the pitch servo

MGL Avionics servo setup

Pitch setup menu
→ Low ASI, force nose lower: 56kts
→ High ASI, force nose up: 130kts
→ Target VSI for ascent: 400fpm
→ Target VSI for descent: 400fpm
→ Pitch servo torque: 80%
→ Altitude control: Medium
→ Glide slope control: 0
→ Pitch angle control Magnitude: 6
→ Pitch change to VSI reaction : Medium
→ Pitch autotrim ☐
→ Pitch down limit 0 Position: 0
→ Pitch up limit 0 Position: 0
→ Identify pitch servo

Pitch servo direction

This function is not available for MGL Avionics servos.

Here you select the servo rotation direction. This depends on your installation. The direction is identified as CW (clockwise) or CCW (counter clockwise) as specified by the servo manufacturer to achieve a pitch up.

The servo direction in usually selected after performing the servo preflight test and noting the control movement vs. the intended movement. If the preflight screen is showing a pitch up and your controls are moving for a pitch down, change this setting.

Low ASI for climb (lower nose)

Select the minimum allowable airspeed during a climb. The autopilot system will control the pitch gyro during a climb such that when this airspeed limit is reached, a pitch down command will be issued to regain airspeed above this value.

Airspeed has priority over ascent or descent rate.

Please choose this value carefully to prevent issues during climbing. Airspeed will reduce during climbs if power is not added. Choose a value that is well above stall speed but not high enough to interfere with the climb.

High ASI for descent (nose up)

Select the maximum allowable airspeed during a descent. The autopilot system will control the pitch gyro during descent such that when this airspeed limit is reached, a pitch up command will be issued to retain airspeed below this value.

Airspeed has priority over ascent or descent rate.

Target VSI for ascent

Select the desired vertical rate of climb for ascent to a new flight altitude. This rate will be used as target if the new altitude is relatively far away.

Avoid the temptation to select a climb rate that is higher than what your aircraft can sustain.

Target VSI for descent

Select the desired vertical rate of descent to a new flight altitude. This rate will be used as target if the new altitude is relatively far away.

Select a target rate of descent that is achievable using elevator control only, taking into account maximum airspeed as selected for the descent.

Pitch servo torque

This entry will only show if you have the MGL Avionics servo selected. Here you select the maximum torque the servo will be able to hold before slipping. 100% is the maximum possible torque. Lower this number if you need the servo to slip at a lower torque setting. You should select a setting that allows an easy override of the servo by the pilot but it should remain high enough so it will not slip during higher control force loads that may be experienced during moderate turbulence.

Altitude control:...

This entry is also available if the external ARINC autopilot has been selected (Odyssey, Voyager or Explorer).

This setting adjust the speed that a pitch angle change may take. Higher values will result in a more aggressive change of pitch angle to follow a given vertical rate. Lower values result in a softer rate of pitch angle change.

Select: Slow, Medium or Fast to best suit your aircraft.

Glide slope control

This setting is normally "0". It can be used to increase glide slope tracking force. You can view this as an extra "Pitch angle control magnitude" addition if a glide slope is being followed. This is effective both with a ILS based glide slope as well as the GPS based GLS glide slope.

Pitch angle control magnitude

This setting sets the amount of servo movement to apply for a given pitch angle change.

If this setting is too low, the aircraft will take too long to change pitch angle and is not able to hold a desired pitch angle. If the value is too high, the pitch control can overreact resulting in a rapid and forceful oscillation around the pitch axis.

Higher performance aircraft or aircraft that are very pitch sensitive (very small amounts of control movement result in a large pitch angle change) will need smaller settings (typically around 5-8) while slower aircraft tend to use values around 8 -15.

This is the first and most critical calibration item that needs to be set as described below.

Pitch change to VSI reaction

This setting informs the autopilot how long it will take for a pitch control surface change to affect the desired vertical rate change. This is related in part to the aircraft's mass and in part to the effectiveness of the aircraft's pitch control surface (elevator).

Pitch autotrim

If you have a SP-10 connected and configured as pitch trim controller, then checking this option will enable the autopilot to control the pitch trim. For this to work the servo torque must not be set higher than 80% (a higher setting prevents the servo from measuring stick forces).

Pitch up limit / Pitch down limit

You cannot use or test the MGL Avionics servos until you have completed the following procedure:

These functions are used to set the pitch up and down limits as well as the required servo direction. Move the stick to the maxiumum pitch up position you would like the autopilot to fly (this may be slightly less than the maximum up position that can be flown). You should see the current position shown in the range of 0 to 4095 as you move the stick. Select the function when you have reached the desired position. This will copy the current position into the limit

field. Repeat this procedure for the pitch down position. It does not matter which you do first and you can do this as many times as needed.

Note: You need to exit all menus to permanently store these settings.

If you do not see the current position field number changing with servo arm position, please check that the servo is powered and that the serial communications link has been connected correctly. Also ensure that you have selected the correct port on the COM Extender for this servo.

Recommended first settings

Low ASI: Slightly above the aircraft's stall speed.
High ASI: Slightly below or at the aircraft's maximum cruise speed.
Target VSI for ascent: 400 ft/min or as suitable for aircraft.
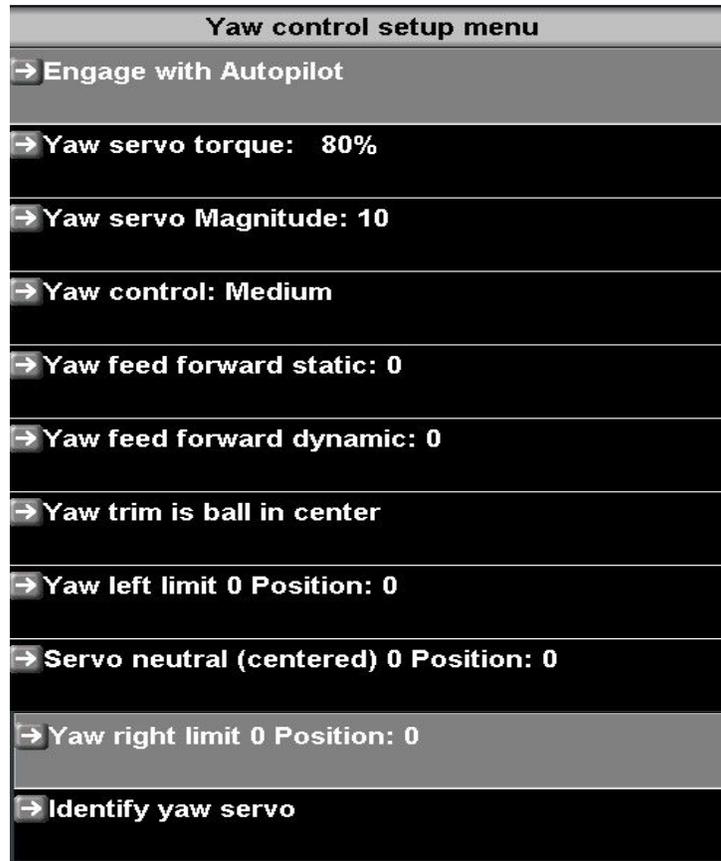Target VSI for descent: 400 ft/min or as suitable for aircraft.
Altitude control: Medium.
Pitch Angle control magnitude: 10.
Pitch change to VSI reaction: Medium.

Configuring the Yaw servo

Yaw can only be supported if an MGL servo is fitted. It cannot be used with Trio or PWM servos.

```
Yaw control setup menu
→ Engage with Autopilot

→ Yaw servo torque:   80%

→ Yaw servo Magnitude: 10

→ Yaw control: Medium

→ Yaw feed forward static: 0

→ Yaw feed forward dynamic: 0

→ Yaw trim is ball in center

→ Yaw left limit 0 Position: 0

→ Servo neutral (centered) 0 Position: 0

→ Yaw right limit 0 Position: 0

→ Identify yaw servo
```

Engage mode

This function allows you to select the desired engage mode of the yaw control.

Yaw control can be disabled, set to engage and disengage with the remainder of the autopilot or it can be selected to behave completely independent from the autopilot (in which case you need to engage yaw control yourself).

Yaw servo torque

Here you select the maximum torque the servo will be able to hold before slipping. 100% is the maximum possible torque. Lower this number if you need the servo to slip at a lower torque setting. You should select a setting that allows an easy override of the servo by the pilot but it should remain high enough so it will not slip during higher control force loads that may be experienced during moderate turbulence.

Yaw servo magnitude

Select the amount of rudder movement to apply for a given yaw error. A number that is too high will result in yaw instability due to over-control while a number too low will result in indifferent yaw control.

Yaw control

This setting should be related to the reaction time of your aircraft to rudder input.

Yaw feed forward static

This setting adds a yaw input proportional to a track error. Effectively this will attempt to force the slip indicator to move to the inside of a turn. For example you would use this if your aircraft requires a slight out of balance during a turn.

For example, during a right turn the rudder will be held to the right as well. You can enter a value from 0 to 10. "0" means this function has no effect. "10" means nearly maximum rudder deflection. Please start with a low number if you intend using this function. Note: Most aircraft will leave this number at "0".

Yaw feed forward dynamic

This setting adds a rudder input when there is a change of track error. The rudder input is to the inside of the turn and will last about a second at peak deflection (related to amount of track error) before being gradually removed.

This is used if your aircraft requires rudder input to start a turn but once a turn is established the rudder should be neutral (slip indicator ball centered).

Control range is from "0" (off) to "20".

Note that you can mix static and dynamic yaw feed forward.

Yaw trim is:

Select the slip indicator position that you would like the yaw control to target. Normally this would be "ball in center" but you have the ability to choose a position for ball left or right in steps of 1/50 of the full range of movement. This can be of advantage to certain aircraft that exhibit yaw instability with the ball in the center.

Important note: "Ball in center" relates to the actual slip indicator before any on-screen correction may have been applied (some EFIS systems allow you to "center" the ball regardless of its actual position – the yaw control uses "actual" position).

Yaw left/right limit and servo center

You cannot use or test the MGL Avionics servos until you have completed the following procedure:

These functions are used to set the yaw left and right limits as well as the required servo direction and the yaw center (rudder center).

Move the rudder to the maximum left yaw position you would like the autopilot to fly (this may be slightly less than the maximum left yaw position that can be flown). You should see the current position shown in the range of 0 to 4095 as you move the rudder. Select the function when you have reached the desired position. This will copy the current position into the limit field. Repeat this procedure for the yaw right and servo center position. It does not matter which you do first and you can do this as many times as needed.

Note: You need to exit all menus to permanently store these settings.

If you do not see the current position field number changing with servo arm position, please check that the servo is powered and that the serial communications link has been connected correctly.

Note: Unlike the pitch and bank servos which are limited to less than 180 degrees movement of the servo arm (typical usable range tends to be 120 degrees unless a capstan servo is used) – the yaw servo may be utilized up to 340 degrees (20 degrees less than a full rotation).
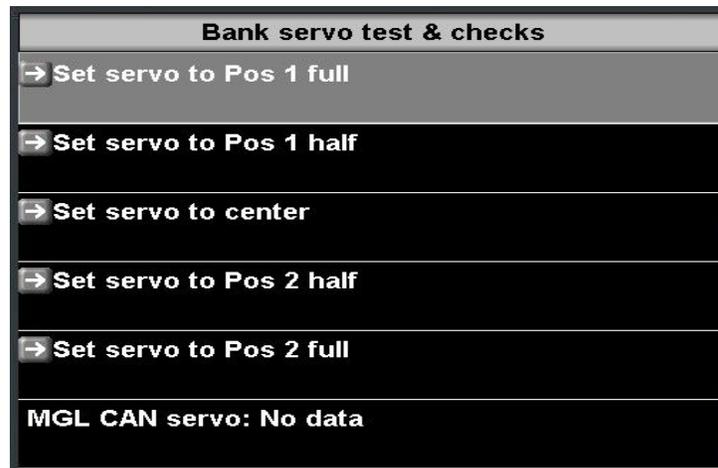
First servo tests

Within the system setup menu you will find the "servo test and checks" menu.

Here you will find a set of functions that will allow you to engage and move the servos and also observe the data that is sent back from the servo.
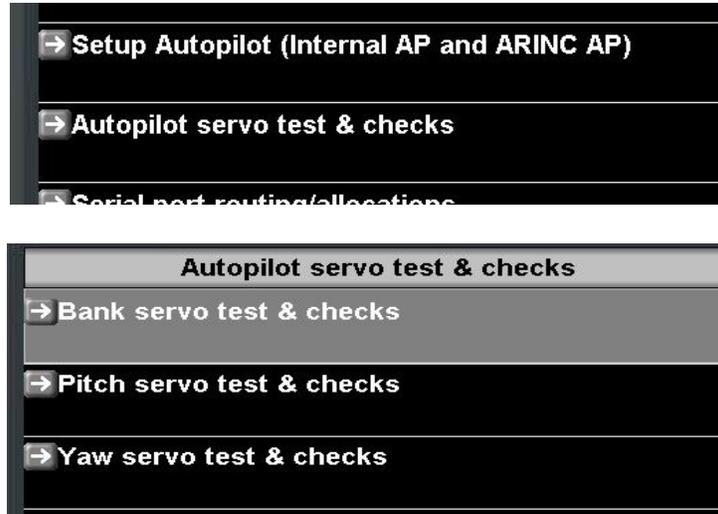
Example: Bank servo test and checks

Use the provided functions to move the servo arm to the positions provided. Ensure that servo movement is smooth and no danger exists that could result in binding controls or jamming of control surfaces.
Ensure that with the servo engaged there is no noticeable play between control surface and servo arm. Every small servo arm movement must result in a corresponding movement of the control surface.

Below the selections, data received back from the servo (digital servos only) will be displayed. The autopilot will not engage if data from a digital servo is not received.

Ground based testing of the autopilot system

Perform the autopilot preflight check. This is an automated procedure accessible from the main menu.
The bank and pitch servos will be activated in turn and each will move to its maximum limits and then center. During this time, the EFIS will inform you of the action it is taking, for example "Bank left". Ensure that the control surfaces of your aircraft are moving in the correct direction. If they are not, correct this by setting the corresponding servo direction setting in the autopilot setup menu.

Use the autopilot preflight check repeatedly to verify that all mechanical linkages are performing correctly and are not binding or have excessive play.
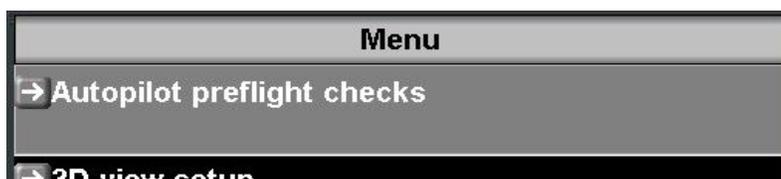
While the preflight check is operating, physically move the control surfaces by hand against the servo force to locate any play. If you find significant play, please fix the cause before attempting a test flight. The autopilot cannot perform correctly if there is excessive play in the controls.

This may also be the correct time to adjust the servo torque. Please refer to the manual of the servo manufacturer on how to adjust the torque. Correct torque is achieved if you can override the servo with fair ease using the control stick but it it firm enough not to cause the servo to slip in turbulent flight.

The autopilot is designed to disengage if it detects a servo slipping for more than one second. This can be used as a convenient method to disengage the autopilot and it the recommended method as this results in your hand on the control as the autopilot disengages.

If your autopilot prelight tests have been completed satisfactory, you can consider a first test flight as outlined in the next chapter.

Test flight based calibration of the autopilot system

During this phase you calibrate each servos response characteristic to match your aircrafts flight dynamics and the servo control linkage to its corresponding control.

While there may be more than one way to go about this, we recommend the following procedure:

Adjusting the bank setups

Using the autopilot setup, disable the pitch servo and only enable the bank servo (ensure type and location of servo are selected correctly).

Set the bank control setup as recommended in the bank servo setup section of this document.

Engage the autopilot and only use pitch control to keep the aircraft level. Use the bank neutral position trim to trim the aircraft for straight flight. This is best done in calm conditions.

Position the aircraft in a stable, straight and level attitude, power the servos and engage the autopilot.

Keep the aircraft level using the pitch, the autopilot should now control the bank. It will not attempt to intercept any particular heading as we have set the heading change magnitude very low. We now want to adjust the PID controller for holding the bank angle. Slowly increase the Bank servo magnitude number until a slight upset of the bank angle will start a relatively fast oscillation, then reduce the number until the oscillation stops, then reduce the number by another 10%.

MGL servos will result in a harsh, forced control if the magnitude is set too high.

A typical setting is "10".

Adjusting the pitch setups.

Once your bank setup is known to be stable and your aircraft is holding a given bank angle, it is time to adjust the autopilot pitch servo settings

Enable the pitch servo in the setup and ensure that the type and location is selected correctly.

We recommend you start with the settings as recommended in the pitch servo setup section of this manual.

Please set ASI speed limits and vertical speeds in accordance with your aircraft's performance.

The first item that needs to be calibrated is the PID controller that controls the aircraft's pitch angle. For this we start by setting the **Pitch angle control Magnitude** to "5". Ensure that during this calibration relatively calm flying conditions are present.

Ensure that the pitch servo is enabled and that the pitch servo direction is set correctly as determined during ground testing.

Engage the autopilot in "**Engage, hold current altitude**" mode. .

Once engaged, open the Pitch setup menu again and start increasing the Pitch angle control Magnitude slowly. At some point you will notice that the pitch angle will start to oscillate (Nose moves up and down and with every cycle it gets worse). This is the point where too much control is present. Note the Magnitude number and reduce it by approximately 30%. The autopilot should now be able to hold any desired pitch angle.

Example: The aircraft starts a pitch oscillation at a magnitude setting of 12. Reduce the

number to 8 or 9. The autopilot should now be able to hold the pitch angle without any sign of oscillation. Reducing the number further is permissible but not lower than about 50% of the value it took to start the oscillation. If the number is too small the servo will move too slowly and the autopilot may not be able to correct pitch angle errors fast enough. This can degrade the autopilot's responses particularly in turbulent conditions.

Once a suitable value for the **Pitch angle control Magnitude is found**, it should not be necessary to change it again unless you change anything in the mechanical servo linkage.

Disengage the autopilot.

Select the altitude control as desired to "slow, medium or fast". This controls how rapid pitch angle is allowed to change, for example if you have set the altitude bug to a new altitude and want the autopilot to follow (assuming the autopilot is enaged in "altitude hold mode").

If the control is set too low, performance will degrade and the autopilot is not able to hold altitude properly. In this case you will find a slow phugoid around the target altitude that may get worse with every cycle. This is due to the autopilot not being allowed to change pitch angle fast enough.

Basic roll and pitch angle control algorithm

The desired bank angle is calculated from the current bank angle and the desired rate of turn to intercept a given heading. This bank angle is used as the flight director's bank angle. The bank angle is a calculation based on:

a) The desired turn rate (calculated from the current heading error)

b) The forward speed (ASI) of the aircraft.

c) The currently measured bank angle.

The system uses the vertical speed ascent and descent settings as guide. These settings will be used for relatively large changes in target altitude. For small changes, these settings are suitably scaled down. If you are exactly at target altitude, the autopilot will attempt to hold a vertical speed of zero feet per minute.

The autopilot follows the flight director (In fact, the flight director is an integral part of the autopilot).

The flight director determines the desired pitch angle to fly depending on the following factors:

a) The desired vertical speed which is based on the current altitude error.

b) The forward speed (ASI) of the aircraft.

c) The current pitch angle.

Interpreting vertical aircraft movements under autopilot control
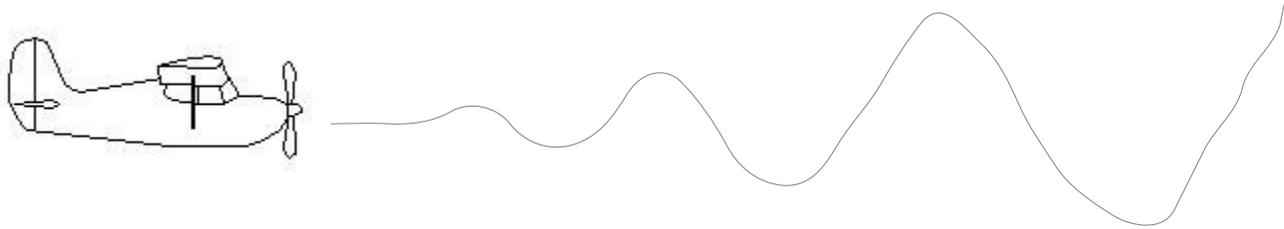
Increasing, fast phugoid oscillations – Disengage the autopilot immediately and lower the Pitch angle control magnitude before engaging the autopilot again.

Similar oscillations of the bank angle are also possible if the bank servo magnitude is set too high.

Oscillations happen if the amount of servo movement is too large to correct a given pitch or bank angle error.

Once your autopilot is matched to your aircraft

When you are satisfied with your autopilot setups, please take some time to note down your various autopilot setups for future reference.

Engine torque effects

Some engines may react with large power output changes related to pitch and speed changes. This may oppose the autopilots attempts at altitude correction to a large degree. The only solution is pilot control of engine power or an autopilot that has control over the engine throttle.
These effects tend to be worse with two-stroke engines.

Typical effect:

Aircraft is slightly above target altitude. AP lowers nose. Speed increases. Engine is unloaded allowing increased RPM and more power is produced. Instead of descending, aircraft gains altitude. Autopilot compensates with even more "nose down". Eventually airframe drag assists and counters the increased power and the aircraft starts to intercept the target altitude again but at increased speed. Depending on the engines torque curve the engine may now maintain an increased power setting even if throttle was not changed.

The reverse of the above is also possible but can be worse as it is possible to slow the aircraft to a high nose attitude with reduced power making it impossible to regain target altitude without the pilot changing throttle position.

Possible error messages on autopilot engage attempt or during autopilot operation.

AP disengage - Lost HSI

No horizontal navigation signal available.

AP disengage - Lost GSI

No vertical navigation signal available.

AP disengage - Lost AHRS

Lost bank/pitch information from AHRS, AHRS not operational.

AP disengage - Bank clutch

Bank servo clutch detected slipping for 1 second or longer

AP disengage - Bank fault

Bank servo communications fault – no response from servo

AP disengage - Pitch clutch

Bank servo clutch detected slipping for 1 second or longer

AP disengage - Pitch fault

Pitch servo communications fault – no response from servo

AP disengage – GPS AHRS

The EFIS system is not currently using a AHRS to measure aircraft attitude. The EFIS is using the GPS to estimate attitude based on the GPS flight path. This form of attitude cannot be used as a base to control the aircraft.

The above drawing shows the installation for a Trio Gold standard digital servo and a PWM servo (in this case a Navaid servo).

The communications link for the Gold standard servo is bi-directional, similar to RS232 but without negative voltage signals. In order for this to operate securely, it must be ensured that the ground of the COM-extender (available on pins 5 of each Rs232 connector) is at the same electrical potential as the servos own ground. Please ensure that you are using a sufficiently thick ground wire for the servos so the voltage potential at the servo will not be raised while the motor is operating.

The autopilot is designed to disengage if it is not able to receive data from the servo.

In case of PWM servos, there is no feedback from the servo back to the autopilot and the autopilot will not disengage in case of a servo fault as it is not able to detect this.

It is highly recommended that 33 ohm resistors of 1/2W rating are inserted into the ground connections from each servo to the COM Extender ground as indicated in the drawing. These resistors will prevent excessive ground current from flowing from the servo though the COM extender and EFIS which could cause damage.
These ground currents will occur if for some reason the servo looses its own supply ground while connected to +12V.

Electrical installation of servos (MGL Avionics servos)

Full details on the MGL servo and its installation are published in the "Servo user manual" available for download from the MGL Avionics website.

Basic electrical installation is repeated here.

Installation of the MGL servo on EFIS systems supporting a CAN interface requires a single twisted cable pair to connect the servos with the EFIS CAN interface.
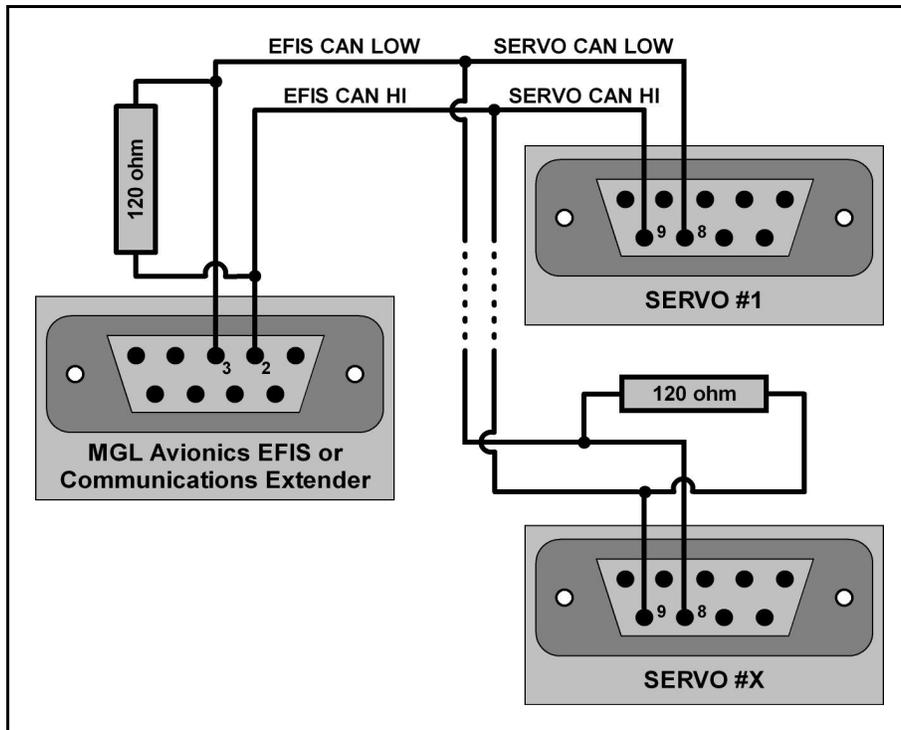
Please note that CAN requires termination resistors to be fitted to the ends of a cable run and that any branches from the cable must be short stubs.

If short cable runs are used, it is usually possible to install just a single resistor at any point in the cable.

At least one resistor must be installed. This forms an essential part of the CAN interface and it does not work at all if this resistor is not fitted.

Longer cable runs (in excess of a few feet) must use resistors on both ends of the cable. Do not fit more than two resistors.

Typical resistor values are 120 ohms. The exact value is not very critical but the combined value (two resistors in parallel) must not be less than 60 ohms. (120 / 2).

Note: The diagram does not show other CAN based equipment that you may connect to the same bus. Note that you will never install more than 2 resistors (one on each end of the bus) and at least one resistor if you have a short wire run (less than 10 feet). The CAN bus does

not work without a resistor !

MGL Servo LED indicator

Please note that the MGL servo has a red LED light.

This light will flash if the servo is being addressed by the EFIS. If the LED is steady on, there are two possible causes:

a) The servo has never been "identified" and is in virgin state as delivered by the factory (please perform the servo identification as outlined in this manual).

b) There is no communications due to a wiring issue.

Using the autopilot

The autopilot can be engaged in various modes and these can be transitioned between. The following text assumes that both bank and pitch servos are fitted. In case only one servo is fitted, some functions will not be available:

Autopilot control on iEFIS systems

If the autopilot is enabled and configured, select the autopilot control dialog using either the "AP" button or tap on the autopilot status display.

Pressing "Engage, straight and level" will engage the autopilot in current heading and altitude hold mode.Heading is derived from GPS heading corrected for local variation to obtain magnetic heading. This means that heading is independent of you compass installation. Altitude is derived from your altimeter and thus responds to local pressure settings. Your altitude bug is set to the nearest 50 ft boundary.

Pressing "Engage active NAV and vertical control" will engage your current navigation solution (primary "HSI"). Typical sources for your "HSI" are GPS navigation (Goto or routes), VOR, GVOR, ILS, GLS or heading bug. You select the required navigation source using the left function keys and you enable these sources for use using the relevant setup menus.
Pitch control source is selected as shown:
Altitude hold takes the current altitude and sets your altitude bug to this altitude.
Altitude preselect takes altitude as currently selected on the altitude bug.
VSI hold will attempt to hold the current vertical speed (usefull for long climbs and descents).
Flightplan vertical navigation will take altitude cues from an active route containing altitude directives.
Pitch attitude hold will attempt to hold your current pitch attitude. This can be used to adjust your "pitch servo magnitude" in the autopilot setup.

Pressing "ALT Hold, Turn 180" will engage the autopilot in a mode where it will attempt to hold the current altitude while reversing course. Once the reverse course has been intercepted, the mode is identical to "Engage, straight and level".

Yaw control is visible if this is configured on your system. You can engage and disengage yaw control independently from the remainder of the autopilot. You can configure the yaw control in the autopilot setup to engage automatically with the autopilot (but you still have independent control) or it can be set to be completely independent from the autopilot.

Note that if you have an Explorer or Challenger, you can also control the AP using the row of buttons below the screen (if the AP menu is showing).

Disengaging the autopilot

Once the autopilot is enaged, the autopilot control menus provide an option to disengage the autopilot.

Typically however, the autopilot is either disengaged by the pilot taking control of the aircraft. This causes one or more servos to slip which disengages the autopilot

Alternatively, the circuit breaker or switch feeding power to the servos is used to remove power from the servos. This also disengages the servos and the autopilot.

Other forms of autopilot control

Using a MGL Avionics iEFIS Extender for the "Lites" or the iBOX it becomes possible to configure one or more push-button switches (momentary contact switches) to engage and disengage the autopilot.

Configure the inputs used for this in the "Digital inputs setup menu"

Autopilot behavior

This chapter explains how the autopilot will react in certain cases:

Activating a GPS "Goto" when not pointing to the destination

You are flying on an arbitrary heading and select a GPS "Goto" that takes you in a new direction.
At the very moment of activating the "goto", the EFIS creates a track to the destination from the exact point of activation. As you are not pointing in this direction you will be immediately off track. The autopilot will now bank towards the track and attempt to intercept the track at an angle of about 45 degrees. At some distance from intercepting the track the autopilot will start gently vectoring towards the track.

Climbing and descending

Clean intercept of a target altitude is very dependent on your aircrafts power control. It makes a big difference how your engine reacts to propeller loading or if you have a constant speed propeller fitted.
Regardless of this, for a clean ascent or descent power should be adjusted to maintain airspeed as required.
The autopilot will attempt to intercept and hold climb and descent rates as you have set in the autopilot setup, be aware that if minimum or maximum speeds are exceeded the autopilot will abandon all attempts at vertical speed tracking and will either raise or lower the aircraft's nose so as to prevent undesired speeds.
The set rates will only apply if you are more than about 100 ft away from the target altitude, if less than this the rates will start to taper off, ever rapidly in order to intercept zero feet per minute rate at the target altitude.
When controlling power, gradually increase or decrease power as required to avoid changes in speed, unless desired.

If you are climbing and leave the engine at climb power, the autopilot is likely to overshoot the target altitude. The reason for this is the additional lift created as your aircraft speeds up due to the climb flattening out. Very similar to this, you will overshoot on a descent if you do not add power due to reduced airspeed and lift. The autopilot will attempt to fix up the overshoots but the correct procedure would be to prevent them from happening.

Similar to non-autopilot flight, power control during ascending and descending is required in order to obtain a clean profile.

Arriving at a waypoint or arriving at the last waypoint in a route

If you do not disengage the autopilot when arriving at a destination, the autopilot will either fly a circle or a figure of eight depending on wind direction in order to repeatedly intercept the waypoint.

Autopilot response in turbulence

The autopilot controls actual pitch and bank angles with reference to the AHRS system, this allows the autopilot to stabilize the flight profile in presence of external disturbances such as caused by turbulence and thermal activity.

The autopilot algorithm is designed to allow increasing tolerance with respect to the target altitude as turbulence increases. In calm conditions altitude tracking is typically +/-20 ft, within

this band the autopilot will be "lazy" in order to prevent excessive activation of the flight controls. In the presence of turbulence this band is gradually widened up to +/-50 ft to avoid unnecessary activity. While in the band, the autopilot will only make small adjustments to capture the target altitude. When outside the band, the autopilot will make a more determined effort to get onto target altitude.

Engaging the autopilot if no navigation solution is selected

If you engage the autopilot without a valid navigation solution, the autopilot will engage and track the current heading and set the altimeter bug to the current altitude.

The autopilot will refuse to engage if there is no vertical guidance selected. In this case please select your GSI source as "altitude bug".

If the current navigation solution is "heading bug" and you engage the autopilot, the heading bug will be set to the current heading.

Please note that the autopilot will use GPS based heading (GPS true track with local variation applied).

Engaging the autopilot if a navigation solution is active

If you engage the autopilot with an active navigation solution (I.e. your "HSI" is set to a valid source) and the source is not "heading bug", then the autopilot will engage the existing solution. If the current solution is "heading bug" then the heading bug will be set to the current heading.

Performing a "direct goto" or activating a route with the autopilot engaged

If the autopilot is engaged and using any navigation solution and you perform a GPS "goto" or activate a route, the autopilot will use the new navigation solution directly. There is no need to change navigation sources.

Using VOR or ILS as source for the autopilot

The autopilot follows any navigation source selected on the primary "HSI". This is the **only** source for the autopilot horizontal navigation. It follows that the autopilot will simply use whatever current source has been selected on the "HSI". This means that you can use any navigation source, regardless if this is an internal or external source.

Please note that you may need to setup the available sources as selectable for the HSI. This is done in the "setup HSI/GSI indicators" and "GLS/GVOR setup". Depending on your sources available, you may also need to configure your "ARINC setup".

Vertical guidance sources

In most cases vertical guidance is taken directly from the GSI (glide slope indicator) which is also active during altitude hold (effectively a zero angle glide slope). It follows that whatever source is selected for the GSI will affect vertical tracking.

In most cases the altitude bug would be the altitude target.

Pitch and Bank trim request display

You can enable pitch and bank trim request displays in the "Equipment enables menu".

Your screen design must have the required visual indicators placed (standard screens have them by default). These are invisible until stick forces are measured that require an adjustment of trim. Note that to be able to measure stick forces servo torque setting must be 80% or less. It is possible to go as much as 85% but with reduced sensitivity.

Typical trim request display – in this case a request to trim nose up.

Note: The trim request display can be used even if an SP-10 with autotrim is connected. In this case you will typically see the trim request display briefly before the SP-10 commands a trim correction.

Autopilot usage requirements – safety checks and considerations

No flight that will use the autopilot will be conducted without satisfactory pre-flight check of the autopilot and its systems.
Autopilot setups should be verified for correctness before flight.
The autopilot algorithms require correctly calibrated and functional airspeed input. If airspeed cannot be measured in flight (for example pitot tube icing), the autopilot must not be engaged as control responses may be incorrect.
It must be possible for an independent system to disengage the autopilot if required. A power switch accessible to the pilot that powers the servos is acceptable.
Pilots using the autopilot must be trained in the use and limitations of this autopilot system.
Installation of all parts related to the autopilot system must be carried out to acceptable aviation standards and comply with safety requirements. All components must be accessible

to regular pre-flight checks. Concealed linkages or servos that cannot be inspected without major effort are not acceptable.

Servo installation must adhere to airworthiness requirements and should be performed in consultation with the manufacturer of the aircraft to ensure safety and operation of the autopilot system and airframe.

The autopilot system is not intended to be used during takeoff and landing of the aircraft.