



# USER MANUAL

## SRV02 Rotary Servo Base Unit

Set Up and Configuration



CAPTIVATE. MOTIVATE. GRADUATE.

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#### CE Compliance

This product meets the essential requirements of applicable European Directives as follows:

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

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# 1 PRESENTATION

## 1.1 Description

The Quanser SRV02 rotary servo plant, pictured in Figure 1.1, consists of a DC motor that is encased in a solid aluminum frame and equipped with a planetary gearbox. The motor has its own internal gearbox that drives external gears. The SRV02 is equipped with three sensors: potentiometer, encoder, and tachometer. The potentiometer and encoder sensors measure the angular position of the load gear and the tachometer can be used to measure its velocity.



Figure 1.1: Quanser SRV02 system

There are two SRV02 options available: SRV02-ET and SRV02-ETS. The SRV02-ETS system includes a slip ring assembly that allows the modules to be rotated the full 360 degrees.

■ **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.

## 1.2 Rotary Modules and Experiment Overview

The SRV02 rotary plant can be used stand-alone for several experiments but it also serve as a base component for several add-on modules. Table 1.1 below lists these modules and the corresponding experiments that are supplied with them. Thus a new plant is obtained by adding a module which presents new modeling and control challenges.



System	Experiment	Description
SRV02	SRV02 QUARC Integration	Describes how to use
SRV02	Modeling	Model the speed of the SRV02 using a first-order transfer function.
SRV02	Position Control	Regulate position of the SRV02 load gear to a desired angle using PID.
SRV02	Speed Control	Control the angular rate of the SRV02 load gears using a PI and a lead compensator.
Ball and beam	Balance Control	Model the system and develop a cascade PD controller to stabilize the ball to a position along the beam.
Flexible Joint	Vibration Control	Derive the plant dynamics and design a controller that compensates for the flexibilities in the joint while regulating the position of the arm tip to desired location.
Flexible Link	Vibration Control	Model the plant and identify the natural frequency of the beam. Then, develop a system that controls the tip of beam to a desired position.
Single Pendulum	Self-Erecting Single Inverted Pendulum Control	Design a nonlinear energy-based swing-up controller and a linear balance compensator to swing-up the pendulum from the resting downward position to the upright vertical position.
Double Pendulum	Double-Inverted Pendulum Balance Control	Model the system and then design a controller that balances the pendulum while the servo is tracking a reference position.
Gyroscope	Heading Control	Design a feedback loop that can maintains the position of the SRV02 load gear, i.e. the heading, while the rotary base underneath is manually perturbed.
1-DOF Torsion	Vibration Control	Control the position of the output shaft to desired setpoint by rejecting the vibrations introduced by the torsional member.
2 DOF Torsion	Vibration Control	Control the position of the output shaft to desired setpoint by rejecting the vibrations introduced by both torsional members.
2 DOF Robot	2D Task-Based Position Control	Control the position of the end-effector given a desired planar (x,y) position. This involves servo position control as well as developing the forward and inverse kinematics of the plant.
2 DOF Pendulum	2 DOF Gantry Control	Control the position of the pendulum tip to a desired (x,y) position while dampening the motions of the pendulum.
2 DOF Pendulum	2 DOF Inverted Pendulum Balance Control	Develop a balance controller that keeps the 2 DOF pendulum in the upright vertical position.
2D Ball Balancer	Ball Position Control	Control the position of a ball that is free to move on a swiveling 2 DOF plate. The plate angles are controlled by attached servo units and the ball position is measured using an overhead digital camera with image processing software.

Table 1.1: SRV02-based Experiments

## 2 SRV02 COMPONENTS

The SRV02 components are identified in Section 2.1. Some of the those components are then described in Section 2.2.

### 2.1 SRV02 Component Nomenclature

The SRV02 components listed in Table 2.1 below are labeled in figures 2.1a, 2.1b, 2.1c, 2.1d, and 2.1e. Note that Figure 2.1a shows the SRV02 in the low-gear configuration and Figure 2.1b is the SRV02 in the high-gear configuration. These different gear setups will be explained later in Section 4.1.

ID	Component	ID	Component
1	Potentiometer	13	Tachometer
2	Bottom plate	14	Ball-bearing block
3	Posts	15	Motor connector
4	Motor pinion gear: 72-teeth (low-gear)	16	Tachometer connector
5	Load gear: 72-teeth (low-gear)	17	Encoder connector
6	Potentiometer anti-backlash gear	18	S1 & S2 connector (i.e. potentiometer)
7	Anti-backlash springs	19	Motor pinion gear: 24-teeth (high-gear)
8	Load shaft (i.e. output shaft)	20	Load gear: 120-teeth (high-gear)
9	Motor	21	Bar inertial load
10	Gearbox	22	Disc inertial load
11	Potentiometer	23	Thumb screws
12	Encoder		

Table 2.1: SRV02 Components

## 2.2 Component Description

### 2.2.1 DC Motor

The SRV02 incorporates a Faulhaber Coreless DC Motor model 2338S006 and is shown in Figure 2.1c with ID #9. This is a high efficiency, low inductance motor that can obtain a much faster response than a conventional dc motor. The complete specification sheet of the motor is included in [2].

■ **Caution:** *High-frequency signal applied to a motor will eventually damage the gearbox motor and the motor brushes.* The most likely source for high frequency noise is derivative feedback. If the derivative gain is set 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 50 Hz.

■ **Caution:** Input  $\pm 15$  V, 3 A peak, 1 A continuous.

■ **Caution:** Exposed moving parts.

### 2.2.2 Potentiometer

All SRV02 models are equipped with a Vishay Spectrol model 132 potentiometer, shown in Figure 2.1c with label #11. It is a single turn 10 k $\Omega$  sensor with no physical stops and has an electrical range of 352 deg. The total output range of the sensor is  $\pm 5$  V over the full 352 deg range. Note that a potentiometer provides an absolute position measurement as opposed to a relative measurement from, for instance, an incremental encoder. See [6] for a full listing of the potentiometer specifications.

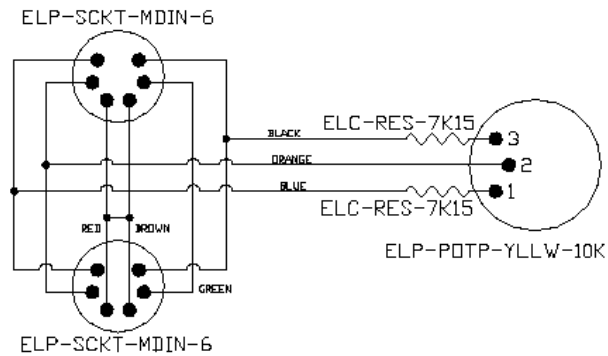


Figure 2.2: SRV02 potentiometer wiring

As illustrated in Figure 2.2, the potentiometer is connected to a  $\pm 12$  V DC power supply through two  $7.15 \text{ k}\Omega$  bias resistors. Under normal operations, terminal 1 should measure  $-5 \text{ V}$  while terminal 3 should measure  $5 \text{ V}$ . The actual position signal is available at terminal 2.

### 2.2.3 Tachometer

All SRV02 models are equipped with a tachometer that is directly attached to the DC motor and is depicted with ID #13 in Figure 2.1c. This prevents any latencies in the timing of the response and ensures that the speed of the motor is accurately measured. Refer to [3] for the tachometer specification sheet.

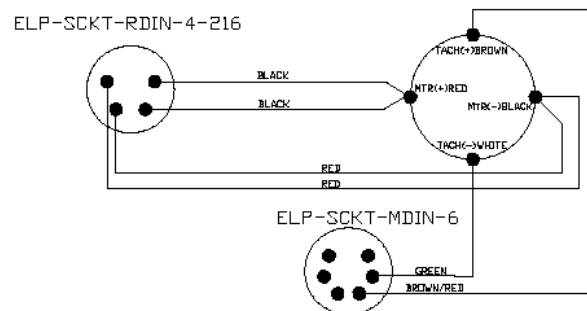


Figure 2.3: SRV02 tachometer wiring

The motor and tachometer wiring diagram is shown in Figure 2.3. The 4-pin DIN motor connector, component #19, connects the power amplifier to the positive and negative motor leads. This is the motor input voltage signal that drives the motor. The 6-pin mini DIN tachometer connector, component #18 shown in Figure 2.1d, is directly wired to the positive and negative tachometer terminals. This supplies a voltage signal that is proportional to the rotational speed. The tachometer connector is typically connected to the S3 analog input connector on the power amplifier.

### 2.2.4 Encoder

All SRV02 models have an optical encoder installed that measures the angular position of the load shaft. It is pictured in Figure 2.1c with the label #12. The encoder used is a US Digital E2 single-ended optical shaft encoder that offers a high resolution of 4096 counts per revolution in quadrature mode (1024 lines per revolution). The complete specification sheet of the E2 optical shaft encoder is given in [1].

Remark that incremental encoders measure the relative angle of the shaft (as opposed to the potentiometer which measures the absolute angle).

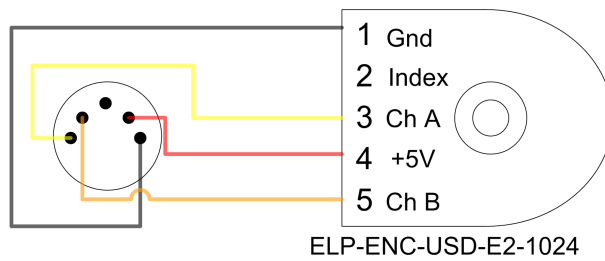


Figure 2.4: SRV02 encoder wiring

The position signal generated by the encoder can be directly connected to the data-acquisition device using a standard 5-pin DIN cable. The internal wiring of the encoder and the 5-pin DIN connector on the SRV02, component #17, is illustrated in Figure 2.4.

■ **Caution:** Make sure you connect the encoder directly to your data-acquisition device and not to the power amplifier.

## 2.3 SRV02-ETS Components

The SRV02-ETS, pictured in Figure 2.5, is an SRV02-ET system with a slip ring mounted on the load gear. This allows an external load attached on top of the slip ring unit to rotate 360 degrees freely without any cable entanglements. In addition to the components listed in Table 2.1, Table 2.2 lists some components found on the SRV02-ETS unit alone.

The components in Table 2.2 are shown and identified in Figure 2.6.

ID	Component	ID	Component
24	Slip ring module chassis	28	Right connector on slip ring
25	Slip ring	29	Left connector on SRV02
26	Slip ring top plate	30	Right connector on SRV02
27	Left connector on slip ring		

Table 2.2: Additional components on the SRV02-ETS

### 2.3.1 Slip Ring Description

The eight-contact slip ring channels the signals attached to the Left and Right connectors on the slip ring, ID #27 and ID #28 depicted in Figure 2.6, to the *Left* and *Right* connectors on the SRV02 base, ID #27 and ID #28 shown in Figure 2.6. This allows the load attached to the load gear atop the slip ring, ID #8, to move freely 360 degrees without any cable entanglements. This is especially useful, for instance, when used with the inverted rotary pendulum experiments.

## 3 SRV02 SPECIFICATIONS

Table 3.1 lists and characterizes the main parameters associated with the SRV02. Some of these are used in the mathematical model. More detailed information about the gears is given in Table 3.2 and the calibration gains for the various sensors on the SRV02 are summarized in Table 3.3.

Symbol	Description	Value	Variation
$V_{nom}$	Motor nominal input voltage	6.0 V	
$R_m$	Motor armature resistance	2.6 $\Omega$	$\pm 12\%$
$L_m$	Motor armature inductance	0.18 mH	
$k_t$	Motor current-torque constant	$7.68 \times 10^{-3}$ N-m/A	$\pm 12\%$
$k_m$	Motor back-emf constant	$7.68 \times 10^{-3}$ V/(rad/s)	$\pm 12\%$
$K_g$	High-gear total gear ratio	70	
	Low-gear total gear ratio	14	
$\eta_m$	Motor efficiency	0.69	$\pm 5\%$
$\eta_g$	Gearbox efficiency	0.90	$\pm 10\%$
$J_{m,rotor}$	Rotor moment of inertia	$3.90 \times 10^{-7}$ kg-m <sup>2</sup>	$\pm 10\%$
$J_{tach}$	Tachometer moment of inertia	$7.06 \times 10^{-8}$ kg-m <sup>2</sup>	$\pm 10\%$
$J_{eq}$	High-gear equivalent moment of inertia without external load	$2.087 \times 10^{-3}$ kg-m <sup>2</sup>	
	Low-gear equivalent moment of inertia without external load	$9.7585 \times 10^{-5}$ kg-m <sup>2</sup>	
$B_{eq}$	High-gear Equivalent viscous damping coefficient	0.015 N-m/(rad/s)	
	Low-Gear Equivalent viscous damping coefficient	$1.50 \times 10^{-4}$ N-m/(rad/s)	
$m_b$	Mass of bar load	0.038 kg	
$L_b$	Length of bar load	0.1525 m	
$m_d$	Mass of disc load	0.04 kg	
$r_d$	Radius of disc load	0.05 m	
$m_{max}$	Maximum load mass	5 kg	
$f_{max}$	Maximum input voltage frequency	50 Hz	
$I_{max}$	Maximum input current	1 A	
$\omega_{max}$	Maximum motor speed	628.3 rad/s	

Table 3.1: Main SRV02 Specifications

Symbol	Description	Value
$K_{gi}$	Internal gearbox ratio	14
$K_{ge,low}$	Internal gearbox ratio (low-gear)	1
$K_{ge,high}$	Internal gearbox ratio (high-gear)	5
$m_{24}$	Mass of 24-tooth gear	0.005 kg
$m_{72}$	Mass of 72-tooth gear	0.030 kg
$m_{120}$	Mass of 120-tooth gear	0.083 kg
$r_{24}$	Radius of 24-tooth gear	$6.35 \times 10^{-3}$ m
$r_{72}$	Radius of 72-tooth gear	0.019 m
$r_{120}$	Radius of 120-tooth gear	0.032 m

Table 3.2: SRV02 Gearhead Specifications

Symbol	Description	Value	Variation
$K_{pot}$	Potentiometer sensitivity	35.2 deg/V	$\pm 2\%$
$K_{enc}$	Encoder sensitivity	4096 counts/rev	
$K_{tach}$	Tachometer sensitivity	1.50 V/kRPM	$\pm 2\%$

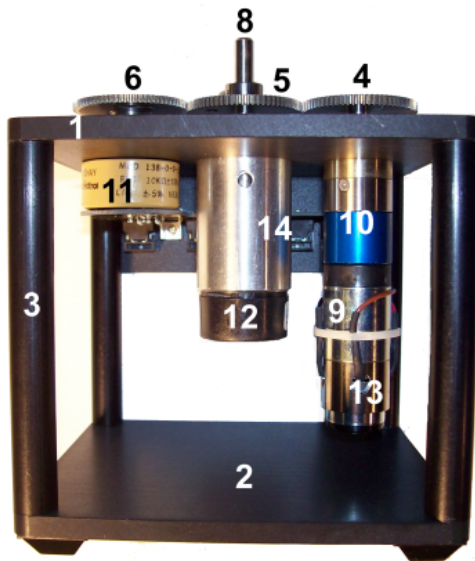
Table 3.3: SRV02 Sensor Specifications



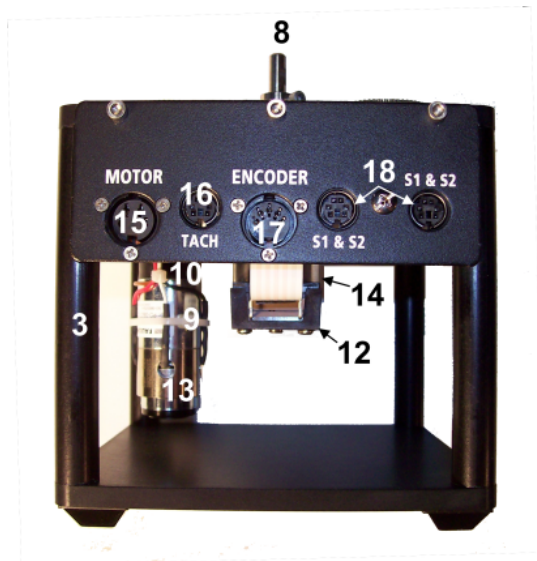
(a) Low-gear



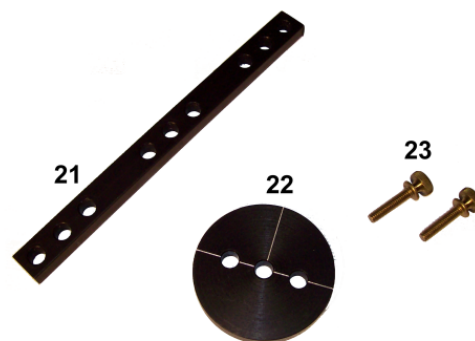
(b) High-gear



(c) Front view



(d) Connectors



(e) Inertial Loads

Figure 2.1: SRV02 components

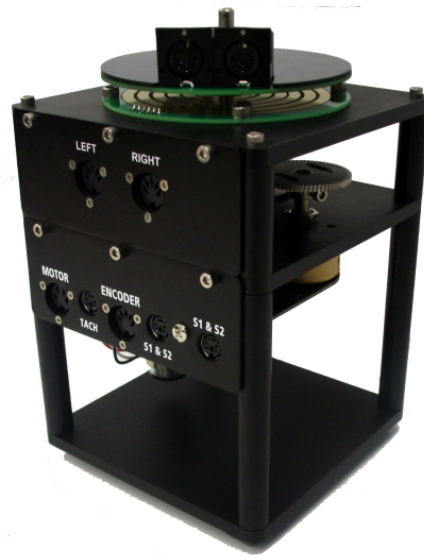


Figure 2.5: SRV02-ETS



Figure 2.6: Components on the SRV02-ETS



# 4 SRV02 SETUP AND CONFIGURATION

As discussed in Section 4.1, the SRV02 can be setup with two different gear configurations depending on the experiment being performed. Also, Section 4.2 shows how the SRV02 can be fitted with different loads.

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

## 4.1 Gear Configuration

### 4.1.1 Description

The SRV02 can be setup in the low-gear configuration or the high-gear configuration, as pictured in Figure 4.1a and Figure 4.1b, respectively. The high-gear setup is required to be used with additional modules such as the ball-and-beam device, the flexible link module, and the gyroscope.

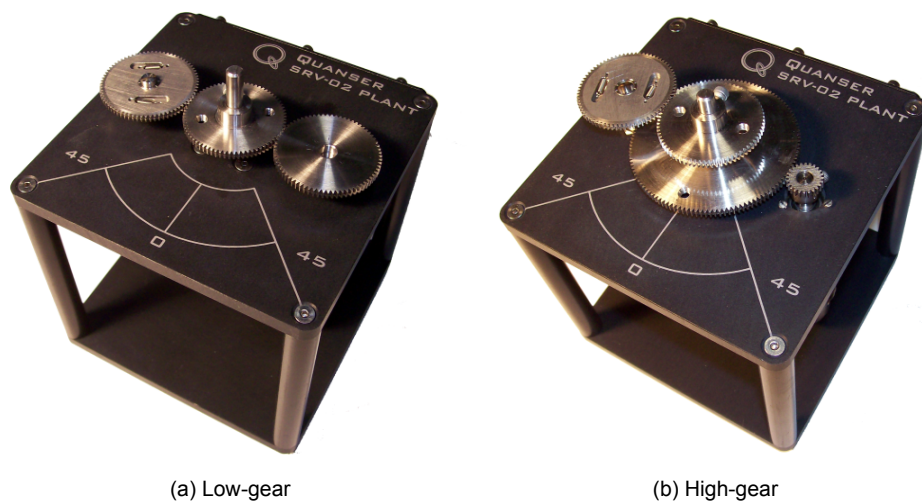


Figure 4.1: SRV02 Gear Configurations

### 4.1.2 Changing Gear Configuration

Follow this procedure to change between high-gear and low-gear ratio:

1. Using the supplied Allen keys, loosen the set screws on the three gear shafts.
2. Remove the gears from the shafts.
3. Slide the new gears into place as described below:
  - Low-gear configuration shown in Figure 4.1a: place the 72-tooth gear, ID #5 in Figure 2.1a, onto the load shaft, ID #8 in Figure 2.1a, and the 72-tooth pinion gear, ID #4 in Figure 2.1a, on the motor shaft.
  - High-gear configuration depicted in Figure 4.1b: slide the 120-tooth gear, ID #20 in Figure 2.1b, followed by the 72-tooth gear, ID #8 in Figure 2.1b, on the load shaft and place the 20-tooth pinion gear, ID #19 in Figure 2.1b, on the motor shaft.



**Note:** The potentiometer gear, component #6 in Figure 2.1b, is an anti-backlash gear and special precaution need to be taken when installing it. In order to insert it properly, rotate its two faces against each other such that the springs are partially pre-loaded. Do not fully extend the springs when you pre-load the gears.

4. Ensure the teeth of all the three gears are meshed together. Remark that in the high-gear setup, the top 72-tooth load gear is meshed with the potentiometer gear, ID #6 in Figure 2.1b.
5. Tighten the set-screws on each shaft with the supplied Allen keys.

## 4.2 Load Configurations

### 4.2.1 Description

The SRV02 is supplied with two external loads: a bar and a disk. These can be attached to the SRV02 load gear to vary the moment of inertia seen at the output. The SRV02 with the end of the bar load connected is pictured in Figure 4.2a. Either the end of the bar or the center of the bar can be used. In Figure 4.2b the SRV02 with the disk load attached is shown.

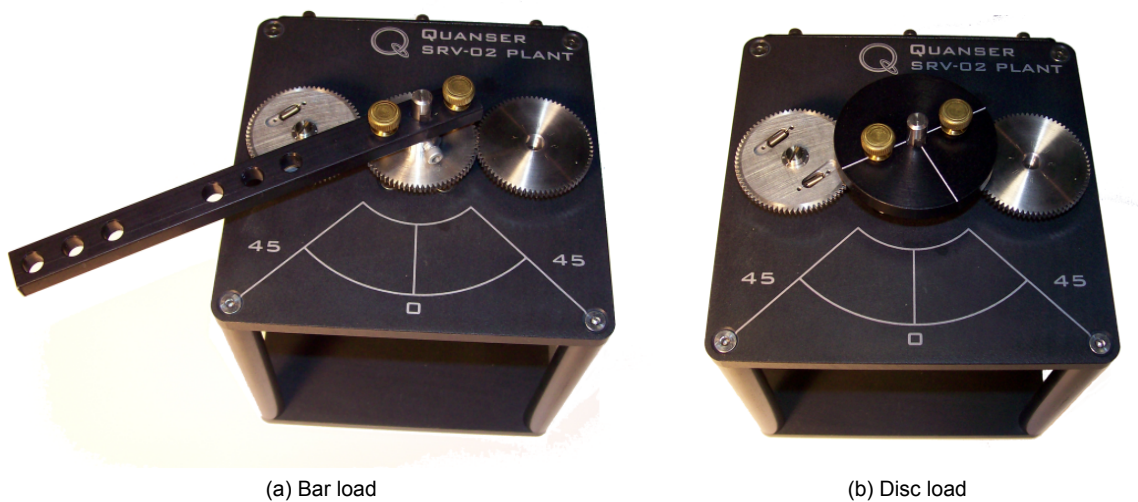


Figure 4.2: SRV02 Load Configurations

### 4.2.2 Installing Load

Follow this procedure to connect either the bar or disc load to the load gear:

1. Slide the center hole of the load on the output shaft of the SRV02, component #8 in Figure 2.1b. For the bar load (ID #21 in Figure 2.1e), use either the center hole in the middle of the bar or the center hole at the an end of the bar onto the output shaft.
2. Align the two holes adjacent to the center hole with the screw holes of the load gear.
3. Using the two 8-32 thumb screws provided, ID #23 in Figure 2.1e, fasten the inertial load to the output gear. The SRV02 with the bar load and the disk load attached is shown in Figure 4.2a and Figure 4.2b, respectively. Make sure all the screws are properly tightened before operating the servo unit.

■ **Caution:** Do not apply a load that weighs over 5 kg at any time.

For instructions on how to install one the SRV02 modules (e.g. rotary flexible joint) see the user manual corresponding to that module.

# 5 WIRING PROCEDURE

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

1. **Power Amplifier:** Quanser VoltPAQ-X1, or equivalent.
2. **Data Acquisition Board:** Quanser Q1-cRIO, Q2-USB, Q8-USB, QPID/QPIDe, NI DAQ, or equivalent.
3. **Rotary Servo Plant:** Quanser SRV02-ET, SRV02-ETS, or equivalent.

See the corresponding documentation for more information on these components. The cables supplied with the SRV02 are described in Section Section 5.1 and the procedure to connect the above components is given in Section 5.2.

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

## 5.1 Cable Nomenclature

The cables used to connect the Quanser SRV02 system with a power amplifier and data acquisition device are shown in Table 5.1. Depending on your configuration, not all these cables are necessary.






Cable	Type	Description
 <p>(a) RCA Cable</p>	2xRCA to 2xRCA	This cable connects an analog output of the data acquisition terminal board to the power module for proper power amplification.
 <p>(b) Motor Cable</p>	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.
 <p>(c) Encoder Cable</p>	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
 <p>(d) Analog Cable</p>	6-pin-mini-DIN to 6-pin-mini-DIN	This cable carries analog signals (e.g., from joystick, plant sensor) to the amplifier, where the signals can be either monitored and/or used by a controller. The cable also carries a $\pm 12$ VDC line from the amplifier in order to power a sensor and/or signal conditioning circuitry.
 <p>(e) 5-pin-DIN to 4xRCA</p>	5-pin-DIN to 4xRCA	This cable carries the analog signals, unchanged, from the amplifier to the Digital-To-Analog input channels on the data acquisition terminal board.

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

## 5.2 Connections for Single Channel DAQ and Amplifier

This section describes the typical connections used to connect the SRV02 plant to a data acquisition device and a power amplifier. **Only the encoder and tachometer sensors are connected (i.e., potentiometer is NOT used).** The connections are summarized in Table 5.2, and pictured in Figure 5.1. Connection details are given below.

**Note:** The wiring diagram shown in Figure 5.1 is using a generic data acquisition device. The same connections can be applied for any data acquisition system that has 1x analog input, 1x analog output, and 1x encoder input (e.g., single Q1-cRIO module).

Cable	From	To	Signal
1	DAQ: Analog Output #0	Amplifier <i>Amplifier Command</i> connector	Control signal to the amplifier.
2	Amplifier: <i>To Load</i> connector	SRV02 <i>Motor</i> connector	Power leads to the SRV02 dc motor.
3	DAQ: Encoder Input #0	SRV02 <i>Encoder</i> connector	Encoder load shaft angle measurement.
4	Amplifier: <i>To ADC</i> connector	DAQ: White (S2) to Analog Input #0	Connects tachometer measurement (white RCA, S2) to Analog Input #0.
5	Amplifier <i>S1 &amp; S2</i> connector	SRV02 <i>TACH</i> connector	Tachometer (S2) load shaft rate measurement.

Table 5.2: SRV02 Wiring

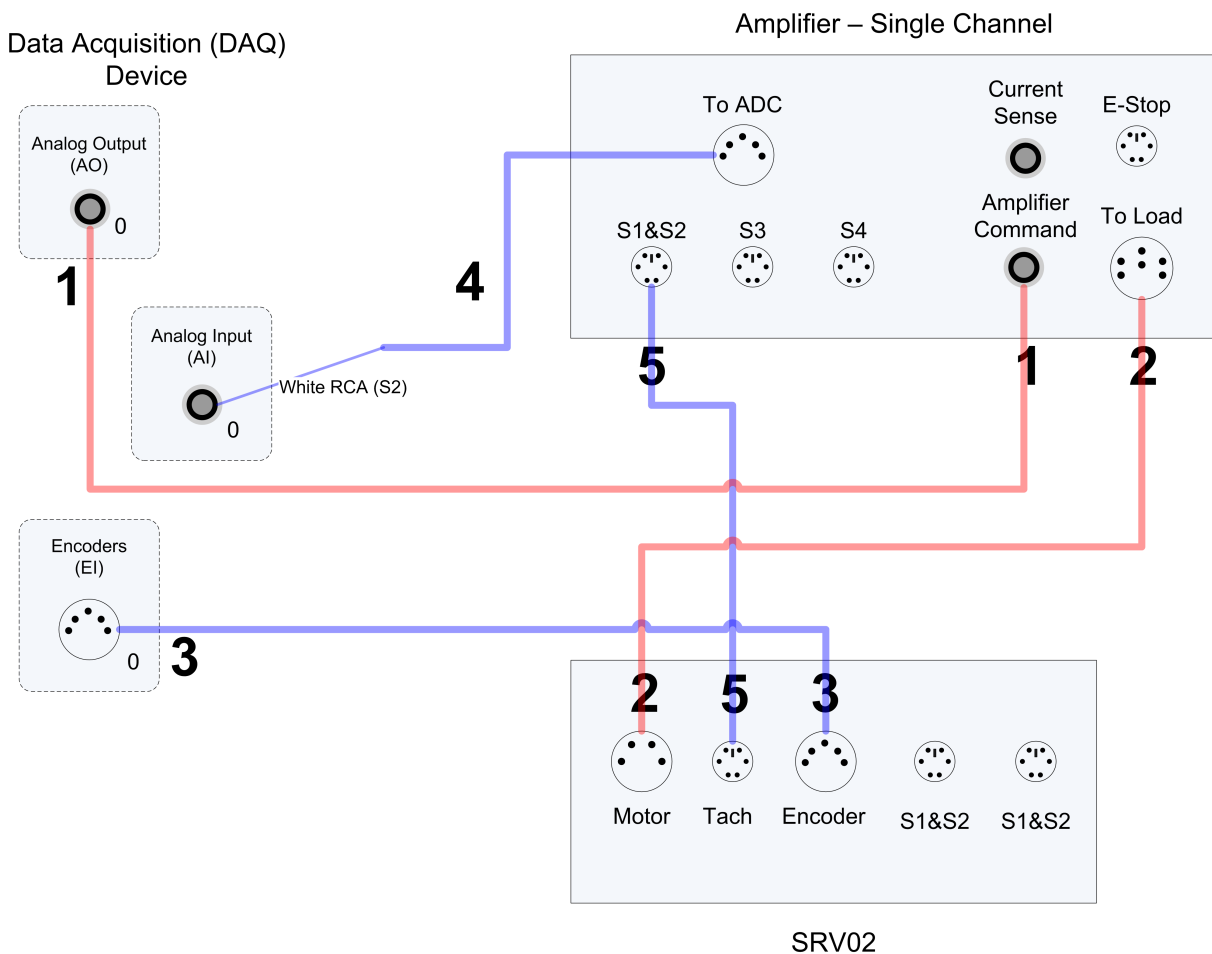


Figure 5.1: Connecting the SRV02 to a Single-Channel DAQ and Amplifier

Follow these steps to connect the SRV02 system:

1. Make sure that your data acquisition device is installed and is operational. For example, if using the Quanser Q2-USB see Reference [5].
2. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the amplifier.

3. Connect one end of the 2xRCA to 2xRCA cable from the Analog Output Channel #0 on the terminal board to the *Amplifier Command* connector on the amplifier, i.e., use both white or both red RCA connectors. See cable #1 shown in Figure 5.1.
4. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN that is labeled from *To Load* on the amplifier to the *Motor* connector on the SRV02. See connection #2 shown in Figure 5.1.
5. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the SRV02 panel to Encoder Input # 0 on the terminal board, as depicted by connection #3 in Figure 5.1.  
**■ Caution:** Any encoder should be directly connected to the data-acquisition terminal board (or equivalent) using a standard 5-pin DIN cable. **DO NOT connect the encoder cable to the amplifier!**
6. Connect the *To ADC* socket on the amplifier to Analog Inputs #0-1 on the terminal board using the 5-pin-DIN to 4xRCA cable, as illustrated in Figure 5.1. The RCA side of the cable is labeled with the channels: yellow is S1, white is S2, red is S3, and black is S4. The yellow S1 connector goes to Analog Input Channel #0 and the white S2 connector goes to Analog Input Channel #1.
7. Connect the *TACH* connector on the SRV02 to the *S1 & S2* socket on the SRV02 using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. This connection is labeled #5 in Figure 5.1. It combines the potentiometer (S1) measurement with the tachometer (S2) measurement.
8. Connect the *S1 & S2* connector on the SRV02 to the *S1 & S2* socket on the amplifier using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. See connection #6 in Figure 5.1. This carries the potentiometer (S1) and tachometer (S2) signals.

## 5.3 Connections for Two-Channel DAQ and Single-Channel Amplifier

This section describes the typical connections used to connect the SRV02 plant to a data acquisition device and a power amplifier. The connections are summarized in Table 5.3, and pictured in Figure 5.2. Connection details are given below.

**Note:** The wiring diagram shown in Figure 5.2 is using a generic data acquisition device. The same connections can be applied for any data acquisition system that has least 2x analog inputs, 1x analog output, and 1x encoder input.

Cable	From	To	Signal
1	Terminal Board: Analog Output #0	Amplifier <i>Amplifier Command</i> connector	Control signal to the amplifier.
2	Amplifier: <i>To Load</i> connector	SRV02 <i>Motor</i> connector	Power leads to the SRV02 dc motor.
3	Terminal Board: Encoder Input #0	SRV02 <i>Encoder</i> connector	Encoder load shaft angle measurement.
4	Amplifier: <i>To ADC</i> connector	Terminal Board: <ul style="list-style-type: none"> <li>S1 to Analog Input #0</li> <li>S2 to Analog Input #1</li> </ul>	Connects analog sensor signals S1 and S2 to Analog Input Channels #0 and #1, respectively.
5	SRV02 <i>S1 &amp; S2</i> connector	SRV02 <i>TACH</i> connector	Combine potentiometer (S1) and tachometer (S2) signals.
6	Amplifier <i>S1 &amp; S2</i> connector	SRV02 <i>S1 &amp; S2</i> connector	Potentiometer load shaft angle (S1) measurement and tachometer (S2) load shaft rate measurement.

Table 5.3: SRV02 Wiring

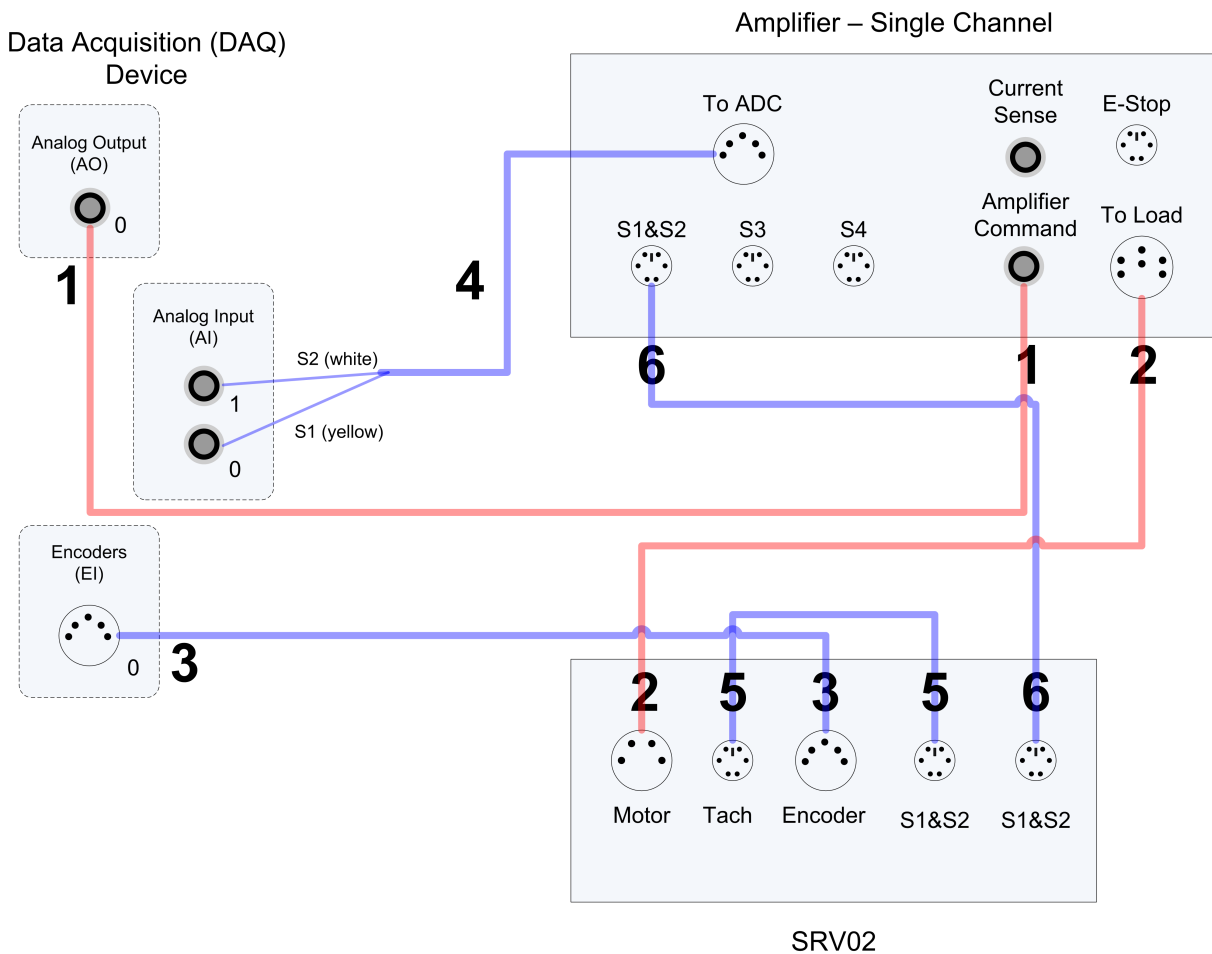


Figure 5.2: Connecting the SRV02 to a Single-Channel Amplifier and Two-Channel DAQ

Follow these steps to connect the SRV02 system:

1. Make sure that your data acquisition device is installed and is operational. For example, if using the Quanser Q2-USB see Reference [5].
2. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the amplifier.
3. Connect one end of the 2xRCA to 2xRCA cable from the Analog Output Channel #0 on the terminal board to the *Amplifier Command* connector on the amplifier, i.e., use both white or both red RCA connectors. See cable #1 shown in Figure 5.1.
4. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN that is labeled from *To Load* on the amplifier to the *Motor* connector on the SRV02. See connection #2 shown in Figure 5.1.
5. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder* connector on the SRV02 panel to Encoder Input # 0 on the terminal board, as depicted by connection #3 in Figure 5.1.  
**■ Caution:** Any encoder should be directly connected to the data-acquisition terminal board (or equivalent) using a standard 5-pin DIN cable. **DO NOT connect the encoder cable to the amplifier!**
6. Connect the *To ADC* socket on the amplifier to Analog Inputs #0-1 on the terminal board using the 5-pin-DIN to 4xRCA cable, as illustrated in Figure 5.1. The RCA side of the cable is labeled with the channels: yellow is S1, white is S2, red is S3, and black is S4. The yellow S1 connector goes to Analog Input Channel #0 and the white S2 connector goes to Analog Input Channel #1.

7. Connect the *TACH* connector on the SRV02 to the *S1* & *S2* socket on the SRV02 using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. This connection is labeled #5 in Figure 5.1. It combines the potentiometer (*S1*) measurement with the tachometer (*S2*) measurement.
8. Connect the *S1* & *S2* connector on the SRV02 to the *S1* & *S2* socket on the amplifier using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. See connection #6 in Figure 5.1. This carries the potentiometer (*S1*) and tachometer (*S2*) signals.

## 5.4 Connections using a Two-Channel Amplifier

This section describes the wiring required for an amplifier that has two channels, e.g., such as the Quanser VoltPAQ-X2. The connections are illustrated in Figure 5.3 and are the same as given above in Table 5.2.

**Note:** The wiring diagram shown in Figure 5.1 is using a generic data acquisition device. The same connections can be applied for any data acquisition system that has least 2x analog inputs, 1x analog output, and 1x encoder input.

**Note:** The power amplifier used resembles a VoltPAQ-X2 system, which is a two-channel amplifier that requires digital enabling and an emergency stop switch to be connected. Remark that the analog sensor are interfaced through an *Analog Signal Conditioner* box to split the potentiometer (*S1*) and tachometer (*S2*) channels.

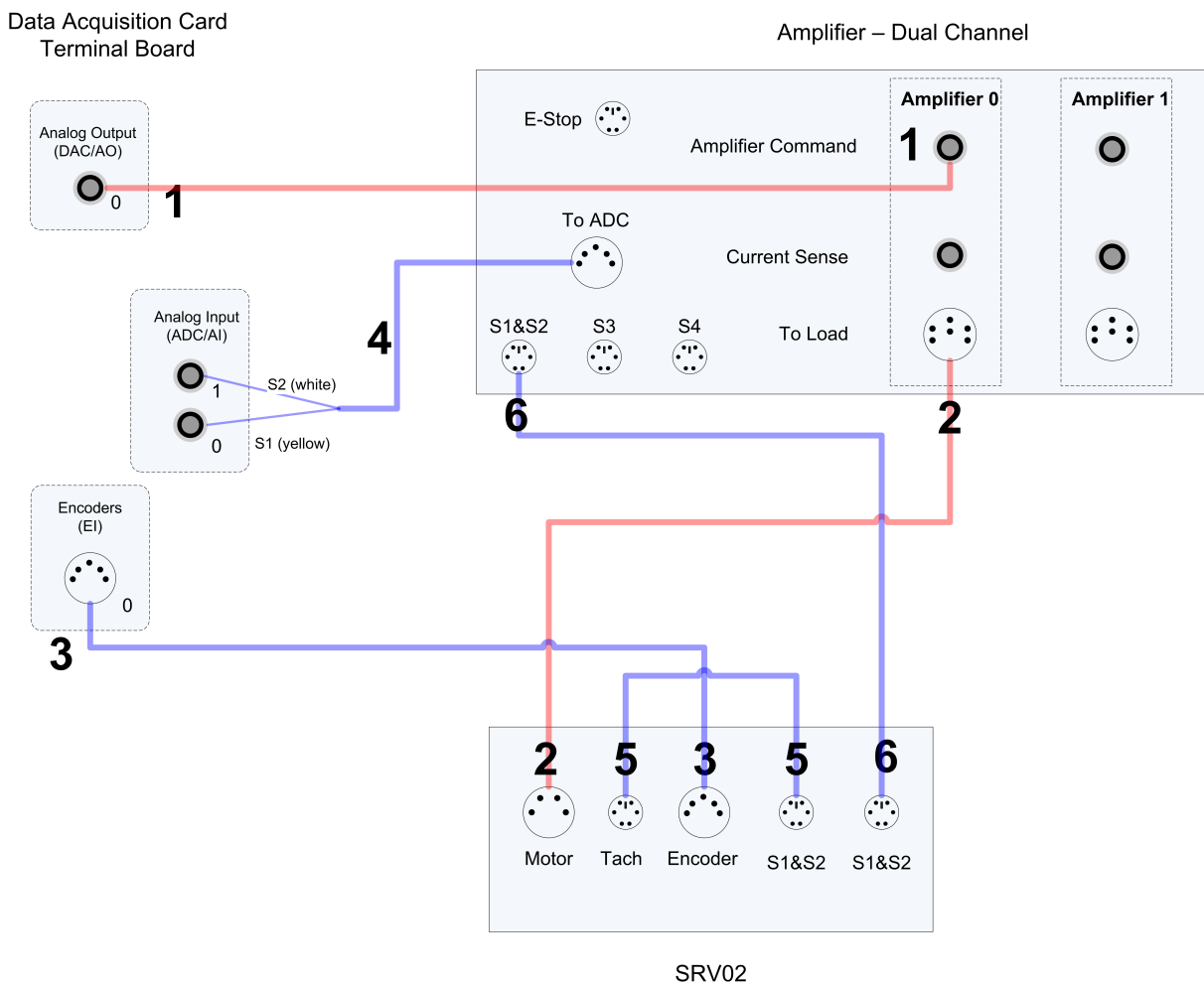


Figure 5.3: Connecting the SRV02 to a Two-Channel Amplifier and DAQ

# 6 TESTING AND TROUBLESHOOTING

This section describes some functional tests to determine if your SRV02 is operating normally. It is assumed that the SRV02 is connected as described in the Section 5, above. To carry out these tests, it is preferable if the user can use a software such as **QUARC®** or **LabVIEW™** to read sensor measurements and feed voltages to the motor. See Reference [4] to learn how to interface the SRV02 with QUARC. Alternatively, these tests can be performed with a signal generator and an oscilloscope.

## 6.1 Motor

### 6.1.1 Testing

Ensure the SRV02 motor is operating correctly by going through this procedure:

1. Apply a voltage to analog output channel #0 of the terminal board using, for example, the QUARC software.
2. The motor gear, component #4 shown in Figure 2.1b, should rotate counter-clockwise when a positive voltage is applied and clockwise when a negative voltage is applied. Remark that the motor shaft and the load shaft turn in opposite directions.

### 6.1.2 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 VoltPAQ device, is the green LED lit?
- Check that the data-acquisition board 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.

## 6.2 Potentiometer

### 6.2.1 Testing

Test the SRV02 potentiometer with the following procedure:

1. Using a program such as QUARC, measure the analog input channel #0.
2. The potentiometer should output a positive voltage when the potentiometer gear, component #6 in Figure 2.1b, is rotated counter-clockwise. The measurement should increase positively towards 5 V until the discontinuity is reached, at which point the signal abruptly changes to -5 V and begins to increase again.



## 6.2.2 Troubleshooting

Follow the steps below if the potentiometer is not measuring correctly:

- Verify that the power amplifier is functional. For example when using the Quanser VoltPAQ device, is the green LED lit? Recall the analog sensor signal go through the amplifier before going to the data-acquisition device (except when using the Q3 ControlPAQ). Therefore the amplifier needs to be turned on to read the potentiometer.
- Check that the data-acquisition board is functional, e.g. ensure it is properly connected, that the fuse is not burnt.
- Measure the voltage across the potentiometer. Ensure the potentiometer is powered with a  $\pm 12$  V at the 6-pin-mini DIN connector and  $\pm 5$  V at the potentiometer terminals, as described in Section 2.2.2. If the voltage from the wiper does not change when you rotate the potentiometer shaft, your potentiometer needs to be replaced. Please see Section 7 for information on contacting Quanser for technical support.

## 6.3 Tachometer

### 6.3.1 Testing

Test the tachometer on the SRV02 by performing the following:

1. Apply a 2.0 V signal to Analog Output Channel #0 in order to drive the motor.
2. Measure Analog Input Channel #2 to read the tachometer. When applying 2.0 V to the motor, the tachometer should be measuring a value of approximately 3.0 V.

### 6.3.2 Troubleshooting

If no signals are received from the tachometer, go through this method:

- Verify that the power amplifier is functional. For example when using the Quanser VoltPAQ device, is the green LED lit? Recall the analog sensor signal go through the amplifier before going to the data-acquisition device (except when using the Q3 ControlPAQ). It needs to be turned on to read from the tachometer.
- Check that the data-acquisition board is functional, e.g. ensure it is properly connected, that the fuse is not burnt.
- Measure the voltage across the tachometer. When moving the load gear back and forth, is the voltage being measured changing? If not, then the tachometer needs to be replaced. Please see Section 7 for information on contacting Quanser for technical support.

## 6.4 Encoder

### 6.4.1 Testing

Follow this procedure to test the SRV02 encoder:

1. Measure Encoder Input Channel #0 using, for instance, the QUARC software.

2. Rotate the SRV02 load gear, component #5 in Figure 2.1b, one rotation and the encoder should measure 4096 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. 1024 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 1024-line encoder results in 4096 integer counts for every full rotation.

### 6.4.2 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.

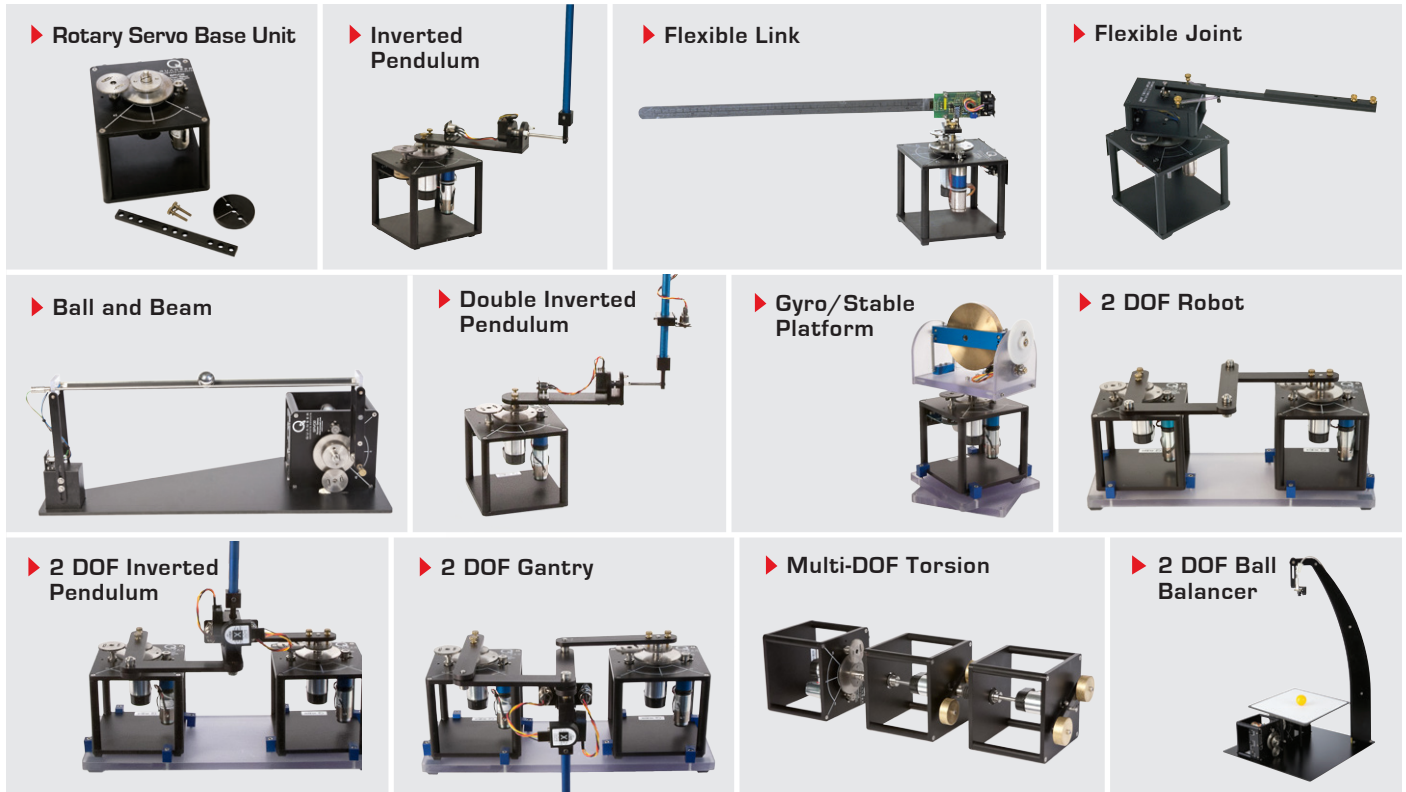
## 7 TECHNICAL SUPPORT

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] US Digital. *E2 Optical Kit Encoder*, 2007.
- [2] Faulhaber. *DC-Micromotors Series 2338*, 2002.
- [3] Faulhaber. *DC-Motor-Tacho Combinations*, 2002.
- [4] Quanser Inc. *SRV02 QUARC Integration*, 2008.
- [5] Quanser Inc. *Q2-USB Data-Acquisition System User's Guide*, 2010.
- [6] Vishay Spectrol. *Model 132, 138, 139*, 2001.

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