

MGL Avionics

EFIS

Integrated Autopilot

User and installation manual

Manual dated 24 May 2010

This manual supersedes all previous versions and is applicable for current EFIS firmware versions

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General

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

This functionality is available in MGL Avionics Xtreme, Enigma, Odyssey and Voyager EFIS systems.

Autopilot support for Xtreme EFIS systems is not currently available but under consideration.

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.

Autopilot functionality

The current release of the MGL Avionics integrated autopilot provides a traditional two axis system intended to control ailerons or rudder and elevator or elevator trim tabs.

Most systems would install a servo connected to ailerons and a second servo connected to elevator.

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 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

Autopilot requirements

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

Either Xtreme, Enigma, Explorer, Voyager or Odyssey EFIS panel operated as master in case of a dual panel system.

SP-2 compass. 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-4 or SP-5 AHRS. The AHRS supplies turn rates, bank and pitch angles for use by the autopilot. The autopilot will not work without an AHRS.

For PWM and Trio Avionics servos: MGL Avionics COM extender module. Using this module up to 4 Trio digital servos and 4 PWM servos can be connected. This module can also be used for other purposes requiring RS232 serial ports.

MGL Avionics servos can also be controlled via the CAN interface on Odyssey, Voyager, Explorer and Xtreme EFIS systems. In case of Enigma systems, the MGL servos need to be controlled using a COM Extender module.

Implementation differences between Enigma and Odyssey based systems.

Odyssey and related systems such as Voyager and Explorer provide external autopilot control via ARINC steering messages. Due to this the autopilot interface can be switched between internal and external ARINC based autopilot. In case the external ARINC autopilot has been selected, some of the internal autopilot adjustments remain available and these will be used

to control the external autopilot. Example: The bank setup “Heading change magnitude” will remain accessible and can be used to change the external autopilots response to required heading/course intercept commands.

For Enigma systems the internal autopilot can be either switched on or off.

Please note: The provided NMEA autopilot interface via RS232 port remains completely independent from anything mentioned in this manual, it is a separate system.

Servos

In keeping with the MGL Avionics flexible autopilot implementation, different types of servos are supported and these can be mixed if required.

PWM servo

This types of servo uses a PWM signal (Pulse width modulation). The servo responds to a repetitive pulse (usually 50 or 100 pulses per second) and the pulse width of the servo (1 to 2 milliseconds) determines the servo position.

This type of servo is generally not recommended but can still be used with the MGL Avionics system (up to 4 PWM servos can be controlled).

PWM servos are not able to report their position to the host system so need to be engaged in a specific position. The servo setup contains setups for these positions if a PWM servo has been chosen for a particular function.

Further limitations of PWM servos are that no reporting of faults, slippage etc can be reported to the host system.

If a PWM servo has been selected for a particular function, a further setup entry will be available for that function to allow selection of the desired position at servo engage. This position can be adjusted in flight.

Bank servo engage position setup

Example servo setup function applicable only for a PWM servo.

Trio Avionics Digital servo

This is the recommended servo for most capture and track applications.

This servo is based on a geared DC motor with a solenoid engage mechanism and a mechanical clutch on the output shaft. This servo has modest power electrical power needs and zero system drag if not engaged. Control speed is modest and control angle is limited. Most applications will install the servo such that it is able to control approximately 50% of the available control movement.

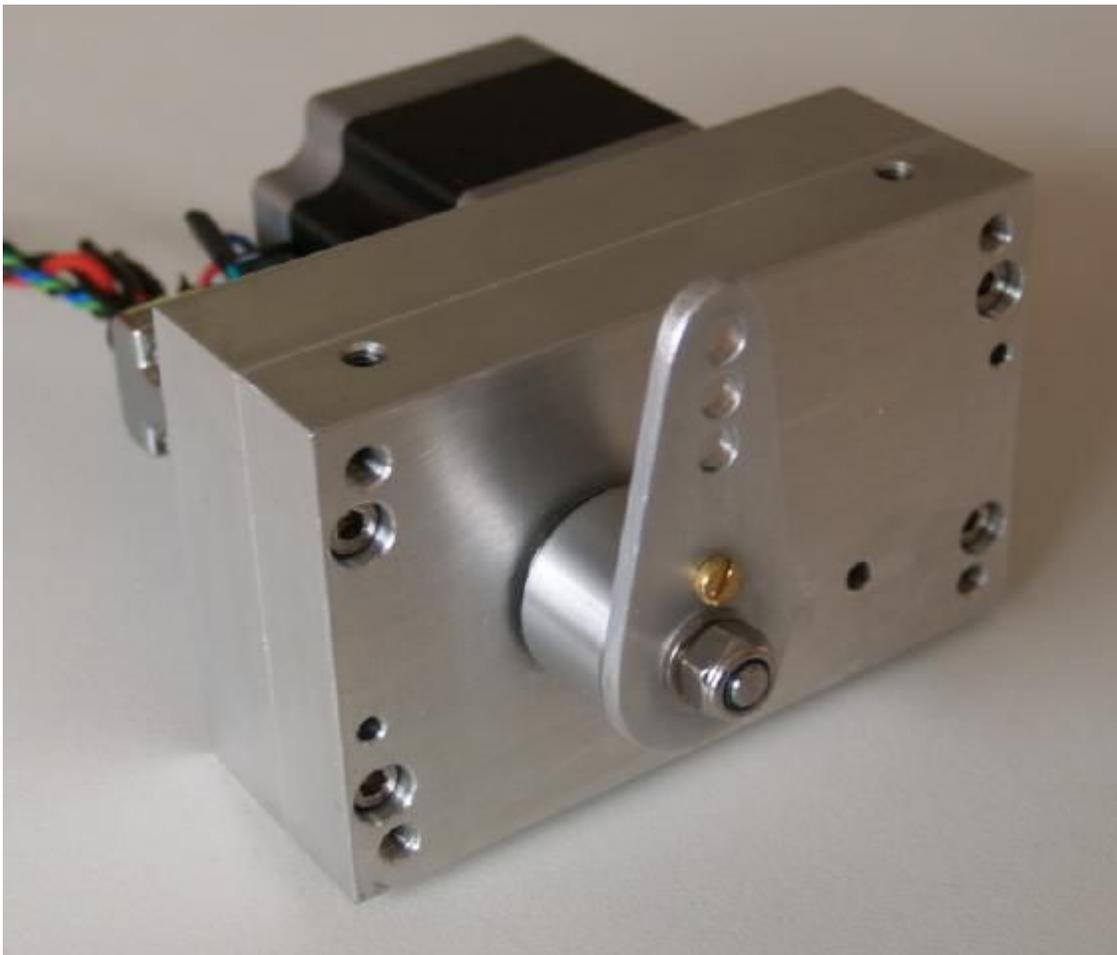
The digital servo provides feedback to the host system and the host is able to engage the servo at its current position. The servo provides feedback on clutch slippage, control limits and internal faults.

MGL Avionics Digital servo

This servo is currently in development. 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 intended mainly for full authority control systems. 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 and is suitable for pitch dual loop control systems. The MGL servo is also able to measure the forces acting on the servo arm to provide automatic trim correction information.

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.



Picture of the MGL servo – shown here in prototype form. Based on high torque stepper motors the servo will be released with three different motors to cover three different torque ranges.

Other servo systems

MGL provides the “MGL Avionics universal 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.

In addition to this, other autopilot manufacturers servos may be able to be used if there is demand for such and the manufacturer is willing to allow use of his servos in MGL systems and will provide the required interfacing information.

Engaging and disengaging the autopilot

The autopilot can be engaged and disengaged in several ways:

- Via the EFIS keypad
- Via autopilot engage/disengage switch (this requires fitting of an I/O extender).
- Via optional autopilot control panel (Planned item)

The autopilot will refuse to engage if:

- The servos are interface using a MGL Avionics COM extender and no communications to this unit can be established.
- A digital servo is used and it reports a position beyond its control limits
- 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 (button push)
- Engage/disengage switch is pressed (switch connected to I/O Extender)
- Disengage button is pressed on optional autopilot control panel
- A digital servo reports that it has reached its control limit
- A digital servo reports a slipping clutch or torque overdrive for 1 second
- Active navigation source has been lost
- G-force acting on aircraft exceeds 2G (not applicable for full authority systems)
- Power is removed from a digital servo (causes RX fault)
- Connection to MGL COM Extender is lost (if this unit is required to control servos)

Preflight check of the autopilot installation

Menu level 2 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 be 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.

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

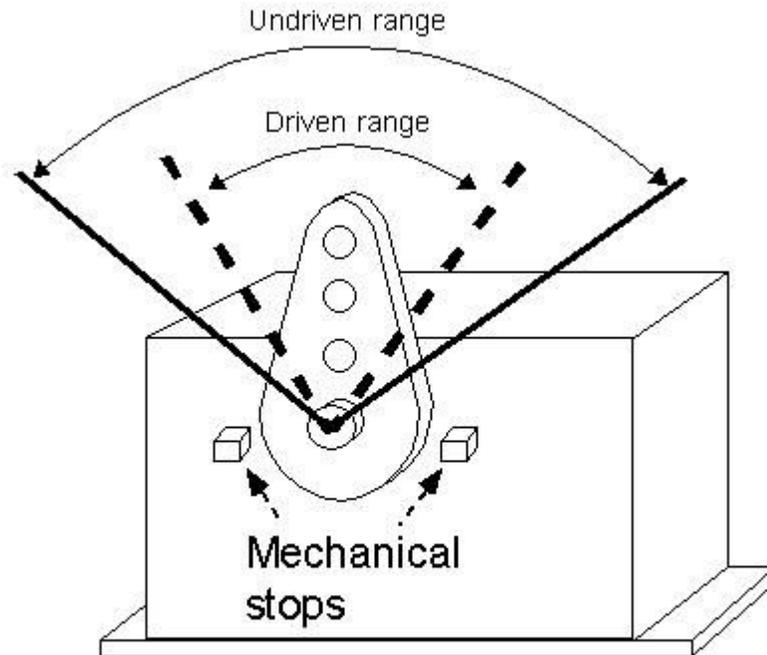
This phase starts with the identification of a suitable location for each servo. In many cases the aircraft manufacturer may have predetermined a suitable location and control linkage. Installation of the servo should be carried out by a suitably qualified aircraft technician.

- 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.

Servo driven and undriven ranges

Applicable: Trio Gold Standard Servo

The Trio servo provides about +/- 40 degrees of active driven range from neutral position. When the servo is not engaged the servo arm can move in a much larger arc.



Undriven range = full range of control surface
Driven range = 50%-70% of full range

The ideal installation will coincide the undriven (large) range with the full stop-to-stop range of the control surface so that the servo, once engaged is able to drive about 50%-70% of the range of the control surface. This is particularly important for higher performance aircraft. This improves the position accuracy and resolution of the servo system when very small adjustments may be needed in flight.

Further considerations:

With the control surface in neutral position, the servo arm must be as close to neutral as possible. There are 4 possible positions of the arm depending on how you mount the servo arm. If none of these positions are satisfactory, consider drilling four additional arm mounting holes to allow use of the arm in an offset position.

The servo arm provides three hole positions to mount the control linkage. Consider drilling a further hole in a more suitable position to lower the active driven range of the servo on the control surface if required.

Post installation checks:

DO NOT FLY THE AIRCRAFT UNTIL THE FOLLOWING POST INSTALLATION CHECKS HAVE BEEN CARRIED OUT AND FULL AND CORRECT FUNCTIONS 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 autopilot's 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 descent rates. You will use 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 your 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-built 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.

3 Setup Autopilot (Internal AP and ARINC AP)

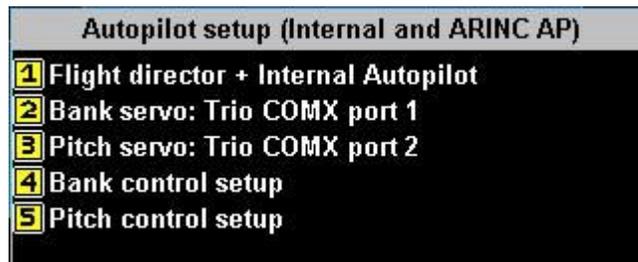
For each servo select the servo type and electrical connection source.

Trio Avionics digital servos are controlled using RS232 serial data connections. The MGL Avionics COM Extender provides four suitable serial ports. RS232 ports available on the EFIS cannot be used. Only COM Extender serial ports may be used.

Each RS232 port provides a bidirectional communications link. The TX connection sends position and other data to the servo while the RX connection receives position and status data from the servo.

PWM servos can be connected to the MGL Avionics COM Extender. Up to four PWM servos can be controlled. PWM servos can be considered as roll, yaw, power or lift servos. PWM servos should not be considered for pitch servos as these need to be engaged at a known position and this is only possible with digital servos.

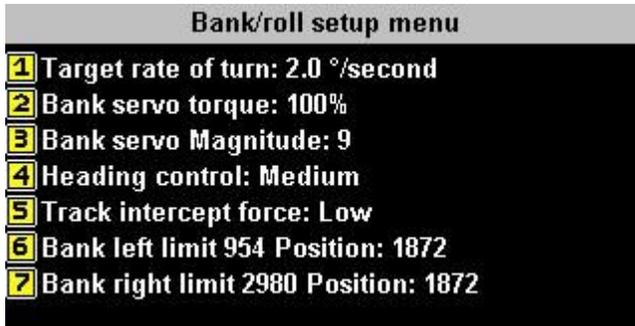
MGL Avionics servos may be connected to either RS232 ports on the COM Extender or they may be connected to the EFIS's AeroCAN interface if the EFIS supports this type of interface.



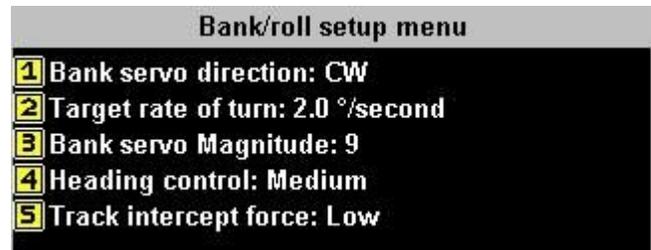
Once the servo type and connection location has been selected, a corresponding configuration menu becomes available for that servo. For example, once you have allocated a bank servo, you will be presented with the Bank control setup menu.

Configuring the roll (bank) servo

MGL Avionics servo setup



Trio 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 is 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.

Track intercept force:...

This setting has three options: Low, medium and high.

Select a suitable setting for your aircraft to hold a track that is NOT heading, for example a GPS track. Here the track error is made up from the actual track error as well as the amount of course deviation (i.e. distance from the desired track).

The MGL Autopilot will intercept a track at an initial 15 degree angle if you are relatively far from the track but as you get closer to the track this setting takes over. It determines how well you would like the autopilot to stay on track. Often it is desirable to allow a small deviation to avoid continuous corrections. Select a value that best satisfies your requirements.

Bank neutral position trim

This entry will only be available if you are using a PWM servo. Here you select the servo position to be used when engaging the autopilot. This position is normally selected during a test flight, trimming out any unwanted turn.

To use this function in flight, the autopilot must not be engaged (this function will not operate if the autopilot is engaged). If you activate this function the bank servo will engage at the current servo neutral position – note that other servos will not engage.

Adjust the neutral position until any tendency to turn has been tuned out. This should best be done during calm flight conditions as turbulence may mask the neutral position.

The bank servo will disengage as you deselect this function or exit the menu.

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 maximum 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.

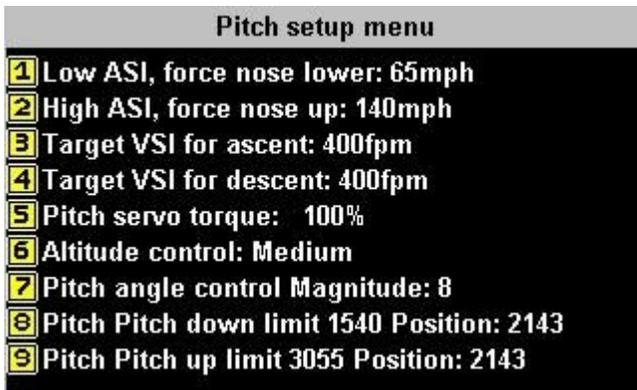
Pitch servo / vertical control

The vertical control part of the autopilot is implemented using an artificial intelligence (AI) system based on a “neural network” feeding desired pitch into a PID controller that compares actual pitch attitude as measured by the connected AHRS with the desired pitch and uses the resultant error to control the pitch servo.

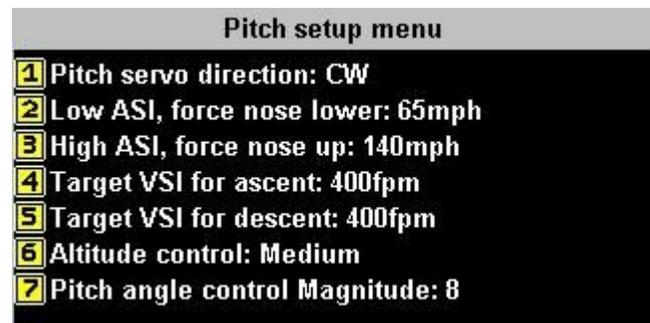
The autopilot will evaluate aircraft response to control inputs and adapt future control inputs accordingly within set limits. This way the autopilot is able to fly pitch sensitive aircraft in the presence of changing conditions.

Configuring the pitch servo

MGL Avionics servo setup



Trio Avionics servo setup



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 is 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.

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 4-5) 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 up limit / Pitch down 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 pitch up and down limits as well as the required servo direction. Move the stick to the maximum 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.

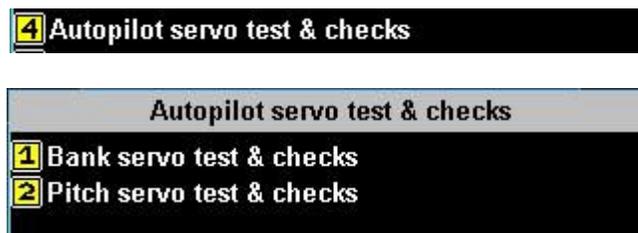
Note: You need to exit all menus to permanently store these settings.

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.

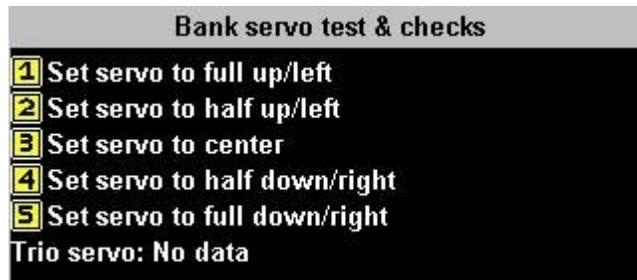
First servo tests

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 from fully clock-wise (CW) to fully counter clock-wise (CCW). This equals the maximum control range of the servo which should not exceed 50%-70% of the control surfaces maximum limit movement.

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

If this is your first installation using the COM extender, first ensure that the COM extender is operational. Ensure that it is connected to any one of the two USB host connectors on the back of the EFIS. Switch the EFIS on.

As you switch the EFIS on, the RED LED on the COM Extender should light and stay on for about 5 seconds. It should then start flashing twice per second. If the LED does not light at all, does not start flashing or if it flashes very fast then there is a problem. Do not proceed until you have resolved the issue.

With the servos connected and the COM Extender LED flashing twice per second, apply power to the servos. The servos should not engage at this stage.

Perform the autopilot preflight check. This is an automated procedure accessible from the main menu level 2.

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 is 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 you have PWM servos connected, use the neutral positioning functions provided in the autopilot setup menus to set an approximate position. You will fine tune this position during flight. Please note: MGL Avionics does not recommend the use of PWM servos for pitch applications and recommends the use of digital servos for all functions.

If your autopilot preflight 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 follows:

Target rate of turn: 2.0 (faster aircraft should select a lower rate of turn to avoid steep banks)

Bank servo magnitude: 5 (typical value after calibration for most aircraft: 10).

Heading control: Medium (select after calibration as desired)

Track intercept force: low (recommended setting for "loose" following of track)

If you are using a PWM servo, you will first perform the bank neutral position trim. This is the servo position that will be used as you engage the autopilot. If you are using a digital servo, skip this step.

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%.

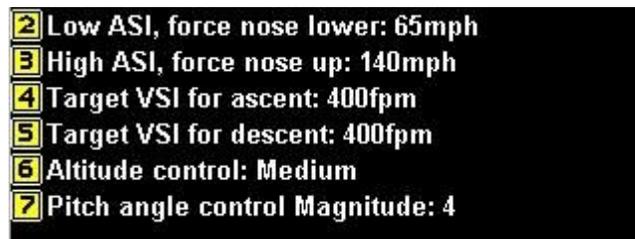
Track intercept force is a setting that is used if you are following a GPS track and are not quite on track. You will adjust this value at a later stage when you fly your first GPS track. Effectively this settings allows the autopilot some error when following a track so not to cause the servos from working overtime trying to keep to the track with unnecessary precision.

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 following settings:



Please set ASI speed limits and vertical speeds in accordance with your aircrafts performance. The values shown above are an example.

If you have a PWM servo connected, use the pitch servo neutral adjustment to find a suitable position for servo engagement. Be aware that large pitch changes may occur if the servo position at point of engagement is incorrect. Be alert and remove power to the servos instantly if pitch change is too large. We at MGL do not recommend the use of PWM servos for pitch as it is not possible to engage them at their current position.

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 "4". 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 engaged 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.

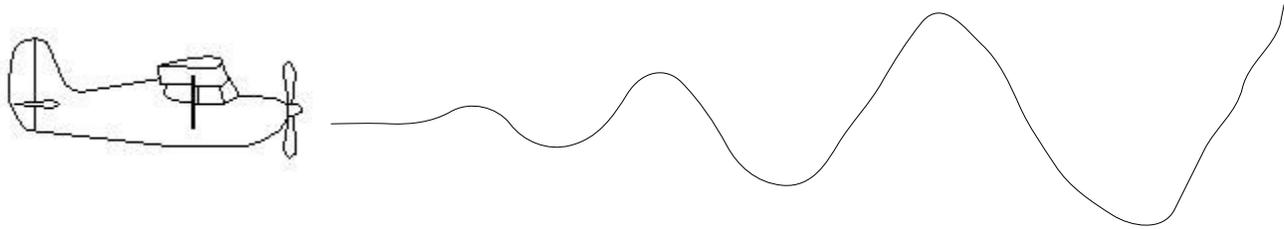
The system uses the vertical speed ascent and descent settings as guide. These settings will be used for relatively large changes in target altitude. For small changes, these settings are suitably scaled down. If you are exactly at target altitude, the autopilot will attempt to hold a vertical speed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

We at MGL would be very interested in your setup values and the type of aircraft you fly and would like to share your experience with pilots of similar aircraft that may ask us for suitable starting values. Please contact us at info@mglavionics.co.za.

Trouble shooting and known issues

Menu level 2 contains a autopilot status viewer which gives a lot of information on what the autopilot is trying to do and current aircraft attitude measurement results.

This is the list of currently know issues we are aware of:

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.

PWM servos

PWM servos cannot be monitored by the autopilot. This means they need to be engaged at a predefined position. This position can be adjusted via the setup menus. It is not possible to monitor servo slip. Generally, PWM servos are not suited for pitch control applications.

Prerequisites

The following prerequisites and parts are required to allow the autopilot to function correctly:

SP-4 or SP-5 AHRS in correctly installed and operating environment. Note: these units **MUST** be set to the 0.1 degree resolution data output mode, the autopilot will refuse to engage if the AHRS is not set to operate in this mode.

SP-2 compass (only used if GPS not operational).

MGL Avionics COM Extender. (Acts as servo interface and provides additional Rs232 ports that can be used for other functions).

Enigma, Voyager or Odyssey EFIS with latest software installed (check on www.MGLAvionics.co.za for updates and current version numbers).

Servos

Compatible servos:

Trio Avionics Gold standard digital servo.

MGL Avionics servo.

Navaid PWM servo and any other PWM servo that can accept a 100Hz PWM signal of 1-2mS pulse width at TTL levels (positive pulse).

Please contact the manufacturer of a given servo for installation hardware, mounting brackets and advice for specific aircraft.

Autopilot messages

The autopilot can fail to engage with any of the following messages:

AP fail: No AHRS

No AHRS detected. The autopilot needs a AHRS like a SP-4 or SP-5 to operate.

AP fail: AHRS data not compatible

AHRS has been detected but is not set to produce correct data. Please ensure that you have the 0.1 degree AHRS selected in the "Horizon setup menu".

AP fail: No COM extender AP RX

COM extender not detected.

AP fail: Pitch servo - no RX

No data received from pitch servo – check servo power and wiring.

AP fail: Bank servo - no RX

No data received from bank servo – check servo power and wiring.

The autopilot can disengage with any of the following messages:

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 - Lost COMEX

Lost connection to COM extender

AP disengage - Bank limits

Servo reports that maximum active control range of servo arm has been exceeded

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 limits

Servo reports that maximum active control range of servo arm has been exceeded

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.

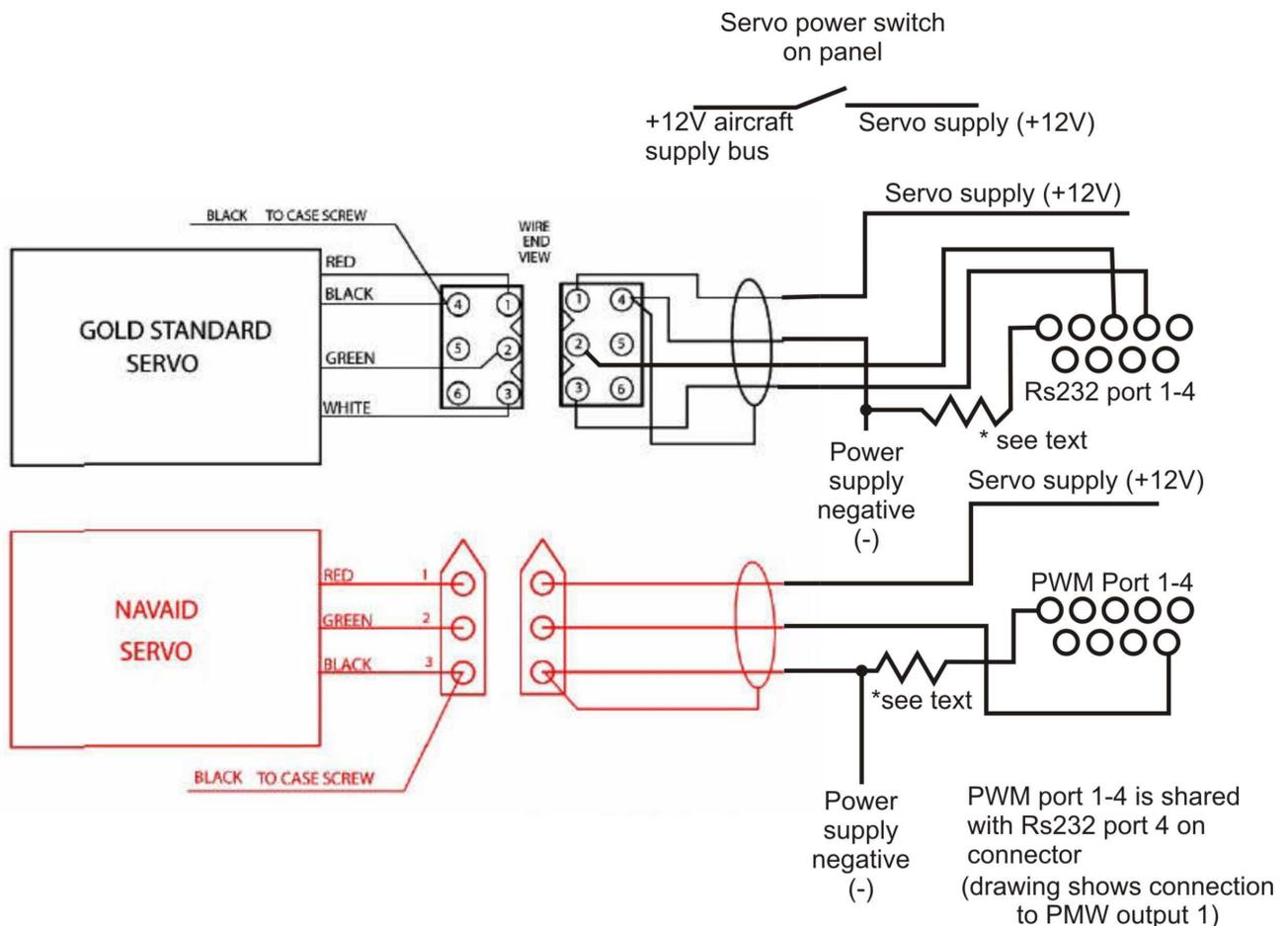
Electrical installation of servos

Servos are powered by the aircrafts power supply bus. Typically this bus supplies either 12V or 24V DC. Ensure that your servos are compatible with the DC supply available.

Ensure that your aircrafts power supply is sufficient to supply your servos peak power demand. Use power cables of sufficient diameter to supply the required current without causing undue voltage loss.

DANGER: Ensure that your servos supply ground is secure at all times. Loss of ground (ground fault) may cause extensive damage to connected systems. Please read notes on preventative measures related to ground faults.

Servo positive power supply should be routed via a latching switch that is easily accessible by the pilot and clearly marked “Autopilot servo power: On/Off”.



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 through the COM extender and EFIS which could cause damage.

These ground currents will occur if for some reason the servo loses its own supply ground while connected to +12V.

Note: Servo communications cables must not be routed close to or alongside audio cables from an intercom system as the signals traveling in these cables may cause interference. It is advised to use shielded cable with the shield itself connected at one location only. The shield must not carry any current as this will result in the shield radiating possible interfering signals.



MGL Avionics USB COM Extender and autopilot servo interface

Sample setup values

The following setup was used on a relatively pitch sensitive but stable high wing aircraft with a cruising speed of about 100mph:

Bank servo: Trio Avionics

Target rate of turn: 3.0

Bank servo magnitude: 10

Heading control: Medium

Track intercept: low

Pitch servo: Trio Avionics

Ascent and descent vertical speeds both set at 400 ft/min

Minimum and maximum speeds set as per aircraft requirements

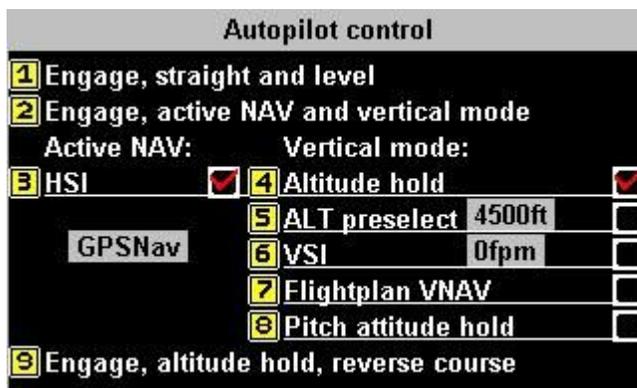
Altitude control: Medium

Pitch angle control magnitude: 10

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 Voyager and Odyssey EFIS systems



If the autopilot is enabled and configured, select the autopilot control menu using the left array of function keys.

Pressing “1” 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 your 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 “2” 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 (useful 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 “9” 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 “1” Engage, straight and level.

Autopilot control on Enigma systems

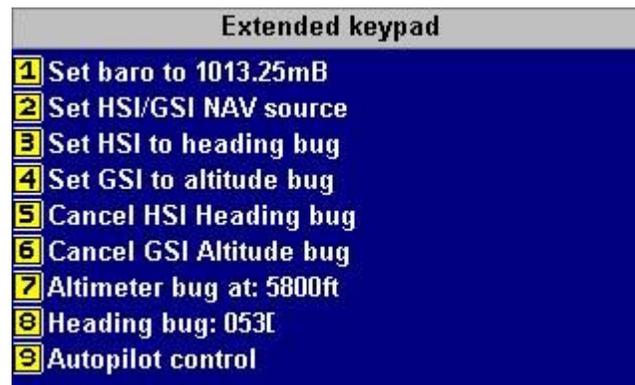


Autopilot control on Enigma systems is very similar to that on Odyssey/Voyager systems providing much the same functionality in a slightly different presentation.

The autopilot control menu is activated using “SHIFT” followed by “Menu” and then selecting “Autopilot control”.

The “extended keypad” menu

As Enigma does not have a function keypad on the left side (as Odyssey/Voyager), a substitute is available by pressing “SHIFT” followed by “Menu”:



This menu provides functions to select the currently active navigation solution, you can set the heading and altitude bugs by direct numeric entry and you can access the autopilot control menu.

Disengaging the autopilot

Once the autopilot is engaged, 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 (Not available for PWM servos)

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. In case of PWM servos removing power disengages the servos but the autopilot still needs to be disengaged using the autopilot control menu. This is due to the fact that the autopilot does not have any form of feedback from PWM servos.

Other forms of autopilot control

Using a MGL Avionics I/O Extender it becomes possible to configure one or more push-button switches (momentary contact switches) to engage and disengage the autopilot.

This requires creation of an I/O Extender script containing instructions on which inputs to use for which functions. The Script editor for this is available as free download from the MGL Avionics website (www.MGLAvionics.co.za) EFIS tools page.

You need as minimum release 2 of the I/O Extender script editor.

The script file, once created is installed into your EFIS using the “Installation tasks” 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. This distance is affected by your autopilot setup “Track force” setting.

Climbing and descending

Clean intercept of a target altitude is very dependent on your aircraft's 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 response is mainly limited by the speed of the servo. Depending on which type of servo you have fitted, different levels of stabilization can be expected.

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.