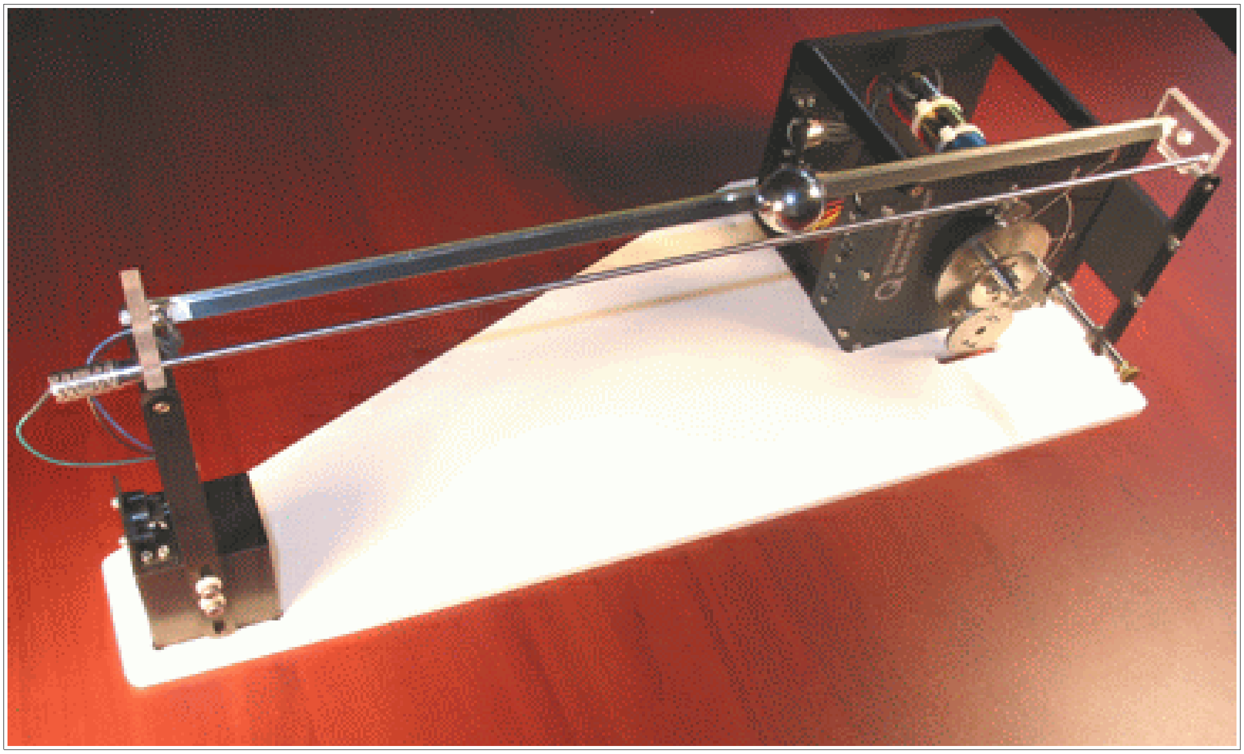
# SRV02-Series

# Ball & Beam



# User Manual

# Table of Contents



# Index of Tables



# Index of Figures

SRV02-Series

# BB01 – Ball & Beam

User Manual

## 1. Description

The Ball & Beam module consists of a steel rod in parallel with a nickel-chromium wire-wound resistor forming the track on which the metal ball is free to roll. The position of the ball is obtained by measuring the voltage at the steel rod. When the ball rolls along the track, it acts as a wiper similar to a potentiometer resulting in the position of the ball. When coupled to the SRV02 plant, the DC motor will drive the beam such that the motor angle controls the tilt angle of the beam. The ball then travels along the length of the beam.

The aim is to design a control system to track the ball to a commanded position. The system is supplied with a dual loop PD controller for the servo as well as the ball position. The Ball & Beam experiment will build on the basics developed on the SRV02 to create an interesting and thought provoking control challenge.

## 1.1 Modular Options

Quanser values itself for the modularity of its experiments. The SRV02 rotary plant module serves as the base component for the rotary family of experiments. This modular philosophy facilitates the change from one experimental setup to another with relative ease of work and a valuable savings in cost. The following table lists the experiments currently available in the rotary family of products utilizing the SRV02 as the base.

| *Module Name* | *Description* |
|---|---|
| Ball & Beam | The Ball & Beam experiment requires the user to manipulate the position of a rolling ball on a beam. |
| Flexible Link | The Flexible Link experiment requires the user to command a *tip* position of the flexible link attached to the SRV02. |
| Flexible Joint | A rigid beam is mounted on a flexible joint that rotates via the SRV02 and the user is to command the tip position of this beam. |
| Gyro/Stable Platform | The purpose is to maintain the line of sight of an instrument mounted on a rotating platform (SRV02). |
| Inverted Pendulum | The purpose is to balance the inverted pendulum through a rotary motion arm (SRV02). |
| Double Inverted Pendulum | The double inverted problem adds to the complexity of the single pendulum by introducing a $2^{nd}$ pendulum. |
| 2 DOF robot module | This experiment requires the x-y positioning of the “end effector”. |
| 2 DOF Rotary Gantry | This experiment requires the control of the swing of a x-y gantry crane using a 5 DOF linkage. |
| 2 DOF inverted pendulum | Balance a pendulum that is free to fall in 2 directions. The pendulum is attached to the tip of the 2 DOF robot. |

*Table 1 - Rotary Family Modules*

## 2. System Nomenclature and Components

Figure 1 & Figure 3 below depict the Ball & Beam module. The standard BB01 is equipped with a strain gage sensor resulting in an analog signal proportional to the location of the steel ball along the beam. Refer to the following table to associate the *components* with their corresponding photographs.

| | | | |
|---|---|---|---|
| **1** | SRV02 Base | **5** | Support Arm |
| **2** | Steel Ball | **6** | Coupling Screw |
| **3** | Beam (Sensor) | **7** | Lever Arm |
| **4** | Support Base | **8** | Calibrated Base |

*Table 2 - Component Names*

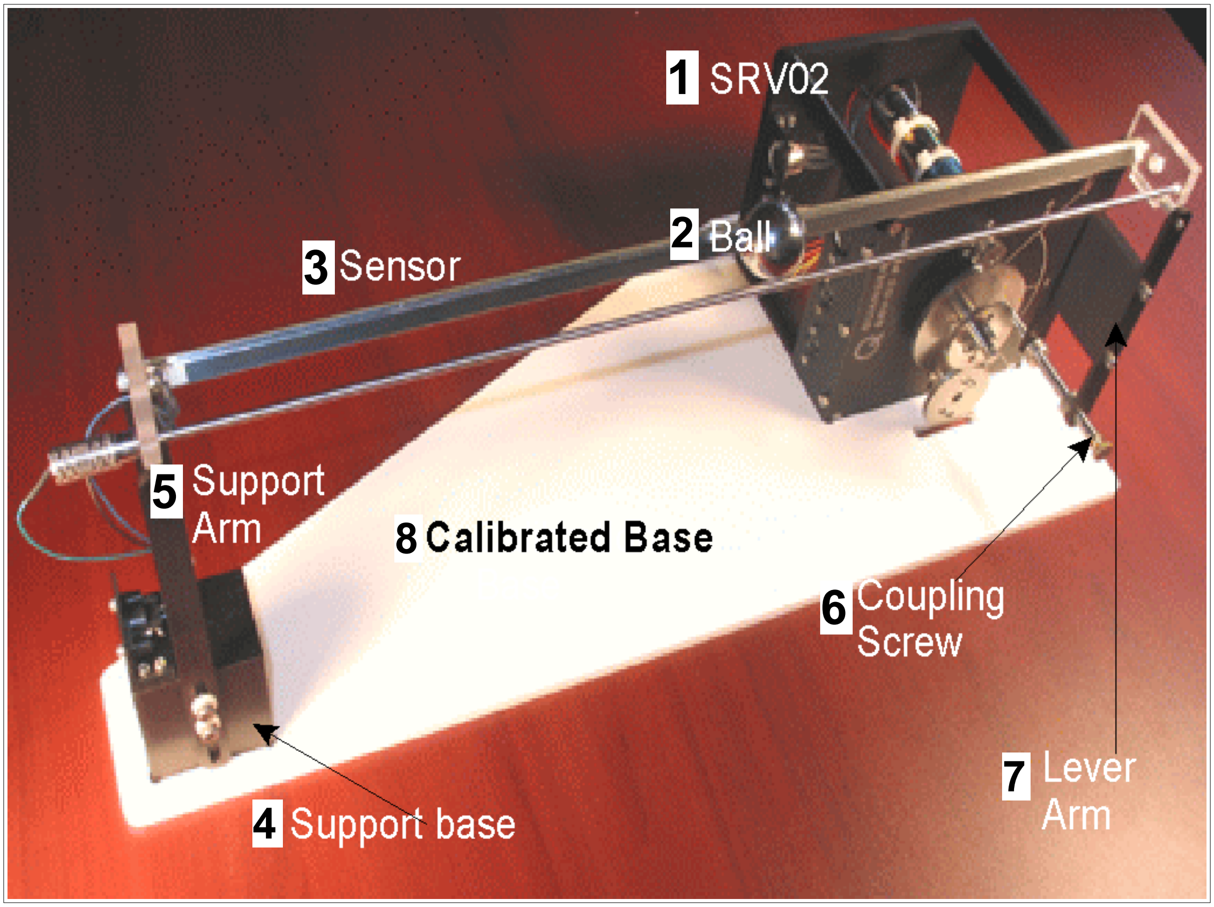



*Figure 1 - Ball & Beam module coupled to the SRV02*

## 3. System Setup and Assembly

The ball & beam module requires minimal assembly. Figure 2 Below shows the components of the BB01 package you should have received. The BB01 package should include all the components listed in Table 2 above.

*Figure 2 - Contents of BB01 package*

Please follow the following assembly instructions required when you receive the ball & beam module:

- Lay the Calibrated Base *(Component 8)* flat on the table.
- Place the SRV02 on its side in the cut out section of the base.
- Attach the coupling screw *(Component 6)* to the SRV02 load gear.

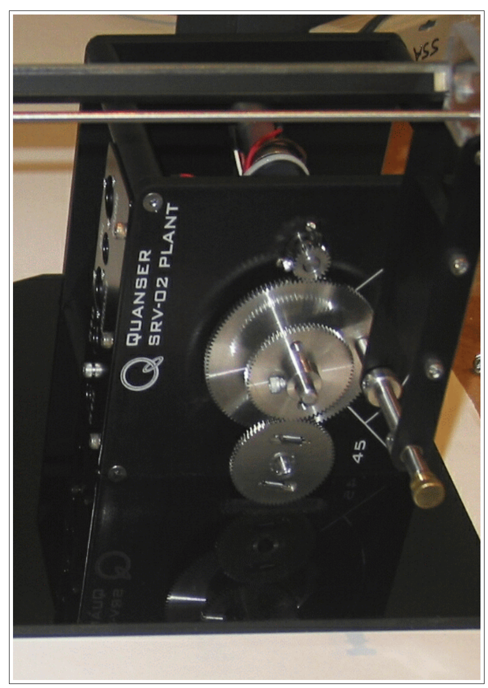



*Figure 3 - Attach the Coupling Screw to the SRV02*

- Place the Support base *(Component 4)* into the pre-cut position on the calibrated base.
- Loosen the screws of the support arm *(Component 5).*
- Place the ball on the beam.
- While holding the servo load gear at the 0° position (coupling screw should be aligned with the 0° position) move the support arm such that the beam is horizontal (the ball should not be moving when the beam is horizontal).
- Tighten the screws on the support arm in the balanced position to finalize the calibration of your ball and beam experiment.

*Figure 4 - Adjust the screws for the support arm.*

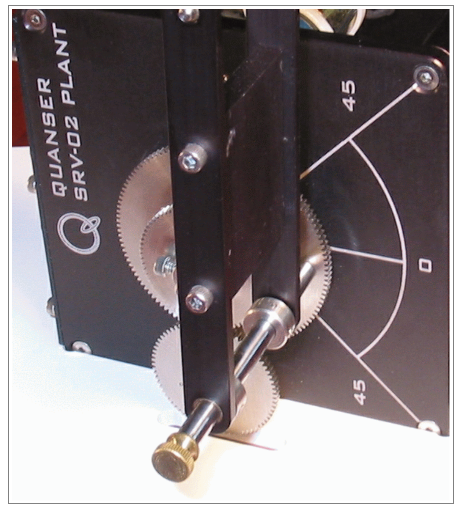



*Figure 5 - Hold the coupling screw in the 0° position.*

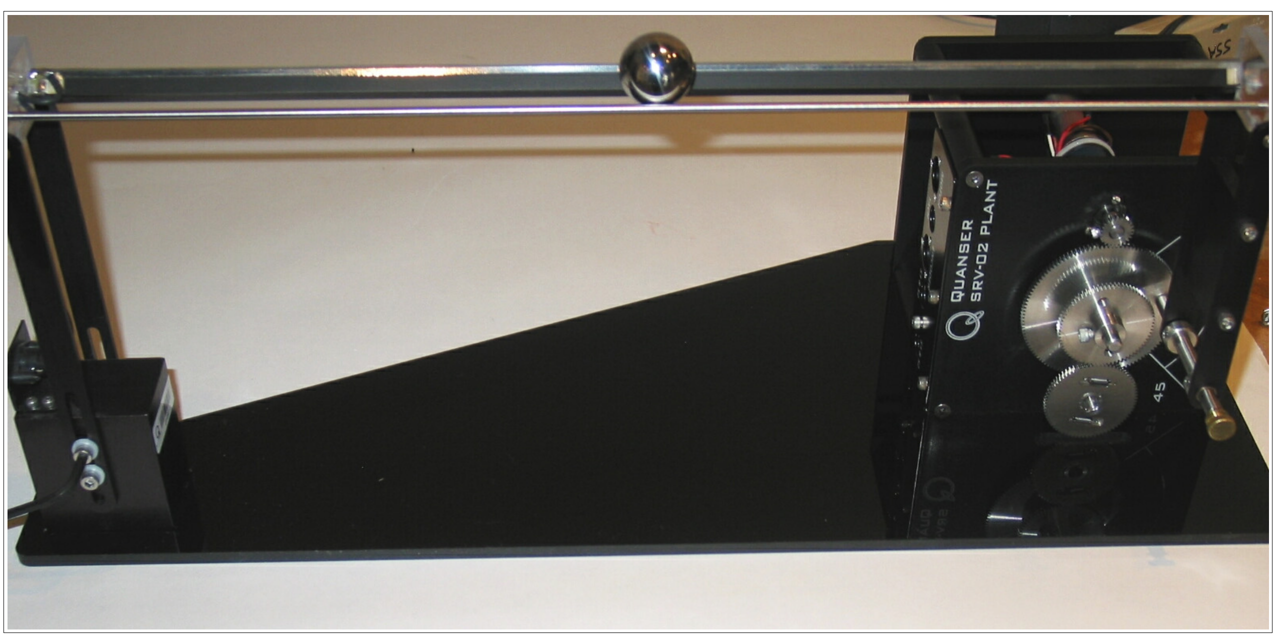



*Figure 6 - Tighten the screws when the ball stops moving.*

## 3.1 Typical Connections for the SRV02 – BB01 Experiment

The following table describes the typical setup using the complete Quanser solution. It is assumed that the BB01 is being used along with an SRV02, UPM and Q8 DAQ board.

| ***From...*** | ***To...*** | ***Cable*** | ***Description*** |
|---|---|---|---|
| Beam Sensor (*Component 3*) | *S1 & S2* Connector on *UPM.* | 6-pin mini DIN to 6-pin mini DIN. | This cable results in delivering a ±12V bias to the sensor and measuring the beam angle signal voltage on *S2* of the UPM. |
| SS01 *'Master'* Sensor<br>**This is the optional module to configure in 'Master – Slave' mode.* | *S3* Connector on *UPM.* | 6-pin mini DIN to 6-pin mini DIN. | This cable results in delivering a ±12V bias to the sensor and measuring the beam angle signal voltage on *S3* of the UPM. |
| SRV02 Encoder<br>**This is the load gear position measurement* | *Encoder 0* connector on the terminal board. | 5-pin Stereo DIN to 5-pin Stereo DIN. | The terminal board should supply the encoder with the +5V and ground. The load shaft position signal will then be measure on Encoder channel 0. |
| *'To Load'* Connector on *UPM.* | *Motor* on SRV02. | 6-pin DIN to 4-pin DIN. | This connects the output of the amplifier to the motor. You can use a variety of cables resulting in a different gain from input to output. The cables available are Gain=1, Gain=3, Gain=5. |
| Analog Signals (*To A/D)* | Analog input channels 0-3 on the DAQ. | 5-pin DIN to 4x RCA. | From the *UPM,* connect all the analog sensor signals to the terminal board such that *S1* is measured on analog input 0. *S2* - AI # 1, *S3* - AI # 2, *S4* - AI # 3. |
| Analog output channel 0 on the DAQ. | *UPM* input (*From D/A)* | RCA to 5-pin DIN. | This is the command output from the DAQ that will be amplified and drive the motor. |

*Table 3 - Typical Connections*

## 3.2 Testing the Ball & Beam Module

The ball position is measured using a conductive plastic element mounted on the beam. Before the module is shipped, the unit would have been fully calibrated to the correct specifications. The following section will describe a test routine in order to ensure the unit maintains its correct operation.

This section describes functional tests to determine if your BB01 & SS01 sensors are operating normally. It does **not** cover any performance tests. All these tests require an understanding of Simulink (or Labview), WinCon (or equivalent), and Q8 (or equivalent data acquisition board you are using). You should be able to *"build"* a controller that can measure and apply desired signals.

In the following sections, it is also assumed that the BB01 is connected as described in the *Typical Connections* table above.

Build a controller that will measure analog inputs #1 and #2. If you do not have the optional SS01 module (remote sensor), you only need to read analog input #1. Once you are reading the 2 channels, move the ball along the beam(s) and check that your measurements are also measuring between +5V to -5V from one end of the beam to the other. As you move the ball along the beam, ensure that the measurement(s) appear to be uniform and continuous.

We would also strongly suggest a regular cleaning of the beam to ensure proper operation of the ball & beam module. A cleaning would consist of apply some rubbing alcohol and wiping along the beam. The ball should also be cleaned with rubbing alcohol at the same time.

For technical support referring to any of the BB01 components, please visit us on the web at: www.Quanser.com.

Under our *Technical Support* section, please fill out a *technical support form* indicating your problem in detail and one of our engineers will be happy to respond to your request.

## 4. Ball & Beam Module – Range of Experiments & Features

The Ball and Beam experiment is an excellent experiment to extend the student's knowledge of the SRV02 system. It is a great introduction to linear systems and cascade controllers.

### BB01 Key Features:

- Modular design
- High quality precision crafted parts
- Robust machined aluminum casing with stainless steel rod
- Fully documented system models & parameters
- Fast and Easy attachment to the SRV02 plant
- Open architecture design
- Fully compatible with Matlab/Simulink
- Optional *Master/Slave* Configuration

### Curriculum Topics:

- Position Control
- Disturbance Rejection
- Tracking Control & Regulation
- PID Controller Design
- Multiple Control Loops
- Lead / Lag Compensation
- State-Feedback
- System Modeling & Simulation
- Root Locus Design
- Nyquist Stability
- Hardware in the Loop
- 2 Bar Linkage Model
- Real-Time Control
- Discrete Time Sampling
- System Identification
- Multivariable Control Design

# 6. System Requirements & Specifications

The Ball & Beam Module (BB01) is designed as an attachment to the SRV02 plant. Along with the SRV02 plant, the following components are required to complete the experimental setup.

| *Component* | *Quanser Recommended (Common Configuration)* | *Alternative* |
|---|---|---|
| Power Module | Quanser UPM 1503/2405 | Other Power Supply that can deliver the required power. |
| Data Acquisition | Quanser Q8 | dSPACE DS 1104 National Instruments E-Series DAQs<br>Any other DAQ with at least one A/D, one D/A and one Encoder input. |
| Control Software | Quanser WinCon / SLX / WebLab | The Mathworks – RTWT, xPC<br>dSPACE – ControlDesk<br>National Instruments – Labview RT |

*Table 4 - System Requirements*

## 6.1 System Specifications

| *Specification* | *Value* | *Units* |
|---|---|---|
| Calibrated Base Dimensions | 50 x 22.5 | $cm^2$ |
| Beam Length | 42.5 | cm |
| Lever Arm Length | 12 | cm |
| Support Arm Length | 16 | cm |
| Ball Diameter | 2.54 | cm |
| Beam Sensor Bias Power | ±12 | Volts |
| Beam Sensor Measurement Range | ±5 | Volts |
| SS-01 Sensor Bias Power | ±12 | Volts |
| SS-01 Measurement Range | ±5 | Volts |
| Ball & Beam Module mass | 0.65 | kg |
| Ball mass | 0.064 | kg |

*Table 5 - BB01 Specifications*