# USER MANUAL

## Gyro/Stable Platform 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 SRV02 plant plus the gyroscope module are depicted in Figure 1.1. The gyroscope module itself consists of a rotating disk mounted inside a frame. It can be actuated about its center through a DC motor. An internal blue frame holds the rotating disk and is attached to an external frame through two shafts at both ends. A gear mechanism is connected between one of these end shafts and an encoder that measures the rotation of the blue frame about the shafts. Two springs are also attached between the other end of the blue frame and the base of the external frame in order to provide tension for the inner frame structure. The external frame has a hole at its base through which it can be mounted on the output shaft of a SRV02 plant. This allows actuation of the gyroscope module about the SRV02 output shaft.

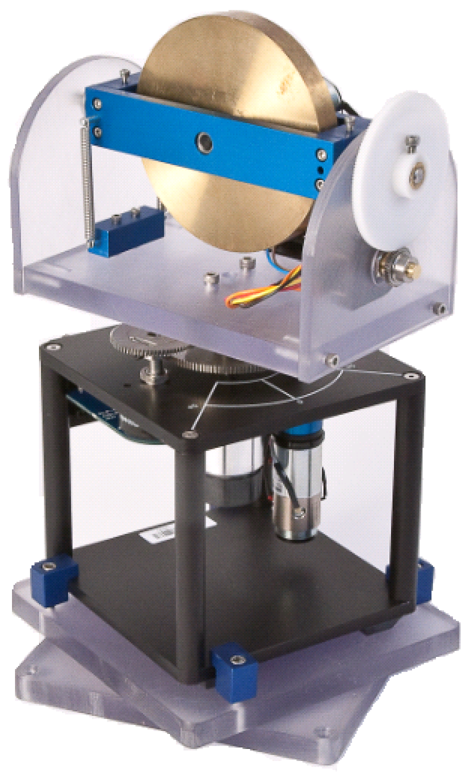


Figure 1.1: Quanser gyroscope/stable platform system

The SRV02 plant is mounted on a 2-plate structure. This structure consists of two plates mounted on top of each other that are free to rotate on top of each other. This allows the SRV02 plus gyroscope structure to be manually rotated relative to a fixed surface. Such an action can be thought of as an external disturbance that one might apply to the gyroscope system. Gyroscopes are widely used in systems that control and guide the orientation of space satellites, airplanes, submarines, etc. The Quanser SRV02 and gyroscope system provides a great platform to study gyroscope properties along with control experiments that resemble real-life applications of the gyro. For more information regarding the SRV02 plant please refer to the SRV02 User Manual [2].

■ **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 SRV02 AND GYROSCOPE PLANT COMPONENTS

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

## 2.1 SRV02 plus Gyroscope Component Nomenclature

The SRV02 plus gyroscope module components are listed below in Table 2.1 and are labeled in figure 2.1.

| ID | Component | ID | Component |
|---|---|---|---|
| 1 | Disk/Rotor | 7 | Gear mechanism |
| 2 | DC motor | 8 | Gyroscope module encoder connector |
| 3 | Inner frame | 9 | SRV02 plant |
| 4 | Encoder for inner frame rotation measurement | 10 | Support base plates |
| 5 | Tension springs | 11 | Hold clamps |
| 6 | Outer frame | 12 | Gyroscope disk motor connector |

Table 2.1: SRV02 plus gyroscope module system components

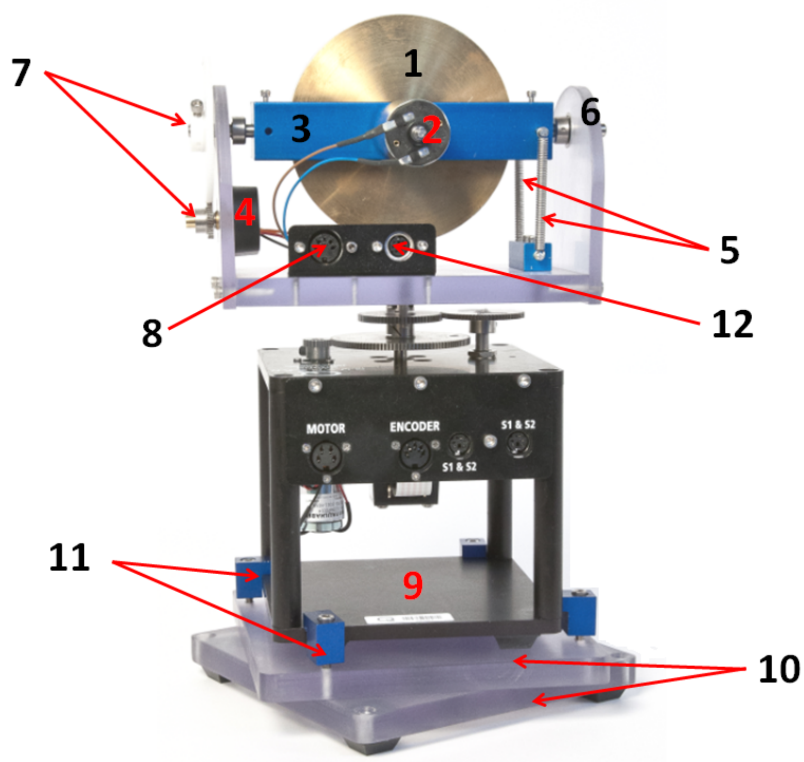



Figure 2.1: SRV02 plus gyroscope module components

## 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 is shown in Figure 2.1 with ID #1.

### 2.2.2 DC Motor

This component is depicted by ID #2 in Figure 2.1 and is used to rotate the disk. The motor is actuated by a constant voltage supplied from the power amplifier unit that accompanies the experiment.

■ **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.

### 2.2.3 Inner Frame

This component is depicted by ID #3 in Figure 2.1. It provides support for the rotor and the DC motor used to spin it. The frame itself is connected to an outer frame via two shafts at its two ends. This allows for rotation of the rotor and inner frame structure about these shafts.

### 2.2.4 Encoder for inner frame rotation measurement

This component is depicted by ID #4 in Figure 2.1. Digital position measurement of the inner frame rotation about its support shafts is done using a US Digital optical high resolution (1024 counts/rev) encoder.

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

### 2.2.5 Support Springs

These components are depicted by ID #5 in Figure 2.1 and are two springs that are attached to the inner frame at one end and to the outer frame base surface at another end. This mechanism stabilizes the inner frame structure from undesired disturbances.

### 2.2.6 Gear Mechanism

This component is identified by ID #7 in Figure 2.1. It is used to translate the rotation of the inner frame and rotor disk structure to the shaft to which the encoder is connected to. This mechanism introduces a 1:4 gear ratio from the frame shaft to encoder shaft that has to be taken account when converting the encoder measurement to inner frame shaft rotation measurement.

### 2.2.7 Gyroscope module encoder connector

This component is identified by ID #8 in Figure 2.1 and provides measurement of the gyroscope module deflection angle.

### 2.2.8 Support base plates

These components are identified by ID #10 in Figure 2.1. One of them to which the rubber plastic pieces are attached is used for support and the second plate with the clamps is used to hold and rotate the SRV02 and gyroscope structure with respect to the support plate.

### 2.2.9 Hold Clamps

These components are identified by ID #11 in Figure 2.1 and are used to tighten the SRV02 plant to the base support plates. This can be done by using an Allen key to tighten the screws of each clamp.

### 2.2.10 Gyroscope rotation disk motor connector

This component is identified by ID #12 in Figure 2.1 and connects to a power source on the amplifier to provide the required voltage for the DC motor of the rotation disk.

# 3 SRV02 PLUS GYROSCOPE SPECIFICATIONS

Table 3.1 lists and characterizes the main parameters associated with the SRV02 plus gyroscope system. Some of these are used in the mathematical model of the plant.

| Symbol | Description | Value | Variation |
|---|---|---|---|
| $V_{nom}$ | Motor nominal input voltage | 12 V | |
| $R_m$ | Motor armature resistance | 5.3 $\Omega$ | $\pm$ 12% |
| $L_m$ | Motor armature inductance | 0.580 mH | |
| $K_t$ | Motor current-torque constant | 0.02 N-m/A | |
| $J_m$ | Armature inertia | $1.4 \times 10^{-6}$ kg-m$^2$ | |
| $I_{nominal}$ | Operating current | 0.23 A | |
| $R_{disk}$ | Flywheel radius | 0.0508 m | |
| $M_{disk}$ | Flywheel mass | 0.8 kg | |
| $J_{disk}$ | Flywheel inertia about spin axis | 1.0323 kg-m$^2$ | |
| $J_g$ | Gyroscope module inertia about input axis | 0.002 kg-m$^2$ | |
| $K_s$ | Spring stiffness | $1.9089 \times 10^3$ N/m | |
| $K_g$ | Gear mechanism ratio | 1/4 | |
| $K_{enc}$ | Encoder resolution (in quadrature mode) | 4096 counts/rev | |

Table 3.1: Main Gyroscope Module Specifications

# 4 SYSTEM SETUP

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

You can use the instructions provided in Section 5 to wire the system together with the amplifier and the terminal board. The following steps should be performed before wiring the system:

1. Setup the SRV02 base plant in the high-gear configuration as explained in the SRV02 User Manual [2].
2. Place the gyroscope module on top of the SRV02 plant such that the servo output shaft inserts the hole on the bottom platform of the gyroscope module and it can freely rotate about the shaft. This is depicted in Figure 4.1.

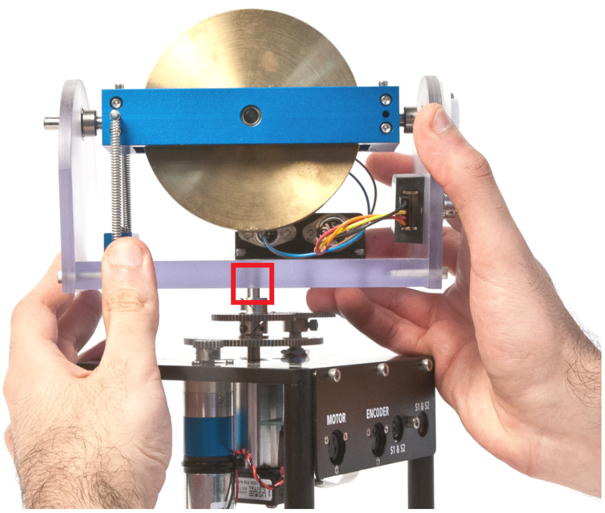



Figure 4.1: Attaching the GYRO-E module to the SRV02 output shaft

3. Insert the two 8-32 1-inch capscrews into the two remaining holes on the GYRO-E module and rotate the module until the screws are aligned with the two holes on the SRV02 72-tooth gear. Tighten these screws using the provided 9/64 allen key as shown in Figure 4.2.


Figure 4.2: Tightening the GYRO-E module screws

4. Place the base plate with the 4 plastic support legs on a flat surface. Place the other support plate with the 4 blue clamps on top the first plate such that the clamps are facing upward and the blue shaft in the middle of the plate inserts the hole on the bottom plate.
5. Place the SRV02 + Gyroscope system on the support plate and secure it in place by rotating the clamps to hold the SRV02 and tightening the screw on each one using the 9/64 allen key as shown in Figure 4.3.

Figure 4.3: Tightening the base plate clamps

# 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 Q2-USB, Q8-USB, QPID 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 plus gyroscope module 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

The cables used to connect the Quanser SRV02 plus gyroscope module 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.

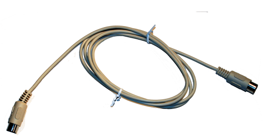
| Cable | Type | Description |
|---|---|---|
|  (a) RCA Cable | 2xRCA to 2xRCA | This cable connects an analog output of the data acquisition terminal board to the power module for proper power amplification. |
|  (b) Motor Cable | 4-pin-DIN to 6-pin-DIN | This cable connects the output of the power 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 |
|  (d) Analog Cable | 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. |

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

## 5.2 Typical Connections

This section describes the typical connections used to connect the SRV02 and gyroscope module plant to a data-acquisition board and a power amplifier. The connections are described in detail in the procedure below, summarized in Table 5.2, and pictured in Figure 5.1.

**Note:** The wiring diagram shown in Figure 5.1 is using a two-channel data-acquisition board, which resembles a Quanser Q2-USB. The same connections can be applied for any data-acquisition system - as long as it has least two analog input, two analog output, and two encoder channels.

Follow these steps to connect the SRV02 and gyroscope module system:

1. Make sure that your data-acquisition device is installed and is operational. For example, if using the Quanser Q2-USB see Reference [3].
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. This carries the attenuated motor voltage control signal, $V_m/K_a$, where $K_a$ is the amplifier gain.

4. Connect the 4-pin-stereo-DIN to 6-pin-stereo-DIN from the connector that is labeled *To Load* on the amplifier to the *Motor* connector on the SRV02. See connection #2 shown in Figure 5.1. The cable transmits the amplified voltage that is applied to the SRV02 motor and is denoted $V_m$.

5. Connect the 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the SRV02 *Encoder* connector to Encoder Input # 0 on the terminal board, as depicted by connection #3 in Figure 5.1. This carries the SRV02 output shaft angle measurement and is denoted by the variable $\theta$ and is only used for monitoring purposes in this experiment.

   ■ **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 6-pin-mini-DIN connector on the gyroscope module to the *S1 & S2* socket on the amplifier using the 6-pin-mini-DIN to 6-pin-mini-DIN cable. See connection #4 in Figure 5.1. This carries a constant voltage command to the rotor DC motor for spinning it.

7. Connect a 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the Gyroscope module *Encoder* connector to Encoder Input # 1 on the terminal board as depicted by connection # 5 in Figure 5.1. This caries the gyroscope module deflection angle.

| Cable | From | To | Signal |
|---|---|---|---|
| 1 | Terminal Board: Analog Output #0 | Amplifier *Amplifier Command* connector | Control signal to the amplifier. |
| 2 | Amplifier: *To Load* connector | SRV02 *Motor* connector | Power leads to the SRV02 dc motor. |
| 3 | Terminal Board: Encoder Input #0 | SRV02 *Encoder* connector | SRV02 load shaft angle measurement. |
| 4 | Amplifier *S1 & S2* connector | Gyroscope module 6-pin-mini-DIN connector | Supply DC voltage for spinning the rotor |
| 5 | Terminal Board: Encoder Input #1 | Gyroscope module *Encoder* connector | Gyroscope module deflection angle measurement. |

Table 5.2: SRV02 and Gyroscope Module Wiring

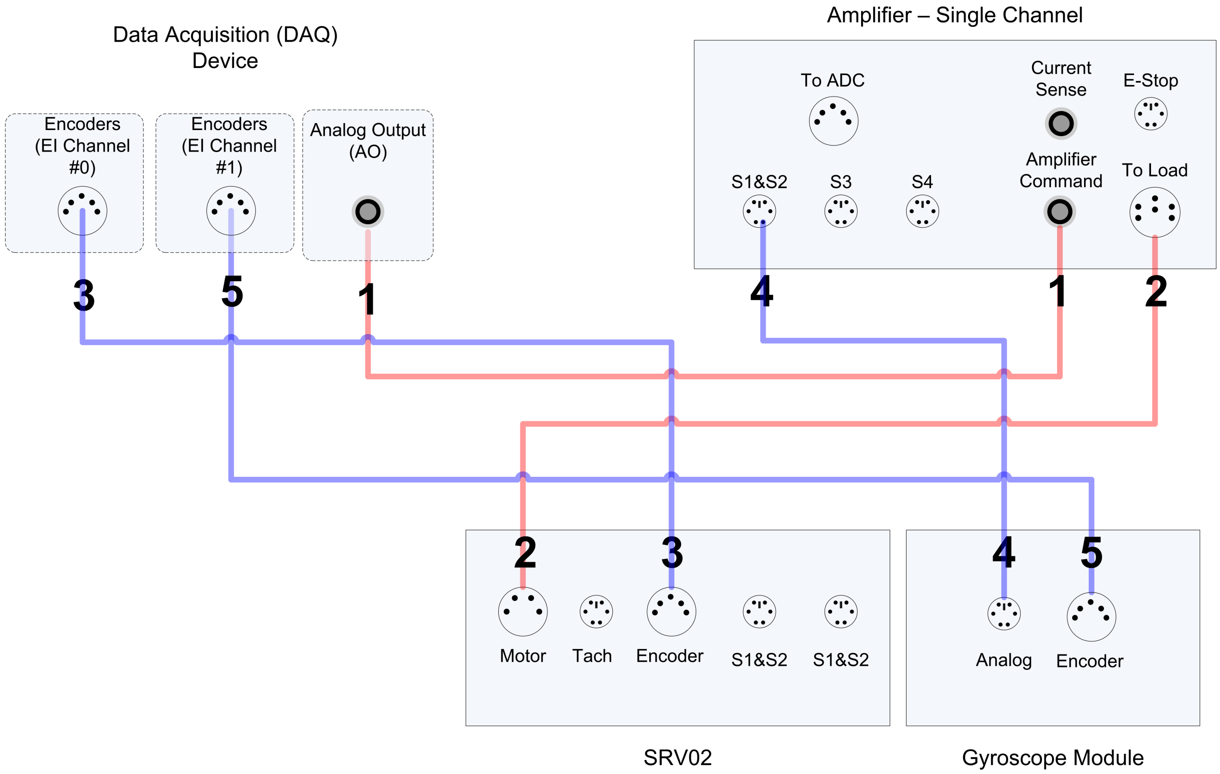



Figure 5.1: Typical SRV02 Gyroscope Connections

# 6 TESTING AND TROUBLESHOOTING

This section describes some functional tests to determine if your gyroscope module is operating normally. It is assumed that the SRV02 and gyroscope module are 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 [1] 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

To ensure that the SRV02 motor is operating correctly please refer to the SRV02 User Manual [2]. To ensure that the gyroscope module motor is working follow this procedure:

1. Turn on the amplifier unit.
2. The gyroscope module disk should start rotating.

### 6.1.2 Troubleshooting

If the motor is not responding, go through these steps:

- Verify that the power amplifier is functional. For example when using the Quanser VoltPAQ device, is the green LED lit?
- 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 Encoder

### 6.2.1 Testing

To ensure that the SRV02 encoder is operating properly please refer to the SRV02 User Manual [2]. Follow this procedure to test the gyroscope encoder:

1. Measure Encoder Input Channel #1 using, for instance, the QUARC software.
2. Rotate the gyroscope module about the blue frame axis and observe the changes in software.

   *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 the SRV02-E or 2048 in the SRV02-EHR. 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.

### 6.2.2 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.

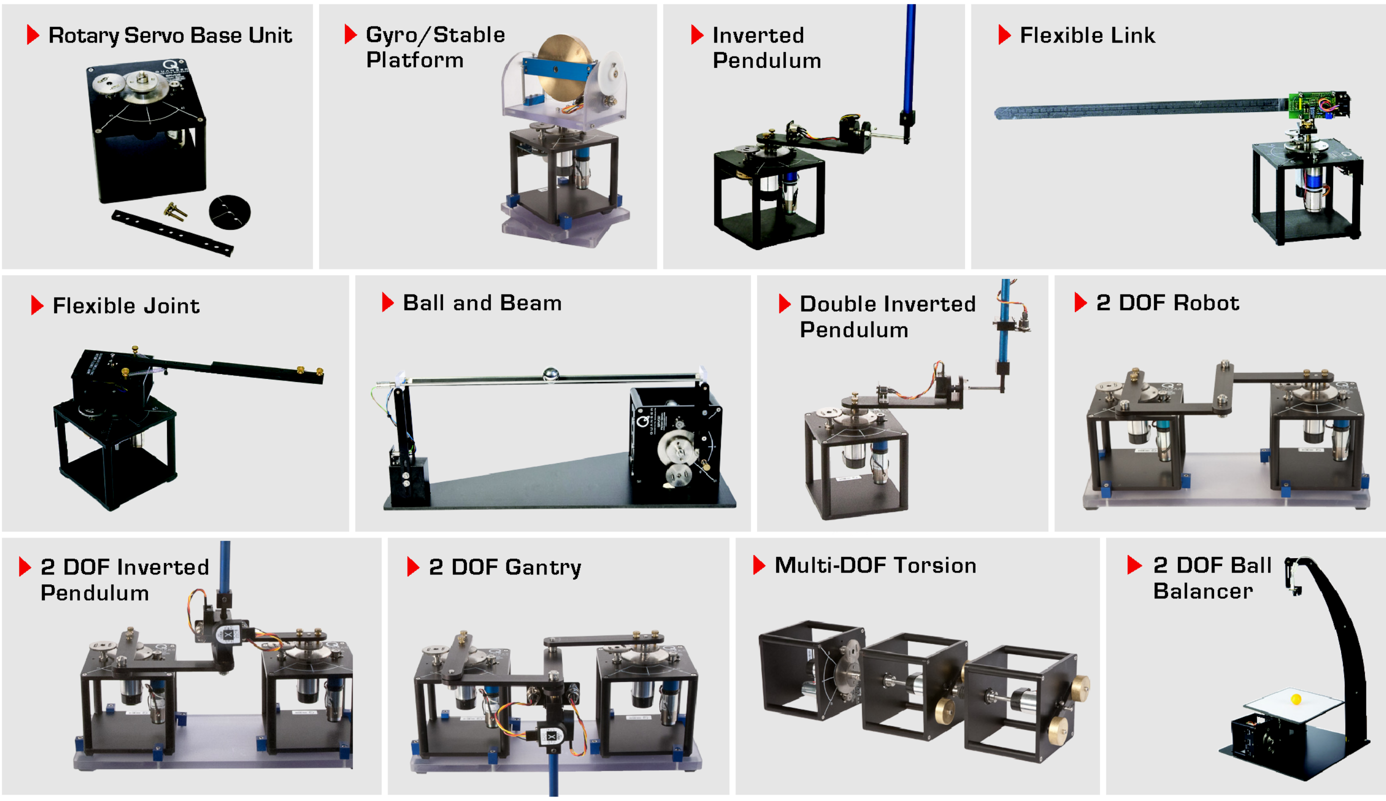
# REFERENCES

[1] Quanser Inc. *SRV02 QUARC Integration*, 2008.

[2] Quanser Inc. *SRV02 User Manual*, 2009.

[3] Quanser Inc. *Q2-USB Data-Acquisition System User's Guide*, 2010.

## Over ten rotary experiments for teaching fundamental and advanced controls concepts

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