USER MANUAL

3 DOF Gyroscope Experiment

Set Up and Configuration

CAPTIVATE. MOTIVATE. GRADUATE.

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- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

CONTENTS

1 PRESENTATION

The Quanser 3 DOF Gyroscope is depicted in Figure 1.1 The system consists of a disk/rotor mounted inside an inner blue gimbal which in turn is mounted inside an outer red gimbal. As seen in the figure, this entire structure is supported by a rectangular silver frame. All these frames are free to rotate about their rotation axes where slip rings are placed to provide infinite continuous motion in each direction. This setup results in three degrees of freedom for the rotor. Each frame can be actuated about its rotation axis through the mounted motors. The disk itself can also be actuated about its spin axis using a separate motor. Digital position measurement on each of these motors is performed using high resolution optical encoders resulting in a total of 4 motors and 4 encoders for this system.

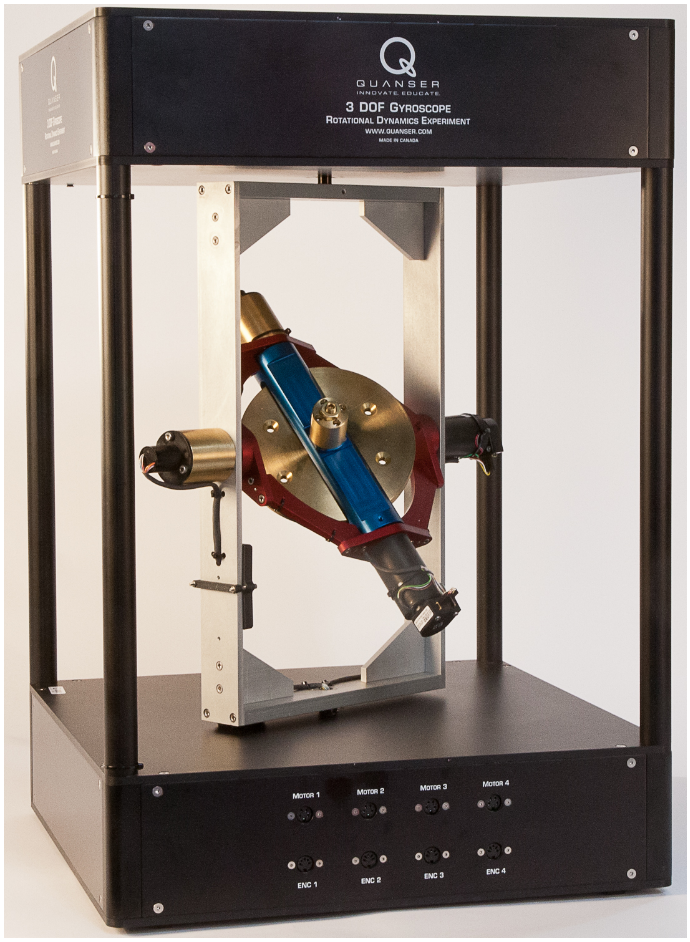


Figure 1.1: Quanser 3 DOF Gyroscope

As mentioned above all frames can have infinite motion about their rotation axes. However some experiments or research studies may require a certain frame to be fixed in this structure while others are in motion. Therefore the device is designed to provide this functionality upon desire. In other words the rectangular frame, outer and inner gimbals can be independently fixed in place upon desire to perform various rotational experiments. Instructions on how to fix each frame are given in later sections of this document. As seen in Figure 1.1 and explained later, the use of mass counter balances results in the device being mechanically balanced across its workspace. In addition very low friction is present on rotation joints making the device an ideal experimental platform for various rotational dynamic studies

■ **Caution: This equipment is designed to be used for educational and research purposes and is not intended for use by the general public. The user is responsible to ensure that the equipment will be used by technically qualified personnel only.**

2 3 DOF GYROSCOPE COMPONENTS

The 3 DOF Gyroscope components are identified in Section 2.1. Some of the those components are then described in Section 2.2

2.1 Component Nomenclature

The main components of the 3 DOF Gyroscope system are labeled below in Figure 2.1 and listed in Table 2.1. Please use the ID # to locate and match each component in the figure as well as the table.

Figure 2.1: 3 DOF Gyroscope Plant Components

ID	Component	ID	Component
1	Disk/Rotor	6	Inner Gimbal Motor/Encoder Pair (M2, E2)
2	Inner Gimbal	7	Outer Gimbal Motor/Encoder Pair (M3, E3)
3	Outer Gimbal	8	Rectangular Frame Motor/Encoder Pair (M4, E4)
4	Rectangular Frame	9	Motor and Encoder Inner Connection Boards
5	Disk Motor/Encoder Pair (M1, E1)	10	Mass Counter Balances

Table 2.1: 3 DOF Gyroscope Components

2.2 Component Description

2.2.1 Disk/Rotor

The rotor is used to acquire angular momentum for rotational dynamics experiments by spinning about its spin axis. It can be rotated using M1.

2.2.2 Inner Gimbal

This component is depicted by #2 in Figure 2.1 and listed in Table 2.1 and supports the rotating disk. The component itself is actuated using M2.

2.2.3 Outer Gimbal

This component is depicted by #3 in Figure 2.1 and listed in Table 2.1 and supports the rotating disk. The component itself is actuated using M3.

2.2.4 Rectangular Frame

This component is denoted by #4 in Table 2.1 and Figure 2.1 and supports the disk and the two gimbals. This frame is also free to rotate about its vertical axis of symmetry. It can be actuated using M4. Please note that this motor is not visible in the system as it resides inside the top compartment of the gyroscope system along with an attached encoder (E4) for measuring the motor shaft displacement.

2.2.5 Disk Motor and Encoder

These components are denoted by #5 in Table 2.1 and Figure 2.1. As mentioned earlier the disk can be actuated about its spin axis to a desired RPM to provide a certain angular momentum. This is done using a FAULHABER 2657-048 CR DC motor. In addition digital position measurement of the motor shaft is done using a US DIGITAL 1024 lines per revolution quadrature encoder.

■ **Caution:** High Frequency signals applied to a motor will eventually damage the gearbox and/or the motor brushes. The most likely source for high frequency noise is derivative feedback. If the derivative gain is too high, a noisy voltage will be fed into the motor. To protect your motor, you should always band limit your signal (especially derivative feedback) to a value of **50Hz.**

■ **Caution:** For Disk Motor (M1): Input $\pm$ 10 V, 3 A Peak, 1 A continuous

2.2.6 Motors M2, M3, M4 and Encoders E2, E3 and E4

These components are denoted by #6, #7 and #8 in Table 2.1 and Figure 2.1. Actuation of the inner and outer gimbals as well as the rectangular frame is done using FAULHABER 3863-048 CR Coreless DC motors. These are high efficiency, low inductance motors resulting in much faster responses than conventional DC motors. Digital position measurement of these motors is done using US DIGITAL 1000 lines per revolution quadrature encoders.

■ **Caution:** High Frequency signals applied to a motor will eventually damage the gearbox and/or the motor brushes. The most likely source for high frequency noise is derivative feedback. If the derivative gain is too high, a noisy voltage will be fed into the motor. To protect your motor, you should always band limit your signal (especially derivative feedback) to a value of **50Hz.**

■ **Caution:** For motors Motors M2, M3 and M4: Input $\pm$ 10 V, 5 A Peak, 3 A continuous

2.2.7 Inner Connection Boards

These are components denoted by #9 in Table 2.1 and Figure 2.1. They are used to provide a clean wiring path for motor and encoder cables and also prevent them from getting disconnected/teared due to extensive use.

2.2.8 Mass Counter-Balances

These are components denoted by #10 in Table 2.1 and Figure 2.1. They are used to balance the mass of motors 1 and 3 giving the device mechanical balance across its workspace.

3 3 DOF GYROSCOPE MODEL PARAMETERS

Table 3.1, below, lists and characterizes the main parameters associated with the 3 DOF Gyroscope system. Some of these parameters can be used for mathematical modeling of the plant as well as to obtain system equations of motion.

Description	Value	Unit
Device Height (top to base)	0.673	m
Base Length	0.457	m
Base Width	0.457	m
Device Mass	27.31	kg
Rotor Mass	1.907	kg
Rotor Diameter	0.1524	m
Rotor Thickness	0.0127	m
Rotor Moment of Inertia about Spin Axis	0.0056	kg-m^2
Inner Gimbal Moment of Inertia about Spin Axis	0.0039	kg-m^2
Outer Gimbal Moment of Inertia about Spin Axis	0.0234	kg-m^2
Rectangular Frame Moment of Inertia about Spin Axis	0.0663	kg-m^2
Disk Encoder Resolution (quadrature)	1024	lines/rev
Inner Gimbal Encoder Resolution (quadrature)	1000	lines/rev
Outer Gimbal Encoder Resolution (quadrature)	1000	lines/rev
Rectangular Frame Encoder Resolution (quadrature)	1000	lines/rev
Disk Motor Output Power	44.5	W
Disk Motor Efficiency	84	%
Gimbals and Rectangular Frame Motors Output Power	226	W
Gimbals and Rectangular Frame Motors Efficiency	85	%

Table 3.1: 3 DOF Gyroscope Specifications

4 SYSTEM SETUP

4.1 Unpacking

To unpack the 3 DOF Gyroscope, carefully remove the foam that is used to fix the outer rectangular frame, outer gimbal, and the disk in place. This is done to ensure that the frames do not move during shipment.

4.2 Fixing Frames

As mentioned earlier in this document, in order to provide flexibility in the range of experiments that can be performed with this plant, it has been designed such that each of its frames can be fixed in place if desired. For this purpose a set of screws and Allen keys are shipped with the device. In this section instructions are provided on fixing each frame.

4.2.1 Fixing the Rectangular Frame

The rectangular frame has a screw hole on its top side. In addition there ere holes drilled on the upper enclusure on which the gyroscope is mounted. In order to fix the rectangular frame, rotate it until these two holes are aligned, put in the supplied M3 screw (longer one) and fasten it using the provided key as depicted in Figure 4.1. Make sure the screw goes through the locking hole on the upper part of the silver frame to one of the locking holes on the upper enclosure. It does not matter which locking hole you choose. It is recomended to use the one that results in better visibility of the experiment to the user.

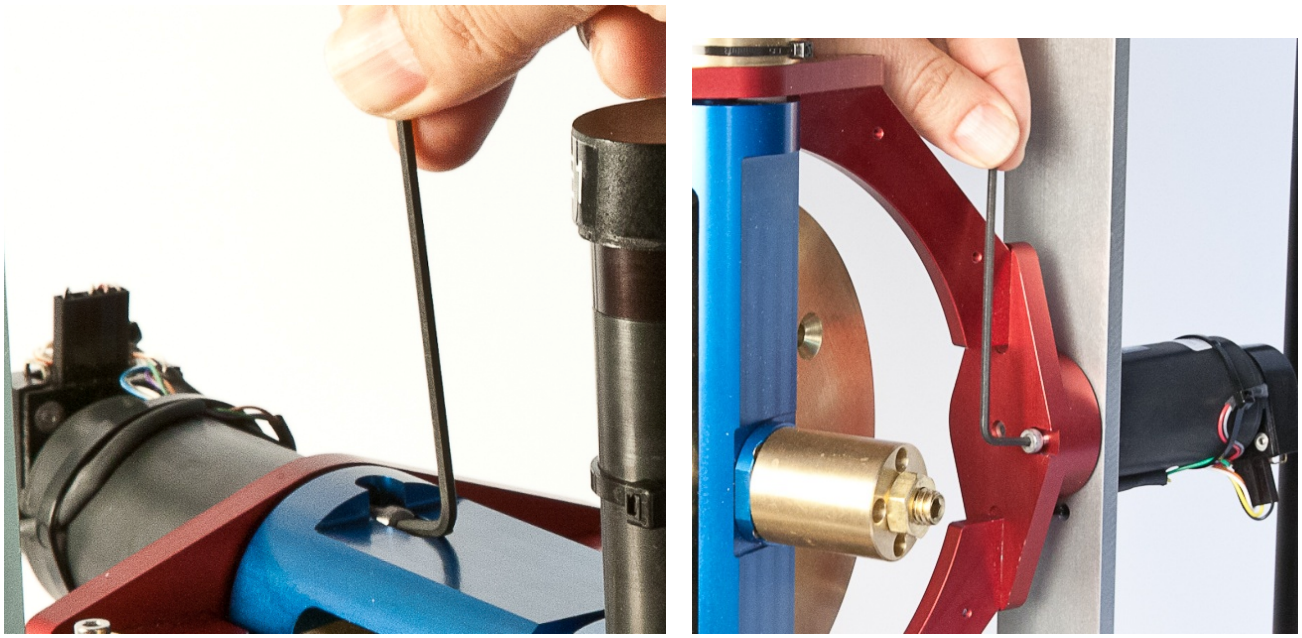
Figure 4.1: Fixing the Rectangular Frame

4.2.2 Fixing the Outer Red Gimbal

This frame can be fixed at its horizontal or vertical orientation using one of the supplied M3 screws (one of the long ones). There is a screw hole on the side of the gimbal that is connected to the rectangular frame. To fix this gimbal, bring it to the horizontal orientation and align the hole in the gimbal with the hole on the rectangular frame. Put in the screw and fasten in with the provided key as illustrated in Figure 4.2b.

4.2.3 Fixing the Inner Blue Gimbal

The inner blue gimbal can be fixed at its horizontal orientation using one of the supplied M3 screws (the short one). There is a screw hole on the inner side of the outer red gimbal. Put in the screw and fasten in with the provided key as illustrated in Figure 4.2a



(a) Fixing the Inner Gimbal (b) Fixing the Outer Gimbal

Figure 4.2: Fixing gimbals

5 WIRING PROCEDURE

The following is a listing of the hardware components used in this experiment:

1. **Power Amplifier**: Quanser 4 Channel AMPAQ [1], or equivalent
2. **Data Acquisition (DAQ) Device**: Q8-USB, QPID, or equivalent.
3. **Experiment Platform**: Quanser 3 DOF Gyroscope.

■ **Caution:** If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

In addition to the above listed components screws, and hex keys are also shipped with the device. These are the pieces that are required to fix individual frames if needed. Instructions on how to use these components to fix frames are given is Section 4.2

5.1 Cable Nomenclature

Table 5.1, provides a listing of the standard cables used in the wiring of the 3 DOF Gyroscope system.

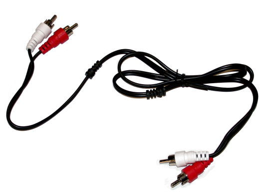
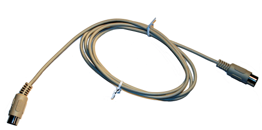
Cable	Type	Description
 (a) RCA Cable	2xRCA to 2xRCA	This cable connects a pair of analog outputs of the Data Acquisition Device (DAQ) to the Amplifier Input port for proper amplification. For the four motors of the 3 DOF Gyroscope two of these cables are needed to connect analog outputs 0, 1, 2 and 3 on the Data Acquisition Device (DAQ) to Input ports 0, 1, 2, and 3 on the Amplifier. To monitor the current measurement signal another two pairs of this cable can be used to connect the Sense ports 0, 1, 2, and 3 on the AMPAQ [1] to analog input ports 0, 1, 2, and 3 on the Data Acquisition Device (DAQ).
 (b) AMPAQ to Motor Cable	AMPAQ to Motor Cable	This cable connects the output ports of the Amplifier (AMPAQ module), after amplification, to the desired DC motors on the gyroscope plant. Typically Output connectors 0, 1, 2 and 3 on the AMPAQ are connected to M1, M2, M3 and M4 on the plant using 4 of these cables.
 (c) 5-pin-stereo-DIN to 5-pin-stereo-DIN	5-pin-stereo-DIN to 5-pin-stereo-DIN	This cable carries the encoder signals between an encoder connector on the plant and one on the terminal board. Namely, these signals are: +5VDC power supply, ground, channel A, and channel B. Typically connectors labeled E1, E2, E3 and E4 on the gyroscope plant are connected to Encoder input channels 0, 1, 2 and 3 on the Data Acquisition Device using 4 of these cables.

Table 5.1: Cable Nomenclature

5.2 Typical Connections

This section describes the typical connections used to connect the 3 DOF Gyroscope plant to a data acquisition (DAQ) device and the Quanser AMPAQ-L4 amplifier. The connections are described in detail in the procedure below and summarized in Table 5.2. It is assumed that the DAQ device has already been installed and tested. Refer to the DAQ user manual for installation and testing instructions.

■ **Caution: Make sure that the Amplifier and your PC unit are turned off while you perform the wiring.**

Figure 5.1 shows the typical wiring between a generic DAQ device, the 3 DOF Gyroscope experiment, and a four-channel amplifier (e.g. AMPAQ-L4). Table 5.2 describes the connections that are illustrated. The numbering used in the **Cable #** column corresponds to the connection labels in Figure 5.1.

Cable #	From	To	Signal
1	DAQ Analog Output **#0**	Amplifier **"Input 0"**	Motor 1 control signal to the amplifier
2	DAQ Analog Output **#1**	Amplifier **"Input 1"**	Motor 2 control signal to the amplifier
3	DAQ Analog Output **#2**	Amplifier **"Input 2"**	Motor 3 control signal to the amplifier
4	DAQ Analog Output **#3**	Amplifier **"Input 3"**	Motor 4 control signal to the amplifier
5	Amplifier **Output 0**	Gyroscope **"MOTOR 1"**	Amplified control signal to Motor 1
6	Amplifier **Output 1**	Gyroscope **"MOTOR 2"**	Amplified control signal to Motor 2
7	Amplifier **Output 2**	Gyroscope **"MOTOR 3"**	Amplified control signal to Motor 3
8	Amplifier **Output 3**	Gyroscope **"MOTOR 4"**	Amplified control signal to Motor 4
9	Gyroscope **ENC 1**	DAQ Encoder Input **"0"**	Encoder Reading for E1
10	Gyroscope **ENC 2**	DAQ Encoder Input **"1"**	Encoder Reading for E2
11	Gyroscope **ENC 3**	DAQ Encoder Input **"2"**	Encoder Reading for E3
12	Gyroscope **ENC 4**	DAQ Encoder Input **"3"**	Encoder Reading for E4

Table 5.2: 3 DOF Gyroscope System Wiring Summary.

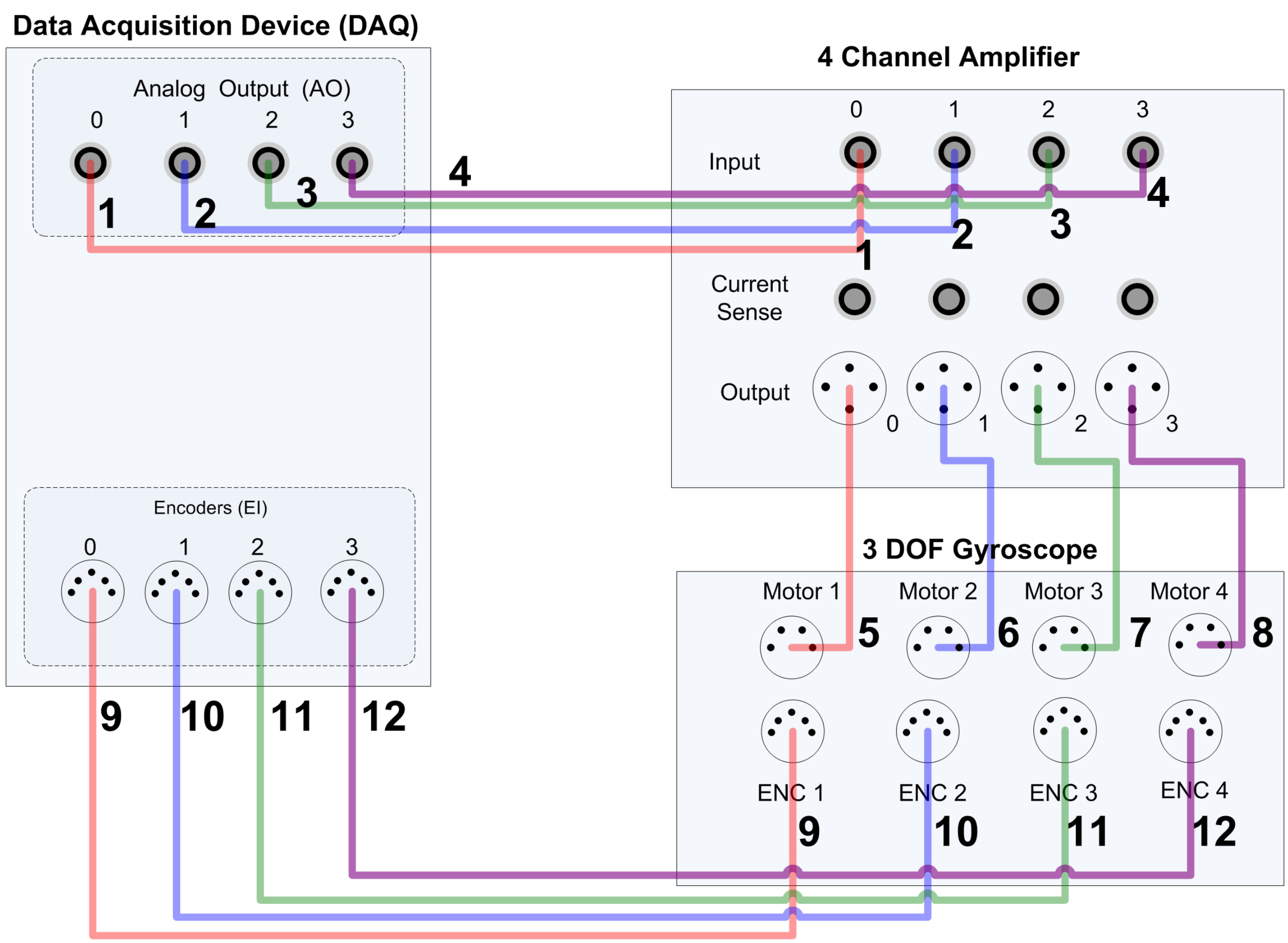


Figure 5.1: 3 DOF Gyroscope Wiring Diagram

Follow these steps to connect your system:

1. Connect one pair of RCA to RCA cables between Data Acquisition Device (DAQ) Analog Outputs 0 and 1 and the Amplifier **Input** ports 0 and 1. This is illustrated by connections 1 and 2 Figure 5.1. Connect another pair between the Data Acquisition Device Analog Outputs 2 and 3 and the Amplifier **Input** ports 2 and 3. This is illustrated by connections 3 and 4 in Figure 5.1.
2. Connect one Amplifier motor cable between the Amplifier **Output** port 0 and the Gyroscope **MOTOR 1** connector. Do the same for the Amplifier **Output** ports 1, 2 and 3 and the Gyroscope **MOTOR 2**, **MOTOR 3** and **MOTOR 4** connectors respectively. This is illustrated by connections 5, 6, 7 and 8 in Figure 5.1.
3. Connect one 5-pin-stereo-din to 5-pin-stereo-din (Encoder) cable between the Data Acquisition Device (DAQ) Encoder Input 0 and the 3 DOF Gyroscope **ENC 1** connector. Do the same for the Data Acquisition Device (DAQ) Encoder Inputs 1, 2 and 3 and the Gyroscope **ENC 2**, **ENC 3** and **ENC 4** connectors respectively. This is illustrated by connections 9, 10, 11 and 12 in Figure 5.1.

6 TESTING AND TROUBLESHOOTING

This section describes some functional tests to determine if your 3 DOF Gyroscope system is operating normally. It is assumed that the system is connected and wired as described in Section 5.2 above. It is recommended to use a software such as QUARC®or LabVIEW™ to read sensor measurements and feed voltages to the motor. Alternatively, these tests can be performed with a signal generator and an oscilloscope.

6.1 Gyroscope Encoders

In order to make sure all four encoders of the 3 DOF Gyroscope system are operating normally, read encoder input channels 0 through 3. Move each frame of the system separately and monitor its corresponding measurement. If you see no change in measurement of an encoder it might require replacement.

6.1.1 Testing

Follow this procedure to test the Gyroscope encoders. Measure Encoder Input Channels #0 to #4 using, for instance, QUARC or LabVIEW.

- Rotate the disk for testing **Encoder 1**, component #1 in Figure 2.1, one rotation and the encoder should measure 4000 counts in quadrature mode.
- Rotate the Inner Gimbal for testing **Encoder 2**, component #2 in Figure 2.1, one rotation and the encoder should measure 4000 counts in quadrature mode.
- Rotate the Outer Gimbal for testing **Encoder 3**, component #3 in Figure 2.1, one rotation and the encoder should measure 4000 counts in quadrature mode.
- Rotate the Rectangular Frame for testing **Encoder 4**, component #4 in Figure 2.1, one rotation and the encoder should measure 4000 counts in quadrature mode.

Note: Some data acquisition systems do not measure in quadrature and, in this case, one-quarter of the expected counts are received, i.e. 1000 counts. In addition, some data acquisition systems measure in quadrature but increment the count by 0.25 (as opposed to having an integer number of counts). Make sure the details of the data-acquisition system being used is known. The counters on the Quanser DAQ boards measure in quadrature and therefore a total of four times the number of encoder lines per rotation, e.g. a 1000-line encoder results in 4000 integer counts for every full rotation.

6.1.2 Troubleshooting

If the encoder is not measuring properly, go through this procedure:

- Check that the data-acquisition board is functional, e.g. ensure it is properly connected, that the fuse is not burnt.
- Check that both the A and B channels from the encoder are properly generated and fed to the data-acquisition device. Using an oscilloscope, there should be two square waves, signals A and B, with a phase shift of 90 degrees. If this is not observed then the encoder may be damaged and need to be replaced. Please see Section 7 for information on contacting Quanser for technical support.

6.2 Gyroscope Motors

6.2.1 Testing

Ensure the Gyroscope motors are operating correctly by going through this procedure:

1. Apply a voltage to analog output channel *#0* from your DAQ Device.
2. The **Disk** motor, component *#1* in Figure 2.1, should rotate clockwise when a positive voltage is applied and counter-clockwise when a negative voltage is applied.
3. Repeat steps 1 and 2 above for analog output channels *#1* to *#3* when testing Inner Gimbal, Outer Gimbal and Rectangular Frame motors respectively. In all cases, the motor shaft should rotate clockwise when a positive voltage is applied and counter-clockwise when a negative voltage is applied.

6.2.2 Troubleshooting

If the motor is not responding to a voltage signal, go through these steps:

- Verify that the power amplifier is functional. For example when using the Quanser Ampaq device, is the *System Power* LED lit?
- Check that the DAQ device is functional, e.g. ensure it is properly connected, that the fuse is not burnt.
- Make sure the voltage is actually reaching the motor terminals (use a voltmeter or oscilloscope).
- If the motor terminals are receiving the signal and the motor is still not turning, your motor might be damaged and will need to be repaired. Please see Section 7 for information on contacting Quanser for technical support.

7 TECHNICAL SUPPORT

To obtain support from Quanser, go to http://www.quanser.com/ and click on the Tech Support link. Fill in the form with all the requested software and hardware information as well as a description of the problem encountered. Also, make sure your e-mail address and telephone number are included. Submit the form and a technical support person will contact you.

REFERENCES

[1] Quanser Inc. *AMPAQ User Manual*, 2012.

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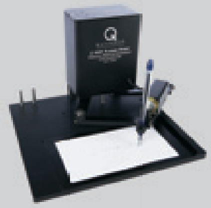
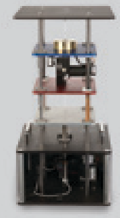
3 DOF Gyroscope

Omni Bundle

2 DOF Planar Robot



Active Suspension



Hexapod*

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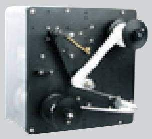

IMDU-Multi DOF Torsion

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