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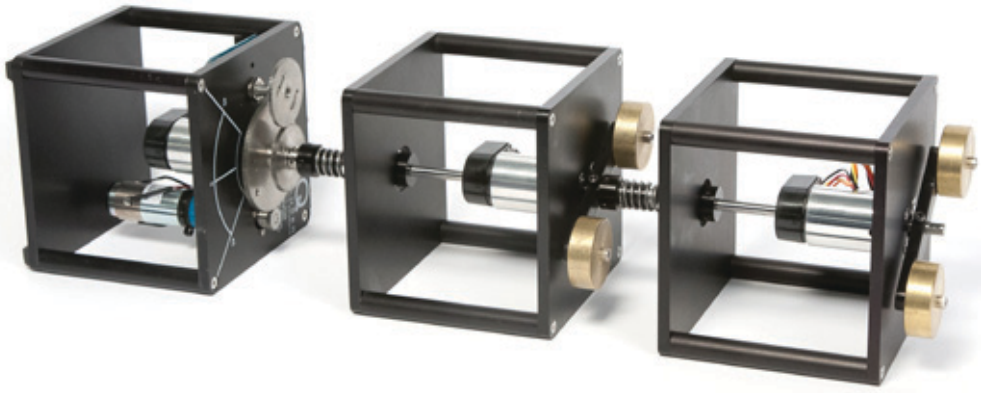
USER MANUAL

Multi-DOF Torsion Experiment

Set Up and Configuration



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

CONTENTS

1 PRESENTATION

1.1 Description

The Quanser Torsion module is a rotary torsional system that consists of an instrumented bearing block, which is mounted in a cubic solid aluminum frame. A shaft is free to spin inside the bearing block. The shaft rotation is measured using an encoder. The shaft can be outfitted with either a pulley or a flexible coupling. The system is designed to couple with a Quanser rotary servo, e.g. SRV02.

As illustrated in Figure 1.1, below, the assembly made of one rotary Torsion module coupled to a SRV02 servo plant constitutes a one-Degree-Of-Freedom (1-DOF) torsional system. The SRV02 unit lies on its side so that its DC motor and output shaft are horizontal and able to rotate a flexible coupling attached to a rotational load. The torsional load consists of two inertial disc masses, which can be located at different anchor points along their support bar. Several torsion modules can be coupled in cascade to allow for multidimensional control problems (up to seven).

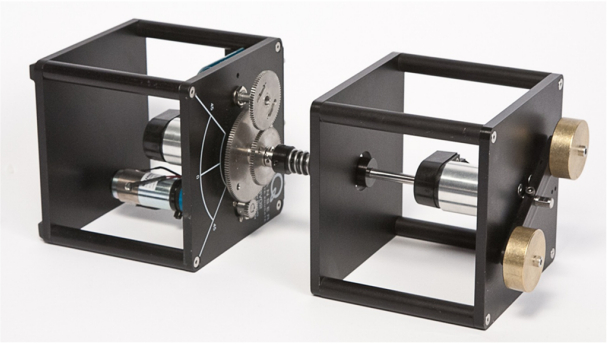


Figure 1.1: SRV02 1-DOF Torsion system

The Two-Degree-Of-Freedom (2-DOF) torsional configuration is shown in Figure 1.2, below, when two rotary Torsion modules are mounted in series with an SRV02 servo plant. Similarly to the 1-DOF Torsion system, the SRV02 lies on its side such that its DC motor and output shaft are horizontal and able to rotate the two cascaded flexible couplings, each attached to a rotational load. Each torsional load consists of two inertial disc masses, which can be located at different anchor points along their support bar.

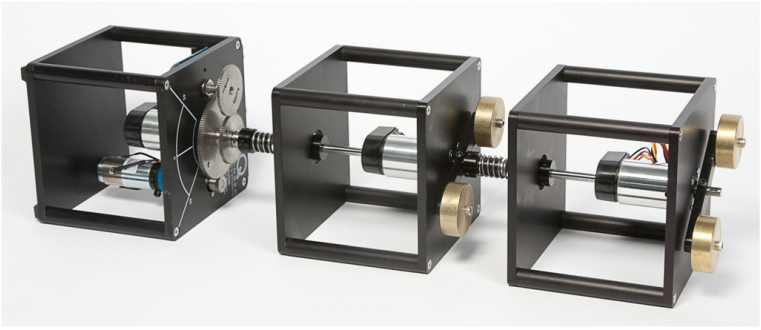


Figure 1.2: SRV02 2-DOF Torsion system.

1.2 Experiment Overview

The experiments supplied with the 1-DOF and 2-DOF Torsion systems is given in Table 1.1, below.

Experiment Name	Description
1-DOF Torsion	Design a state-feedback system that controls the position of the torsion output load shaft to a desired angle while dampening the flexible coupling
2-DOF Torsion	Design a state-feedback system that controls the position of both torsion output load shafts to a desired angle while dampening for the flexible coupling of each torsion module.

Table 1.1: Supplied experiments with 1-DOF and 2-DOF Torsion modules

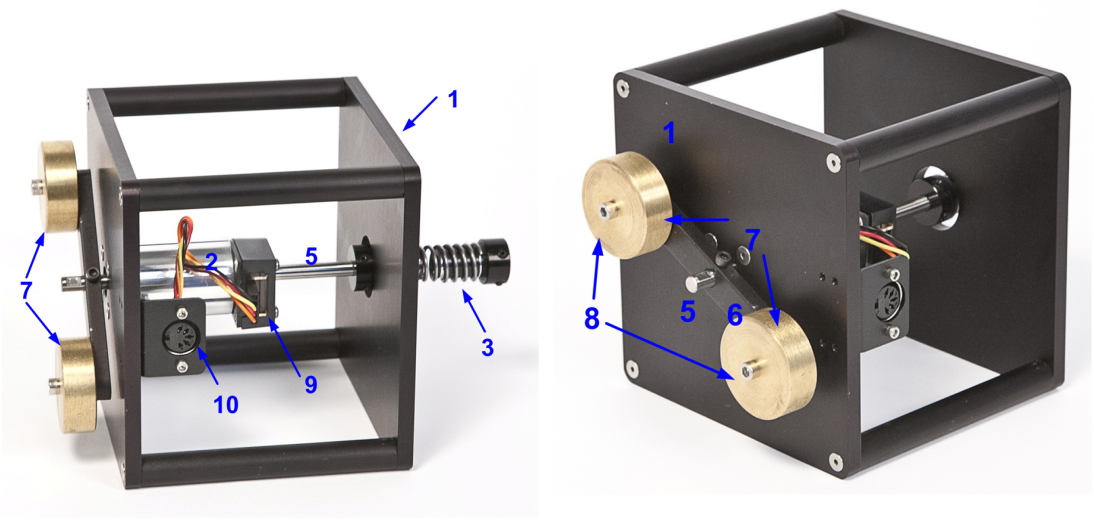
Caution: This equipment is designed to be used for educational and research purposes and is not intended for use by the general public. The user is responsible to ensure that the equipment will be used by technically qualified personnel only.

2 TORSION MODULE COMPONENTS

The components of the Torsion module system are listed in Table 2.1 and labeled in Figure 2.1a, Figure 2.1b, Figure 2.2a, and Figure 2.2b.

ID	Component	ID	Component
1	Torsion module frame	7	Load weight
2	Bearing block	8	Load weight set-screw (9/64-inch)
3	Flexible coupling	9	Load encoder
4	Coupling set screw (1/16-inch)	10	Load encoder connector
5	Load shaft	11	Support bar set screw (3/32-inch)
6	Load weight support bar		

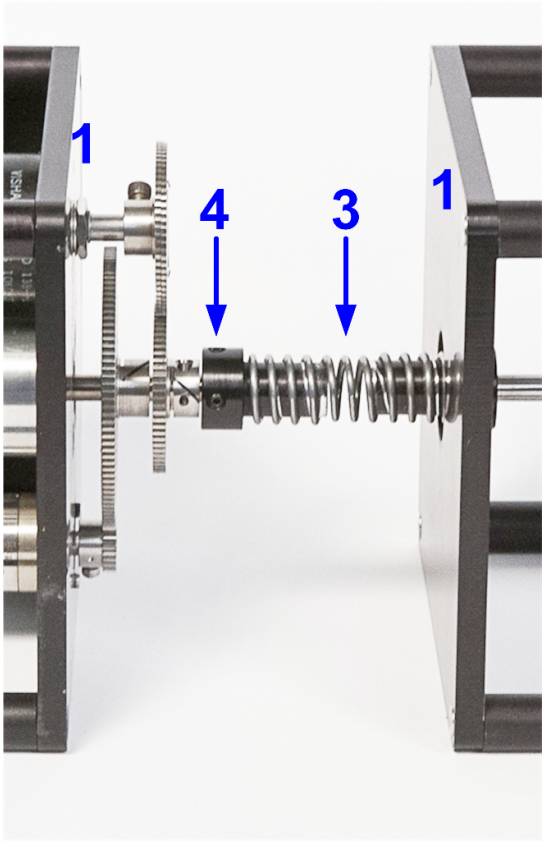
Table 2.1: SRV02 Torsion module components



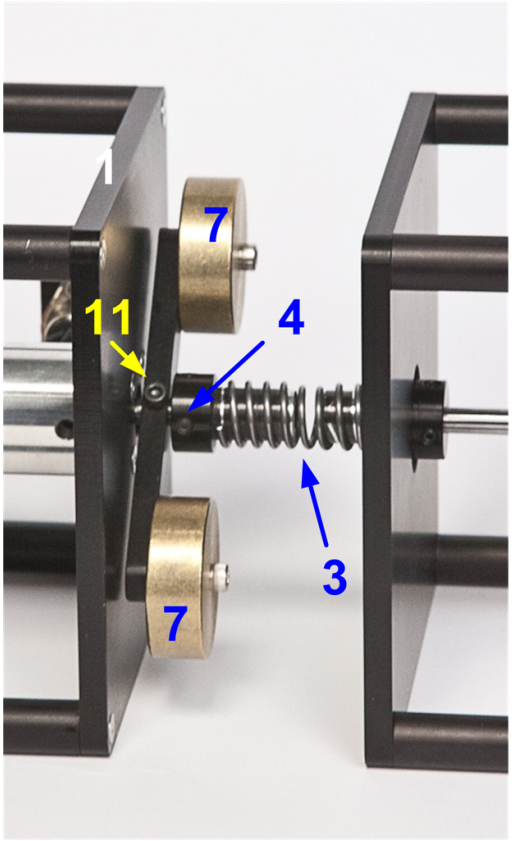
(a) Components of 1-DOF Torsion module

(b) Components of load on Torsion module.

Figure 2.1: SRV02 Torsion module components



(a) Components of coupling between SRV02 and Torsion module



(b) Components of coupling between two torsion modules

Figure 2.2: Coupling between modules

3 SPECIFICATIONS

Table 3.1, below, lists and characterizes the main parameters associated with the torsion module. Some of these parameters are used in the mathematical model.

Symbol	Description	Value	Unit
J_1	Equivalent Moment of Inertia, as seen at the SRV02 Load Shaft	0.0022	kg-m^2
B_1	Equivalent Viscous Damping Coefficient, as seen at the SRV02 Load Shaft	0.0150	N-m-s/rad
M_b	Disc weight mass	0.0022	kg
D_w	Disc weight diameter	0.0380	m
K_s	Flexible coupling stiffness	1.0000	N-m/rad
L_b	Load support bar length	0.044	m
M_b	Load support bar mass	0.21	kg
J_2	Equivalent moment of inertia seen from the Torsion module.	0.000545	kg-m^2 [1]
B_2	Equivalent Viscous Damping Coefficient, as seen at the SRV02 Load Shaft	0.0015	N-m-s/rad
K_s1	Fexible coupling stiffness	1.000	N-m/rad [1]
	Overall dimensions of torsion module	21x13x13	cm
	Total mass of torsion module	1.2	kg

Table 3.1: 1 DOF Torsion system specifications.

[1] These were found experimentally and there will be some variation between different flexible couplings

4 SYSTEM SETUP

4.1 1-DOF Torsion System Setup

1. Ensure the SRV02 is setup in the high-gear configuration as detailed in [1].
2. Place the SRV02 on its side with the connectors facing on one side.
3. To connect the Quanser Torsion Module to the SRV02 as shown in Figure 1.1 above, slide the flexible coupling, ID #3, onto the load output shaft of the SRV02 plant. This is illustrated in Figure 2.2a. Ensure the encoder connector on the torsion module is on the same side as the SRV02 connectors.
4. Tighten the flexible coupling set-screw, ID #4 in Figure 2.2a, to ensure the torsion unit is fastened onto the load shaft of the servo unit
5. Before running any experiments, it is recommended that the SRV02 be clamped down onto an edge of a table. This reduces the amount the system moves while running experiments and prevents anything from falling over.

4.2 2-DOF Torsion System Setup

Follow this procedure to setup the SRV02 2-DOF Torsion system:

1. To setup the 2-DOF Torsion system, shown in Figure 1.2, above, go through the procedure given in Section 4.1 to assemble the 1-DOF Torsion system.
2. To add the second Quanser Torsion Module, slide the flexible coupling of the second torsion unit onto the load shaft of the first torsion module, as illustrated in Figure 2.2b,above.
3. Tighten the set-screw on the second flexible coupling member, shown by ID #4 in Figure 2.2b.

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

5 WIRING PROCEDURE

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

1. **Power Amplifier**: Quanser VoltPAQ, or equivalent.
2. **Data Acquisition (DAQ) Device**: Q1-cRIO, Q2-USB, Q8-USB, QPID/QPIDe, NI DAQ Device, or equivalent.
3. **Rotary Servo Plant**: Quanser SRV02-ET.
4. **Rotary Torsional Module**: Quanser Torsion module.

See the references listed for more information on these components. The cables supplied with the system are described in Section Section 5.1 and the procedure to connect the above components is given in Section 5.2.

Caution: When using the Quanser VoltPAQ-X1 power amplifier, **make sure you set the Gain to 1**!

5.1 Cable Nomenclature

Table 5.1, below, provides a description of the standard cables used in the wiring of the Quanser Torsion Module.

Cable	Type	Description
 (a) RCA Cable	2xRCA to 2xRCA	This cable connects an analog output of the data acquisition terminal board to the power module for proper power amplification.
 (b) Motor Cable	4-pin-DIN to 6-pin-DIN	This cable connects the output of the power module, after amplification, to the desired DC motor on the servo.
 (c) Encoder Cable	5-pin-stereo-DIN to 5-pin-stereo-DIN	This cable carries the encoder signals between an encoder connector and the data acquisition board (to the encoder counter). Namely, these signals are: +5 VDC power supply, ground, channel A, and channel B

Table 5.1: Cables used to connect SRV02 to amplifier and DAQ device

5.2 Connections for 1-DOF Torsion

This section describes the typical connections used to connect the SRV02 1-DOF Torsion system to a data-acquisition device and the power amplifier. The connections are shown in Figure 5.1 and given in Table 5.2. Wiring details are

given below.

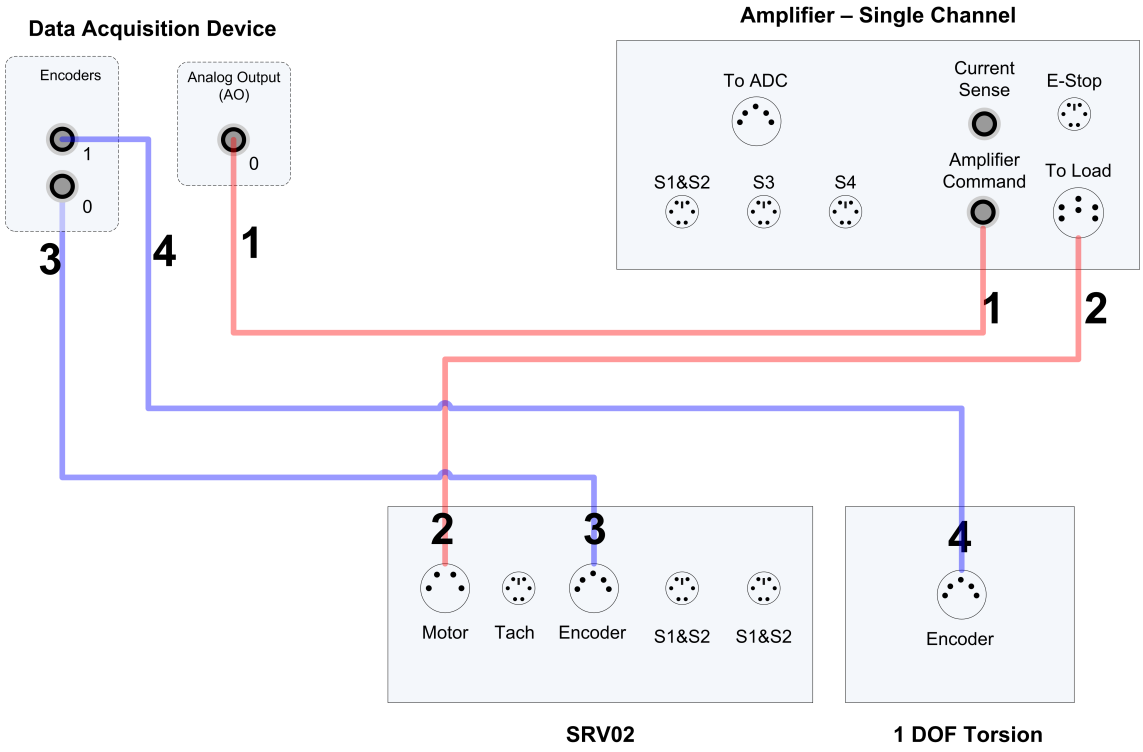


Figure 5.1: Connecting the 1-DOF Torsion System to the DAQ Device and Power Amplifier

Follow these steps to connect the SRV02-E and 1-DOF Torsion system:

1. It is assumed that the data-acquisition board is already installed as discussed in the Reference [1]. If another data-acquisition device is being used, e.g. NI M-Series board, then go to its corresponding documentation and ensure it is properly installed.
2. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the amplifier.
3. Connect the one of the ends of the 2xRCA to 2xRCA cable from the *Analog Output Channel #0* on the terminal board to the *Amplifier Command* connector on the amplifier that will be connected to SRV02. See cable #1 shown in Figure 5.1 and Figure 5.2. This carries the attenuated SRV02 motor voltage control signal, Vm/Ka, where Ka is the amplifier gain.
4. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN that from the *To Load* on the amplifier to the *Motor* connector on the SRV02. See connection #2 shown in Figure 5.1 and Figure 5.2. The cable transmits the amplified voltage that is applied to the SRV02 motor and is denoted Vm.
5. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the SRV02 A panel to *Input # 0* on the terminal board, as depicted by connection #3 in Figure 5.1. This carries the SRV02 load shaft angle measurement and is denoted by the variable θ_1.

   Caution: Any encoder should be directly connected to the Quanser terminal board (or equivalent) using a standard 5-pin DIN cable. **DO NOT connect the encoder cable to the amplifier!**
6. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the Torsion module panel to *Input # 1* on the terminal board, as depicted by connection #4 in Figure 5.1. This carries the 1-DOF Torsion load shaft angle measurement and is denoted by the variable θ_2.

Cable #	From	To	Signal
1	Terminal Board: Analog Output #0	Amplifier *"From D/A"* connector	Control signal to the amplifier driving SRV02.
2	Amplifier: *To Load* connector	SRV02 *Motor* connector	Power leads to the DC motor of SRV02.
3	Terminal Board: Encoder Input #0	SRV02 *Encoder* connector	Encoder load shaft angle measurement.
4	Terminal Board: Encoder Input #1	Torsion Module "Encoder" connector	Torsion module encoder load shaft angle measurement.

Table 5.2: Quanser 1-DOF Torsion system wiring summary

5.3 Connections for 2-DOF Torsion

This section describes the typical connections used to connect the SRV02 2 DOF Torsion system to a data acquisition device and power amplifier. The connections are described in detail in the procedure below and summarized in Table 5.3.

Follow these steps to connect the SRV02-E and 2-DOF Torsion system:

1. Follow the wiring procedure of the 1-DOF Torsion system detailed in Section 5.2.
2. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the second Torsion module panel to *Encoder Input # 2* on the terminal board, as depicted by connection #5 in Figure 5.2. This carries the 2-DOF Torsion load shaft angle measurement and is denoted by the variable θ_3.

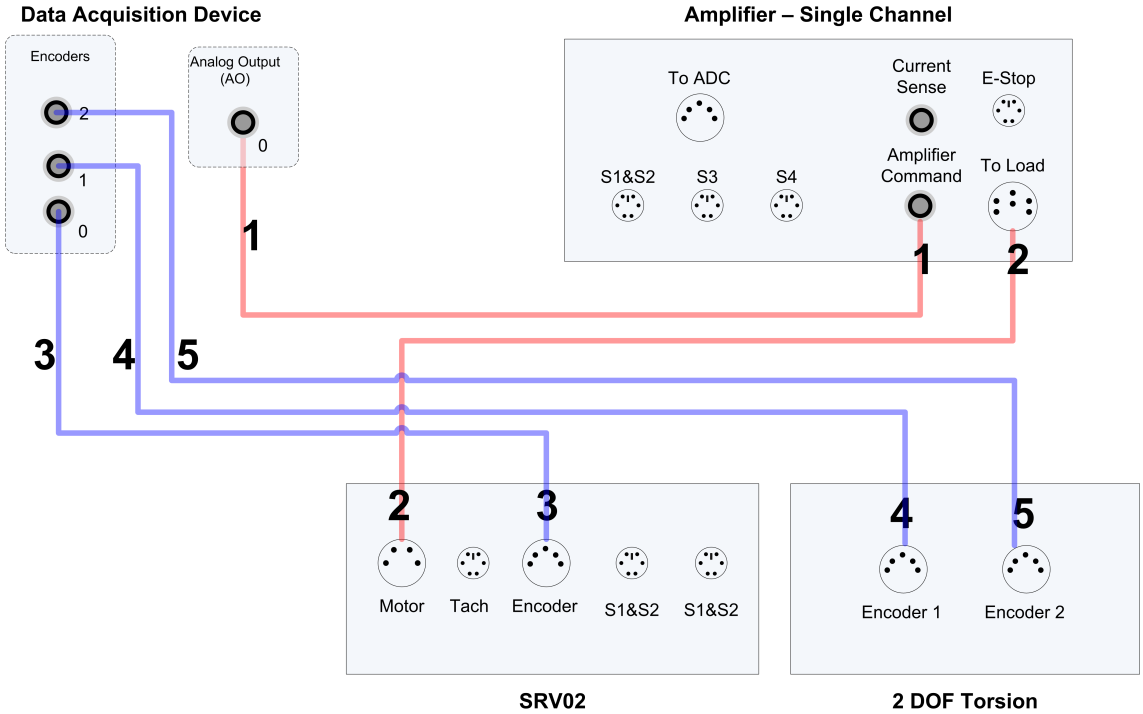


Figure 5.2: Connecting the 2-DOF Torsion System to the DAQ Device and Power Amplifier

Cable #	From	To	Signal
1	Terminal Board: Analog Output #0	Amplifier *"From D/A"* connector	Control signal to the amplifier driving SRV02.
2	Amplifier: *To Load* connector	SRV02 *Motor* connector	Power leads to the DC motor of SRV02.
3	Terminal Board: Encoder Input #0	SRV02 *Encoder* connector	SRV02 encoder load shaft angle measurement.
4	Terminal Board: Encoder Input #1	Torsion Module "Encoder" connector	Torsion module encoder load shaft angle measurement.
5	Terminal Board: Encoder Input #2	Torsion Module "Encoder" connector	2-DOF Torsion module encoder load shaft angle measurement.

Table 5.3: Quanser 2-DOF Torsion System Wiring Summary

6 TESTING AND TROUBLESHOOTING

See Reference [1] for any information regarding the testing and troubleshooting of the SRV02 devices. The encoder on the torsion module is the same as the encoder on the SRV02-E plant. Therefore see Reference [1] for encoder specifications as well as how to test and troubleshoot them.

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. *SRV02 User Manual*, 2009.

Over ten rotary experiments for teaching fundamental and advanced controls concepts

Rotary Servo Base Unit

Multi-DOF Torsion

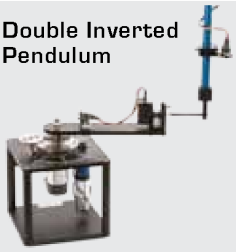
Inverted Pendulum

Flexible Link

Flexible Joint

Ball and Beam

Double Inverted Pendulum

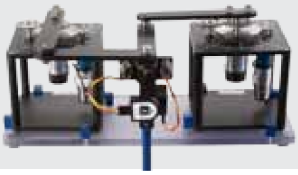


Gyro/Stable Platform

2 DOF Robot

2 DOF Inverted Pendulum

2 DOF Gantry



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