Gyro Stabilized
Pan and Tilt Camera Platform

Owner's Manual

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Watson Industries prides itself on solving customer problems and serving their needs in a timely fashion. This manual is intended to facilitate this goal and to provide written information about your product. We ask that you carefully read this manual. Becoming familiar with the manual will help you understand the product's capabilities and limitations, as well as provide you with a basic understanding of its operation. If, after reading the manual, you require further assistance, do not hesitate to call Watson Industries with your questions and comments.

CAUTION!

Watson Sensors are rugged devices that have been used successfully in a number of harsh environments. The components have been qualified to withstand a mechanical shock of 1000g 's or greater, and most enclosures provide near that level of protection. However, dropping a sensor from waist height onto a hard floor can cause a shock level of 600g's. At this level, given some resonance, damage is possible.

Introduction

The Watson Industries Gyro Stabilized Pan and Tilt is a platform for a video camera that employs gyroscopes to stabilize the camera against vehicle motion, achieving a still picture in mobile applications. The platform allows a camera to be accurately positioned on a target, irrespective of the motion of the vehicle on which it is mounted. A joystick is used to maneuver the camera in both the pan and the tilt axes. Push-button switches and LED indications are incorporated, along with a serial data interface, to control the finer aspects of the platform and to monitor its performance.

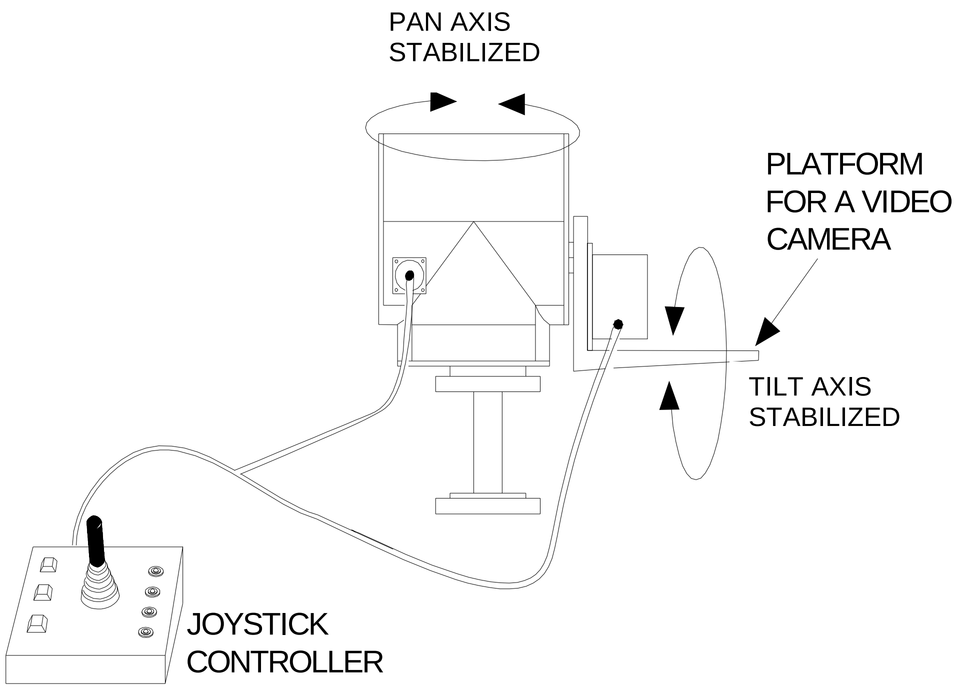


Figure 1 Gyro Stabilized Pan and Tilt

Product Description

The camera platform is a M.A.D. Homburg Pan and Tilt head into which Watson Industries has installed gyro stabilization.

Each axis utilizes a servo-motor driving the platform through anti-backlash gearing, a precision potentiometer for positional measurement, and a pair of limit stops. Furthermore, Watson Industries has installed a Gyro module for each axis, a Servo Driver module that is primarily used to derive power for the motors, and a Joystick Controller to operate the platform.

The two Gyro modules each contain a rugged vibrating-structure gyroscope, whose angular rate signal is converted from analog to 16-bit digital form. The effect of temperature variation on the DC bias of the gyro is corrected and then the digital angular rate signal is output to the Joystick Controller, on request. The pan Gyro module is located inside the Pan and Tilt head and the tilt Gyro module is located outside, on the platform or inside the camera housing.

The Joystick Controller assesses the desired motion of the platform based on an operator's use of the joystick. It then compares this desired motion against the real motion of the platform, sensed by the two Gyro modules, developing a rate error value. A servo-control system (P.I.D. algorithm), uses the current (Proportional), past (Integral), and predicted future (Differential) value of this error to derive a motor voltage that will drive the error to zero. The servo-control system ensures that the motion of the platform exactly matches that of the joystick.

The Servo Driver module accepts pan and tilt motor voltages from the Joystick Controller in digital form, converts them to pulse-width modulation and then applies this to the two motors, deriving power from two full-bridge motor drivers.

The Joystick Controller handles all communication between the modules over a robust two-wire RS485 bus, which is slew-rate limited so as to ensure low electro-magnetic emission. Isolated DC-to-DC converters are employed in every module to isolate the signal ground from that of the incoming power supply.

The platform is designed to be rugged and reliable. Particular attention has been paid to minimizing the effects of noise in the system to achieve a highly stable platform.

Modes of Operation

The Joystick Controller incorporates three push-button switches. Once pressed, these switches will remain on until such time that they are pressed again to turn them off. Each switch is accompanied by an LED that provides a positive confirmation that the Joystick Controller is performing the function associated with the switch. These functions are described in the following sub-sections.

Additionally there are four separate LED indications. These will be described in the following sub-sections, apart from one; the "Power" LED which provides positive confirmation that DC power is being supplied to the Joystick Controller and that the power supplies within this module are operating correctly. The Joystick Controller distributes DC power to all the other modules in the platform. It is fused and provides reverse and over-voltage protection for the whole system. For this reason, **external equipment must not tap into the Pan and Tilt power connections. A separate cable must be run from the external power source to supply power to equipment located on the platform.**

Unstabilized Mode

When the "Stabilized" switch is off, all modules are fully powered except for the pan and tilt motors, to which brakes are applied so that the platform cannot move around under its own weight. The platform can be maneuvered using the joystick, during which time the appropriate brake is released and then reapplied. The brake release action is audible.

Moving the joystick left or right maneuvers the pan axis left or right. Pulling the joystick back maneuvers the tilt axis upwards and pushing the joystick forwards maneuvers the tilt axis downwards. The further the joystick is moved from its center position, the faster the platform will move. Delivery of power to the motors is fixed for a specific joystick position, so influences such as mechanical stiffness, cable drag, and high wind, can affect the rate at which the platform turns during a maneuver, particularly at low speeds.

The green “Pan” or “Tilt” LED indications are only illuminated when the platform is being maneuvered in the appropriate axis. The rest of the time they are extinguished.

In the unstabilized mode of operation, the platform is not stabilized against vehicle motion. For example, consider the scenario illustrated in *Figure 2*, in which a Pan and Tilt is mounted on a boat. A camera operator maneuvers the platform so as to point the camera at a distant object on the horizon. The boat then turns to port. So too does the camera because the platform is unstabilized. The operator may well lose sight of the object altogether, particularly if the camera zoom was at maximum range.

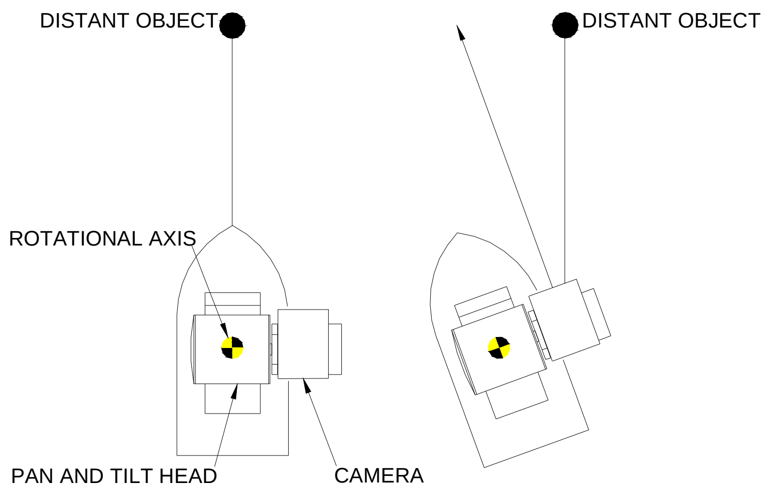


Figure 2 Unstabilized Pan and Tilt

Stabilized Mode

When the “Stabilized” switch is on, the brakes are continuously released and servo-controlled power is delivered to the pan and tilt motors to stabilize the platform.

The platform can be maneuvered using the joystick as previously described, although the way in which power is delivered to the motors differs considerably from that of the unstabilized mode.

In the Stabilized mode, the servo-control system applies whatever power is necessary to the motor so as to ensure that the platform moves at the correct rate, as set by the joystick and as sensed by the Gyro modules. The resultant motion is therefore much more positive than that of the unstabilized mode.

Both the green “Pan” and “Tilt” LED indications are continuously illuminated.

In the Stabilized mode of operation, the platform is stabilized against vehicle motion. For example, consider the scenario illustrated in *Figure 3*, in which a Pan and Tilt is again mounted on a boat. A camera operator maneuvers the platform so as to point the camera at a distant object on the horizon. The boat then turns to port, exercising the pan axis. Now that the platform is stabilized, the camera remains on the object.

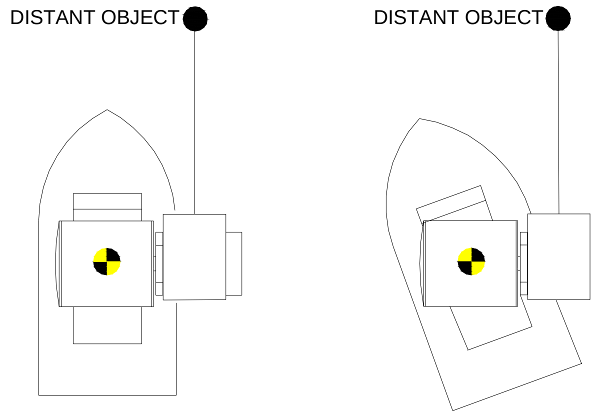


Figure 3 Stabilized Pan Axis

Now consider the scenario illustrated in *Figure 4*. The boat pitches up, and over a wave, exercising the tilt axis. Still, the camera remains on the object.

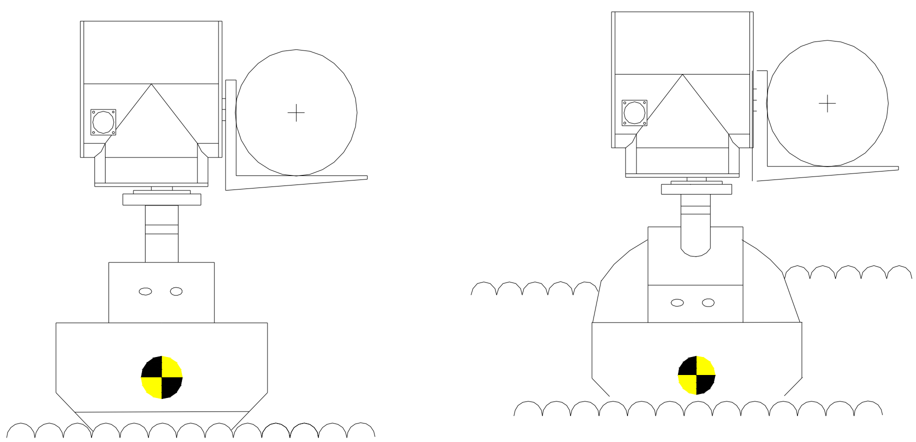


Figure 4 Stabilized Tilt Axis

It is important to recognize that the Pan and Tilt can stabilize motion in only two axes. Consider the scenario in *Figure 5*, in which the boat rolls somewhat as it turns to starboard. The Pan and Tilt cannot stabilize against the roll motion in this third axis

When the camera is looking at a distant object on the horizon, as in the top-right illustration, the unstabilized roll motion is seen as a rotation of the image. The human eye can cope with rotation much better than it can linear motion, so the roll motion goes unnoticed.

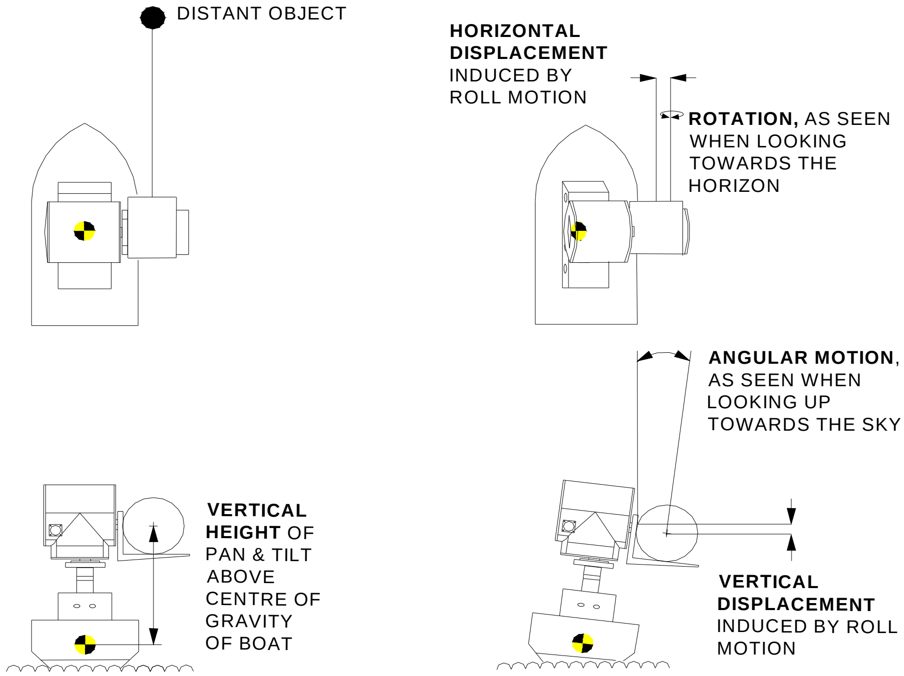


Figure 5 Unstabilized Axis

Some linear motion is inevitable, as can also be seen in the top-right illustration. Ideally, the Pan and Tilt should be located at the center of gravity of the vehicle, though usually this is not possible because the camera needs to be up high enough to see outside the vehicle. This is true of the boat example, where the unstabilized roll motion has induced a horizontal displacement due to the vertical height of the Pan and Tilt above the center of gravity. Such a displacement can be calculated for any given situation;

Horizontal displacement = Height above center of gravity $\times$ sin (unstabilized motion)
= 5m $\times$ sin (20°)
= 1.7m, for a large boat undergoing a severe roll.

The bottom-right illustration shows that unstabilized roll motion also induces a vertical displacement, to a lesser extent, which can be calculated for any given situation;

Vertical displacement = Height $\times$ (1 – cos (unstabilized motion))
= 5m $\times$ (1 – cos (20°))
= 0.3m, for a large boat undergoing a severe roll.

These linear displacements would still occur even if the third axis were stabilized.
The only way to minimize them is to locate the Pan and Tilt closer to the center of gravity of the vehicle. The effect of linear motion on the image depends on how far away the object is (the further the better) and how close the camera is zoomed in on it (the less zoom the better).

The bottom-right illustration also clarifies an important point. As the camera is tilted up, from an object on the horizon, towards the sky directly above the Pan and Tilt, the effect of unstabilized motion goes through a transformation, from an unnoticed rotation of the image to a full angular motion, making it difficult (if not impossible) to keep an airborne object in the picture. The Gyro Stabilized Pan and Tilt is therefore most useful for looking at objects near to the horizon.

It is not just the height of the Pan and Tilt above the vehicle's center of gravity that is important. Placement of the Pan and Tilt in relation to the other rotational axes of the vehicle is important too, if linear motion is to be minimized. For example, consider the scenario illustrated in *Figure 6*, in which the Pan and Tilt is located aft of the yaw axis of the boat. Even though the pan axis has successfully stabilized the angular motion associated with a turn to port, a horizontal displacement has been induced, resulting in the camera pointing to the right of the object. Again, such a displacement can be calculated for any given situation;

Horizontal displacement = Distance between pan & yaw axes $\times$ sin (yaw motion)
= 5m $\times$ sin (90°)
= 5m max. for a 90° turn with pan axis 5m aft of yaw axis

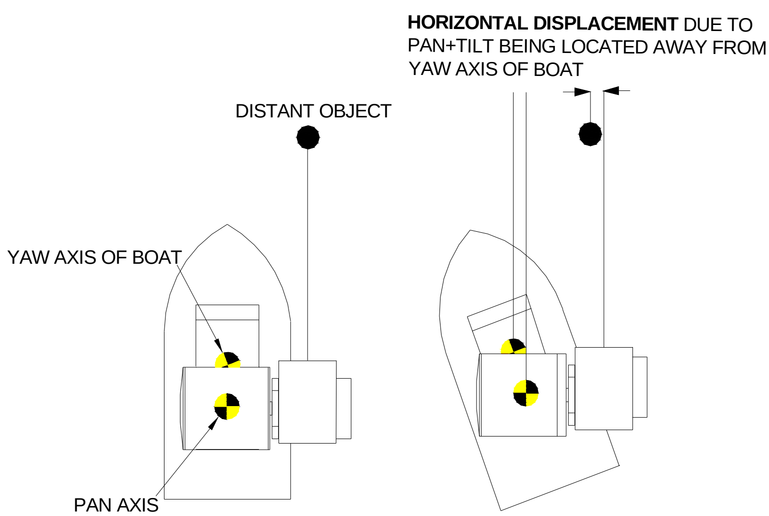


Figure 6 Pan Axis Offset from Yaw Axis

Similarly, a vertical displacement is induced by a pitch motion when the Pan and Tilt is located offset from the pitch axis. The general rule, as far as minimizing all linear motion is concerned, is to place the Pan and Tilt as close as possible to all three of the rotational axes of the vehicle.

It is important to recognize that, as far as the unstabilized axis is concerned, the pitch and roll axes are interchangeable; it just depends on where the camera is pointing. Revisiting the boat example, if the camera was looking out from the side of the boat, instead of over the bow, the roll axis would be stabilized and the pitch axis would not.

Pan Mode

Pan mode overrides joystick control of the pan axis, sweeping the platform ±45° left and right of the position that it was facing when the "Pan Mode" switch was first pressed, at an angular rate of 2.5°/s. The joystick can still be used to control the tilt axis.

Pan mode can be stabilized or unstabilized. When it is stabilized, the platform will continue to pan about the same geographical point that it was facing to begin with, even if the vehicle makes a turn. If the platform runs into one of the limit stops, the mid-point of the pan range will be shifted such that, at its extremity, it just touches the limit stop.

When the Pan mode is unstabilized, the platform will continue to pan about the same point on the vehicle that it was facing to begin with, unless it runs into a limit stop, in which case the pan range will again be shifted. The angular rate and pan range defined above will not be met when the Pan mode is unstabilized. This is because the delivery of power to the motor is fixed and, particularly at such a low angular rate, may have difficulty overcoming some of the aforementioned influences.

Null Bias Mode

The DC bias of industrial-grade gyroscopes, even the high performance ones that are employed in this platform, are inherently unstable. Watson Industries has characterized the performance of each gyro, as regards DC bias, across a wide range of carefully chosen temperatures so as to develop a temperature correction curve, which is individual to each gyro. This curve has been embedded into each Gyro module.

Temperature correction removes most of the DC bias variation, but bias has many other sources whose overall effect is to introduce an uncertainty of up to 0.5°/s of DC bias. This could result in the platform drifting by up to 30°/minute while stabilized. Further correction is therefore necessary, and this is achieved using the Null Bias mode.

When the “Null Bias” switch is pressed, the platform is no longer operating in a positional sense. Moving the joystick left-right or forward-backward now changes the DC bias of the appropriate axis, increasing or decreasing the rate at which the platform drifts in both the pan and the tilt axis.

Procedure to null the DC bias of the platform:

1. With the “Null Bias” switch off, use the joystick to position the camera on a distant object.

2. Press the “Null Bias” switch on, then move the joystick left-right and forward-backward to bring the distant object to a standstill on the monitor. If the drift is only slight, zoom in on the object to better see it.

3. Press the “Null Bias” switch off.

If the distant object is seen to drift out of the picture, repeat instructions 1 and 2 as many times as is necessary, before applying instruction 3.

The DC bias can be adjusted across a ±5°/s range, in 0.003°/s increments. Once the DC bias is close to being nulled, very fine adjustments can be made. To aid with such fine adjustment, the yellow LED that accompanies the “Null Bias” switch will flash once for each incremental change.

The rate at which the DC bias is adjusted depends on how far the joystick is moved. Nudging the joystick a small distance from its center position, then releasing it, will result in a change of one increment. Holding the joystick a small distance from its center position will result in the DC bias being changed at a minimum rate of 2 increments (0.006°) per second. Moving the joystick all the way to its end-stop will result in the DC bias being changed at a maximum rate of 100 increments (0.3°) per second.

Once the DC bias has been successfully nulled, the "Null Bias" switch should be turned off, returning the platform to its normal positional mode. The nulled DC bias will remain in force until power is removed and then reapplied to the platform. It is possible to save the nulled DC bias to permanent memory within the Joystick Controller.

Procedure for saving the nulled DC bias to permanent memory:

1. With the "Null Bias" switch on, press the "Stabilized" switch off

2. Press the "Null Bias" switch off.

This procedure should be used to save the nulled DC bias to permanent memory following installation of the platform on a vehicle. Afterwards, **it is intended that the camera operator experiment with nulling the DC bias of the platform over a period of time, arriving at a good general null, which the operator can save to permanent memory, making temporary adjustments to this as and when necessary.**

Safety Features

The Gyro Stabilized Pan and Tilt head incorporates three key safety features.

The first of these concerns the operation of the servo-control system, which is only applicable when the platform is in the stabilized mode of operation. This system supplies whatever power is necessary to the motors so as to ensure that the platform moves at the correct rate, as set by the joystick and as sensed by the Gyro modules. If a fault was to occur in one of the Gyro modules, or in the RS485 bus between the Gyro module and the Joystick Controller, the servo-control system could respond by driving the corresponding motor to maximum speed in an uncontrolled manner.

The Joystick Controller monitors both the angular rate, to verify that it is changing frequently (as would be expected of a servo-controlled system), and the magnitude of the rate error value, which must be less than a 25°/s limit.

If either persists beyond a 50ms tolerance period, potentially giving rise to 2.4° of uncontrolled motion, the Joystick Controller will turn off the servo-control system on the faulty axis. The appropriate "Pan" or "Tilt" green LED will be extinguished to indicate a fault. The faulty axis can still be maneuvered using the joystick, but it will be unstabilized. However, the good axis will remain stabilized. **Once the fault has been fixed, or indeed to confirm that a fault persists, switch the platform to unstabilized mode then back to stabilized mode. If all is well, stabilization will be reinstated on the previously faulty axis.**

The second of the safety features is the limit stops. These comprise a set of lever-activated micro-switches, which are carefully positioned so as to cut power to the appropriate motor when either of the two limit pins collides with the adjustable limit stops. This is to protect both the precision potentiometers inside the Pan and Tilt head and the interconnecting cables outside from harm in the event that the platform attempts to move beyond these safe limits. In the unlikely event that the platform crashes hard into a limit switch, and a pin is damaged, the pin can easily be replaced from outside the platform; it is held in place by a simple rubber grommet.

The pan limit stops have been carefully positioned so as to allow maximum maneuverability of the pan axis, achieving 345° range. It is recommended that the pan limit stops not be adjusted. When installing the Pan and Tilt head, consideration must be made of the desired field of view in relation to the vehicle. For example, if the field of view is in front and to either side of a vehicle, such as the boat application described previously, then the Pan and Tilt head must be installed with the pan limit stops orientated towards the rear of the vehicle.

The tilt limit stops have been positioned at ±45° about the horizontal. These limit stops can be adjusted. However, the stability of stabilization will deteriorate significantly beyond these limits for the reasons explained previously.

Activation of a limit stop may not necessarily be caused by a fault; if the DC bias is not fully nulled, and the platform is left unattended for some time in stabilized mode, it could slowly drift into a limit stop. This will cause the platform no harm. The operator can simply maneuver the platform away from the limit stop into a more useable position, at his leisure. However, **it is good practice to select the unstabilized mode when the camera is not in use. This ensures that the brakes are applied; reducing both the power consumption and mechanical wear.**

The third and final safety feature is incorporated into the hardware of the Servo Driver module so that, in the unlikely event of a microcontroller fault, the platform will protect itself from harm. The full-bridge motor drivers monitor the current drawn by the pan and tilt motors. If the platform is obstructed in any way, the servo-control system will provide more power to the appropriate motor so as to overcome the obstruction. Should the current drawn by the motor exceed its safe limit, approximately 0.8A at 24V DC for example, the Servo Driver module will limit the current at this level for a period of approximately 1.5 seconds. During this time, the appropriate “Pan” or “Tilt” green LED will flash, warning that one of the axes is current-limited. If the obstruction is overcome within this time, the platform will return to normal operation and the flashing LED will go back to being fully illuminated.

If the obstruction persists at the end of this period, both axes will be turned off; the unobstructed “Pan” or “Tilt” green LED will remain illuminated, the LED associated with the obstructed axis will be extinguished, and the red “Overcurrent” LED illuminated.

The green LED that is extinguished shows which axis has been obstructed, and the red LED provides reassurance that the platform is no longer in operation.

Once the “Overcurrent” lockout feature has been activated, an operator must remove the obstruction (the brakes are still released so that the platform can be manually maneuvered), then power must be removed and reapplied to the platform in order to return it to normal operation.

Specifications

Mechanical

Capacity:	20kg with load carefully balanced about pan and tilt axes
Pan axis range:	345° with 2 limit stops
Tilt axis range:	±45° stabilized -45° to +25° stabilized
Backlash:	0.15° typical; see paragraph 5.3 Performance
Weight:	12kg typical
Base fixings:	4 x M6 tapped holes 4”/101.6mm PCD
	4 x 6.35mm diameter holes 4”/101.6mm PCD
Platform fixings:	Key-hole slots 4”/101.6mm PCD
Standard color:	Goose gray, textured, semi-gloss (BS4800 00 A05)
Temperature range:	-20°C to +50°C

Electrical

Options:	<u>12V version</u>	<u>24V version</u>
Voltage range:	+10V to +30V DC	+18V to +30V DC
Current:	1.2A nominal	0.4A nominal
	3.2A peak	1.7A peak

Although the 12V version operates over a wider voltage range, the 24V version provides some significant advantages. It delivers considerably more torque than the 12V version and it is much more power efficient. This is primarily due to the brakes, which run at a lower temperature in the 24V version than they do in the 12V version. Indeed, the minimum voltage stated is determined by the brakes. A minimum voltage of +10V is required to release the brakes in the 12V version and a minimum of +18V in the 24V version when the “Stabilized” switch is first pressed. After this, both versions will remain stabilized with a DC voltage down to +9V.

The maximum voltage stated is defined by reverse and over voltage protection diodes. **Should the power supply voltage exceed this, the re-settable fuse is at risk of being tripped. If this happens, remove power from the Joystick Controller, wait a few minutes for the fuse to recover, and then reapply power.**

Performance

<u>Gyro</u>

Angular rate:	±100°/s
Resolution:	0.003°/s; 16-bit analog-to-digital conversion
Bias:	0.5°/s typical; following temperature correction
	Remaining bias corrected using Null Bias mode
Scale factor:	+/-1%; temperature range -40°C to +85°C
Noise:	1.5°/hr typical; low point in Allan Variance curve
Bandwidth:	70Hz

Platform	
Sample rate:	1000Hz
Maneuver rate:	±0.025 to ±12.5°/s typical; depends on gyro scale factor
Stabilization rate:	±48°/s
Stabilization accuracy:	0.1°/s typical; depends on angular rate

Although the gyros can measure up to 100°/s of angular vehicle motion, the Pan and Tilt gearbox limits the maximum turn rate of the platform to 48°/s. This is the maximum continuous angular rate that the Pan and Tilt can stabilize against if, for example, a vehicle makes a turn. There is another factor that affects performance and that is mechanical backlash in the gearbox.

Consider the scenario illustrated in *Figure 7*, in which a Pan and Tilt is again mounted on a boat. A camera operator maneuvers the platform so as to point the camera at a distant object on the horizon. As the boat continues to turn to port, and as long as the turn rate is less than 48°/s, the camera remains on the object. When the boat turns to starboard, the camera rotates though a small angle as the gears mesh the other way. The platform remains stabilized as the boat continues to turn to starboard, but the camera is now pointing immediately to the right of the object.

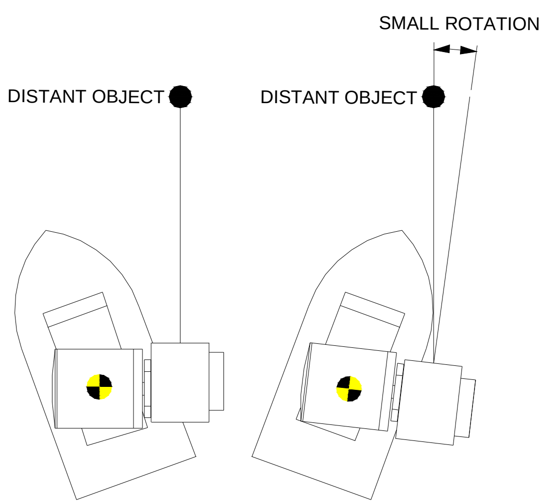


Figure 7 Effect of Backlash on the Stabilized Pan Axis

Although backlash in the gearbox is fixed, the small rotation that it induces is dependent on how quickly the vehicle changes direction and on the responsiveness of the servo-control system. *Figure 8* provides an illustration of the effect that backlash has on stabilization performance. It is a plot of this rotation, or stabilization accuracy, against the maximum angular rate of motion encountered during a change of direction. A large slow motion, such as a small boat in a large ocean swell, could ensure a similar angular rate as a small fast motion, such as a road vehicle going over a bump. It is the maximum angular rate that is important, not the magnitude or frequency of the motion.

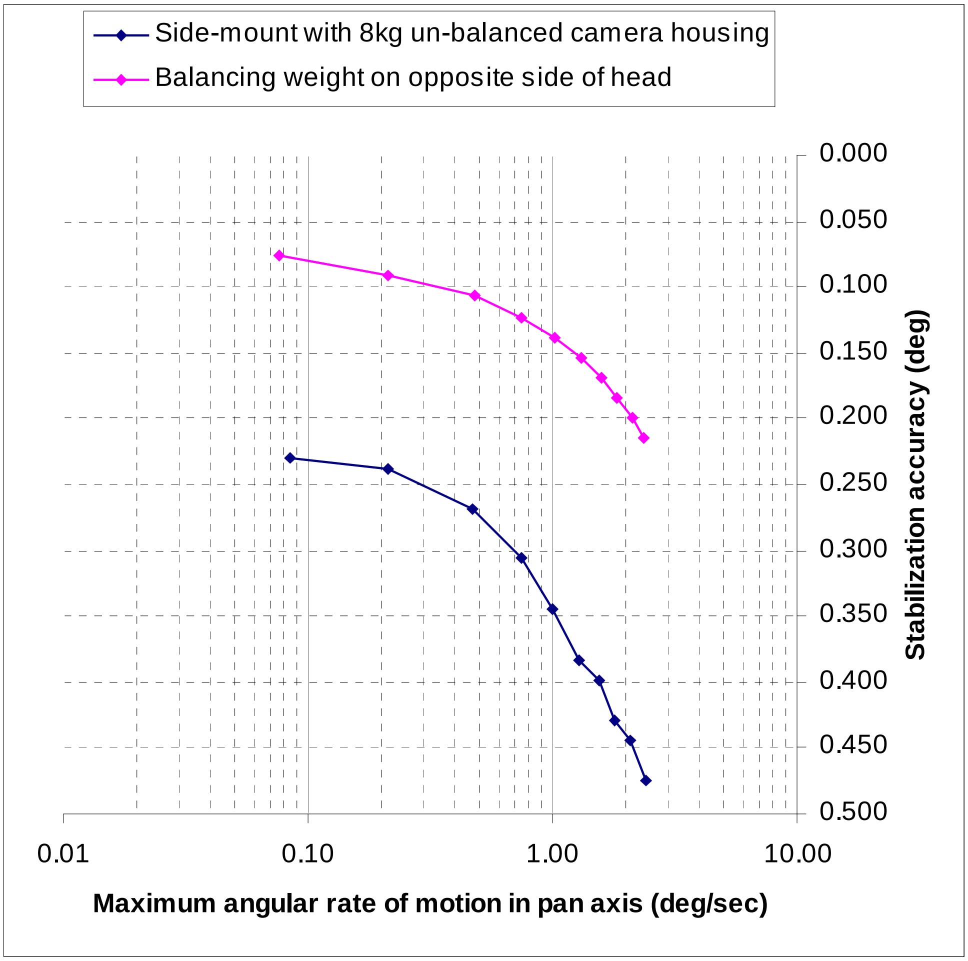


Figure 8 Effect of Backlash on Stabilization Performance

The stabilization accuracy decreases with increasing angular rate, far beyond what is shown in the graph. Stabilization accuracy can be significantly improved by tuning the servo-control system to be more responsive, although this is only possible if sufficient care has been taken in balancing the distribution of mass about the pan and tilt axes. Careful balancing has enabled the transformation of the blue curve into the pink one, significantly improving the fundamental stabilization accuracy, from 0.23° to 0.08° at low angular rates, and the steepness with which it rolls off.

The important task of balancing the distribution of equipment mounted on the Pan and Tilt must be carried out before the responsiveness of the servo-control system can be optimized. This tuning can be carried out with a laptop computer on location.

Once it has been tuned, the Pan and Tilt is highly responsive to motion. It is essential that it be securely bolted to the vehicle. The mounting fixture must be mechanically stiff. Any looseness or softness will allow the Pan and Tilt to induce motion in the fixture, to which it will respond, leading to oscillation and possible damage to equipment.

Connections

Joystick Controller

Power Connector Pinout

Pin	Description
A	Power Ground
B	V+ Power Input

Pan and Tilt Connectors Pinout

Pin	Description
A	Power Ground
B	Signal Ground
C	No Connection
D	RS-485 Negative *
E	RS-485 Positive*
F	V+ Power

9 Pin Female D-Sub Connector

Pin	Description
2	RS-232 TXD output
3	RS-232 RXD input
5	Signal Ground
6 - 9	Firmware upgrade (do not connect)**

* The RS485 connections facilitate a two-wire, bi-directional, serial data bus operating at 500k baud, which interconnects all of the modules.

The RS232 connections facilitate a serial data interface for control and monitoring of the Pan and Tilt, operating at 9600 baud.

** **Do not connect to the firmware upgrade pins. These allow the Joystick Controller firmware to be upgraded on location. Any inadvertent connection to these pins may result in permanent damage to the Joystick Controller.**

Pan and Tilt Head

17 Pin Connector

Pin	Description
P	Power Ground
M	Signal Ground
K	RS-485 Negative
J	RS-485 Positive
T	V+ Power Input

Gyro Module

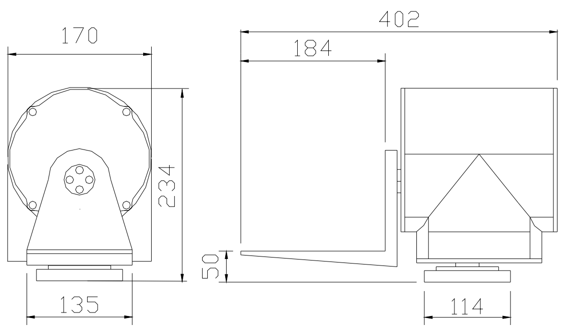
9 Pin D-Sub Connector

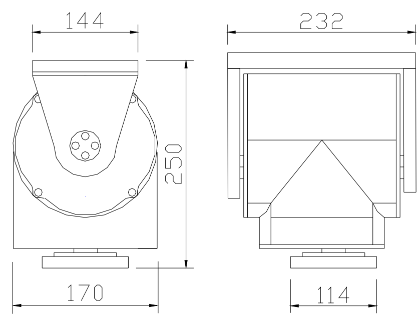
Pin	Description
1	Power Ground
2	Signal Ground
3	RS-485 Negative
4	RS-485 Positive
5	V+ Power Input
6 - 9	Firmware upgrade (do not connect)**

****Do not connect to the firmware upgrade pins. These allow the Gyro Module firmware to be upgraded on location. Any inadvertent connection to these pins may result in permanent damage to the Gyro Module.**

Dimensions

Options: Side-mounted version Top-mounted version





WARNING

Rough handling or dropping of this unit is likely to cause damage. Over-voltage and/or miswiring of this unit will cause damage. This unit should be protected against prolonged exposure to high humidity and/or salt air environments.

DISCLAIMER

The information contained in this manual is believed to be accurate and reliable; however, it is the user's responsibility to test and to determine whether a Watson Industries' product is suitable for a particular use.

Suggestion of uses should not be taken as inducements to infringe upon any patents.

WARRANTY

Watson Industries, Inc. warrants, to the original purchaser, this product to be free from defective material or workmanship for a period of two full years from the date of purchase. Watson Industries' liability under this warranty is limited to repairing or replacing, at Watson Industries' sole discretion, the defective product when returned to the factory, shipping charges prepaid, within two full years from the date of purchase. The warranty described in this paragraph shall be in lieu of any other warranty, express or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose.

Excluded from any warranty given by Watson Industries are products that have been subject to abuse, misuse, damage or accident; that have been connected, installed or adjusted contrary to the instructions furnished by seller; or that have been repaired by persons not authorized by Watson Industries.

Watson Industries reserves the right to discontinue models, to change specifications, price or design of this product at any time without notice and without incurring any obligation whatsoever.

The purchaser agrees to assume all liabilities for any damages and/or bodily injury which may result from the use, or misuse, of this product by the purchaser, his employees or agents. The purchaser further agrees that seller shall not be liable in any way for consequential damages resulting from the use of this product.

No agent or representative of Watson Industries is authorized to assume, and Watson Industries will not be bound by any other obligation or representation made in connection with the sale and/or purchase of this product.

PRODUCT LIFE

The maximum expected life of this product is 20 years from the date of purchase. Watson Industries, Inc. recommends the replacement of any product that has exceeded the product life expectation.

SERVICE

Watson Industries, Inc. has no service outlets. All service is performed at the factory. In order to insure prompt service, prior to returning a unit for repair please call, write, fax or email:

Watson Industries, Inc.
3041 Melby Road
Eau Claire, WI 54703
ATTN: Service Department
Telephone: (715) 839-0628 Fax: (715) 839-8248 email:support@watson-gyro.com

All sensors returned under warranty will be repaired (or replaced at the sole option of Watson Industries) at no cost to the customer other than shipping charge from customer to Watson Industries (plus any export and transportation charges outside the United States).

In the case of units not under warranty, a flat repair fee will be charged. This fee can be determined by contacting Watson Industries. Modified units or those subjected to extreme abuse may be returned to the customer unrepaired.