QUANSER
INNOVATE·EDUCATE

THE ROTARY CONTROL LAB

A Modular Single Source Solution You Can Control

WWW.QUANSER.COM

THE MODULAR ROTARY CONTROL LAB
FROM QUANSER

ROTARY SERVO BASE UNIT
SRV02

As a provider of engineering controls education, you may face several challenges. They could include attracting the best students, ensuring students graduate with industry-ready skills, meeting the curriculum's goals while still finding enough time for research, and last but not least, sourcing reliable lab equipment and educational tools while staying within budget. Quanser's Rotary Control Lab helps overcome many of your challenges.

Convenient Turn-Key Solution.
You get "ready to go, right out of the box" efficiency. All components, software-neutral peripherals and teaching experiments are included.

Timesaving Course Materials.
The instructor and student course materials offer proven, ABET-aligned practical exercises - a Quanser exclusive. Your students will easily turn theory into practice.

Budget-Friendly Modular Design.
Our integrated, add-on modules and peripherals work together seamlessly. The open architecture, "building blocks" approach provides you with greater teaching and research flexibility, while allowing students to quickly reach their learning goals.

Robust Quality and Precision.
Quanser systems are durable enough to accommodate enthusiastic undergraduates. The systems' inherent precision help deliver accurate, repeatable results.

Efficient, Ongoing Tech Support.
Whether your lab requires months or years to complete, you can rely on ongoing support. In addition, there will be little or no downtime since the same engineers who designed and built this system also service it.

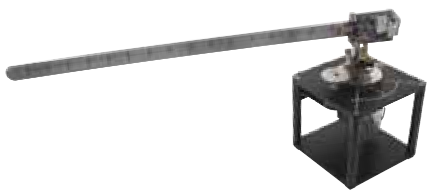
The Right Partner.
As academic specialists, we are uniquely placed to help meet the challenges facing engineering faculties today.

10 ADD-ON MODULES TO CHOOSE FROM

You can select from 10 add-on modules for the Rotary Servo Base Unit to create experiments of varying complexity across a wide range of topics, disciplines and courses. These workstations are an ideal choice for introductory, intermediate and advanced studies. Comprehensive courseware is included to save you time. Most of the workstations are compatible with LabVIEW™ and MATLAB®/Simulink®.

+ ADD-ON MODULES FOR THE SRV02 ROTARY SERVO BASE UNIT

Ball and Beam
See pages 7, 8



Rotary Flexible Link
See pages 9, 10

Rotary Flexible Joint
See pages 11, 12

Rotary Inverted Pendulum
See pages 13, 14

Rotary Double Inverted Pendulum
See pages 15, 16

Gyro/Stable Platform
See pages 17, 18

2 DOF Robot
See pages 19, 20

2 DOF Inverted Pendulum
See pages 21, 22

Multi-DOF Torsion
See pages 23, 24

2 DOF Ball Balancer
See pages 25, 26

"Quanser excels in developing research and educational systems that illuminate control concepts, advance learning and more importantly facilitate greater understanding and insight into control issues."

Dr. Dennis Bernstein,
Professor, Department of Aerospace Engineering,
University of Michigan, USA

Pictured above: Quanser VoltPAQ-X1 amplifier, Quanser rotary servo (SRV02) base unit, Quanser Q2-USB

A SINGLE SOURCE SOLUTION
YOU CAN CONTROL

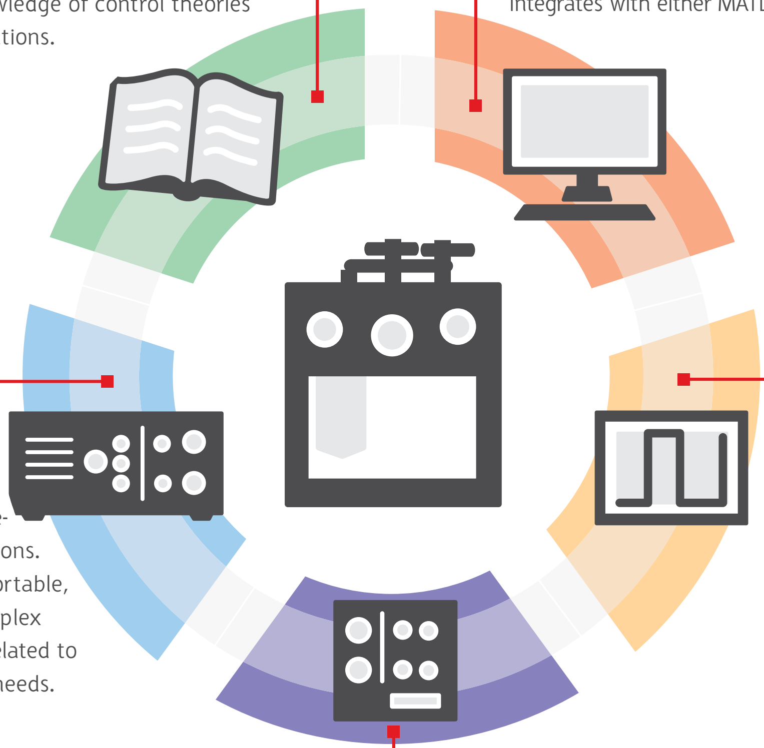
Quanser single source, turn key systems for engineering labs come complete with all components and peripherals you will need, including an amplifier, data acquisition device, control design software, pre-designed controllers, dynamic model and courseware materials. This gives you a versatile, robust and flexible workstation optimized for maximum efficiency and your teaching and research needs.

COMPREHENSIVE COURSEWARE MATERIALS

Get started quickly with the resources included with the experiments. The step-by-step workbooks cover a range of control challenges. Students can establish basic and advanced knowledge of control theories through practical applications.

CONTROL DESIGN SOFTWARE

Quanser's control design software makes developing and running real-time control models straightforward, eliminating any need for hand-coding. It seamlessly integrates with either MATLAB®/Simulink® or NI LabVIEW™.



AMPLIFIERS

VoltPAQ amplifiers deliver reliable, real-time performance for hardware-in-the-loop implementations. Small, lightweight and portable, they are ideal for all complex controls configurations related to educational or research needs.

PRE-DESIGNED CONTROLLERS AND DYNAMIC SYSTEM MODELS

The experiments come with pre-designed controllers, based on either Quanser QUARC® for MATLAB®/Simulink® or Quanser RCP Toolkit for NI LabVIEW™*.

DATA ACQUISITION AND CONTROL

Quanser's groundbreaking USB data acquisition technology delivers reliable, real-time performance via a USB interface. For easy and quick access to signals, the Q2-USB and Q8-USB devices combine Quanser DAQ technology with our standard connector interfaces. Easy connectivity, low I/O conversion time and up to 2 kHz close-loop control rate, make these devices ideal for teaching control concepts as and control systems research. Quanser rotary experiments can also be configured with NI myRIO or CompactRIO with Quanser Q1-cRIO module(s). For details contact Quanser@NI.com

ROTARY SERVO BASE UNIT (SRV02)

The Rotary Servo Base Unit (SRV02) is the fundamental element of the Quanser Rotary Control experiments. It is ideally suited to introduce basic control concepts and theories on an easy-to-use and intuitive platform.

Use it on its own to perform several experiments, or expand the scope of this unit by adding on other modules to teach an even wider range of control concepts. Instructors can thus expose students to a variety of rotary control challenges for a minimal investment. Real-world applications of the rotary servomotor include the autofocus feature in modern cameras, cruise control in automobiles, and speed control in CD players.

Courseware for the Rotary Servo Base Unit covers three main labs: Modelling, Position Control, and Speed Control. For each of these topics, the workbooks guide students through rigorous background derivations, provide some pre-lab questions and take the students through the in-lab exercises with the hardware. Students will compare their theoretically modelled results to those of the real device. This marriage of theoretical and practical controls will give your students an understanding of the controls concepts you are teaching that is not possible with standard approaches.

HOW IT WORKS

The Rotary Servo Base Unit is a geared servo-mechanism system. The plant consists of a DC motor in a solid alum frame. This DC motor drives the smaller pinion gear thrc an internal gear box. The pinion gear is fixed to a larger m gear that rotates on the load shaft. The position of the lc shaft can be measured using a high resolution optical encc

The Rotary Servo Base Unit is also equipped with an optical encoder and a potentiometer to measure the output shaft position, and a tachometer to measure the speed of the motor.

The Rotary Servo Base Unit experiment acquaints students with the concept of rotary displacement control, which is integral to such high-precision applications as a CD-ROM drive.

WORKSTATION COMPONENTS ROTARY SERVO BASE UNIT

Component	Description
Plant	• Servo Base Unit (SRV02)
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• ABET-aligned* instructor workbook** • ABET-aligned* student workbook** • User Manual** • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW™? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS ROTARY SERVO BASE UNIT

CURRICULUM TOPICS PROVIDED

Modeling Topics
- First-principles derivation
- Experimental derivation
- Transfer function representation
- Frequency response representation
- Model validation

Control Topics
- PID
- Lead Compensator

FEATURES

- Ten add-on modules are easily interchangeable
- High quality DC motor and gearbox
- High resolution optical encoders to sense position
- Continuous turn potentiometer to sense position
- Tachometer to sense motor speed
- Robust machined aluminum casing with stainless steel gears
- Variable loads and gear ratios
- Optional slip ring for continuous measurement from instrumented modules
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Plant Dimensions (L x W x H)	15 x 15 x 18	cm
Plant Weight	1.2	kg
Nominal Voltage	6	V
Motor Maximum Continuous Current (recommended)	1	A
Motor Maximum Speed (recommended)	6000	RPM
Potentiometer Bias Power	±12	V
Potentiometer Measurement Range	±5	V
Tachometer Bias Power	±12	V
Tachometer Measurement Range	±5	V
Tachometer Sensitivity	0.0015	V/RPM
Encoder Resolution	4096	counts/rev.
Gear Ratio (high gear configuration)	70	n/a

* ABET, Inc., is the recognized accreditor for college and university programs in applied science, computing, engineering, and technology
** Hard copies are not included. Documentation is supplied in electronic format on a CD
1 MATLAB®/Simulink®, LabVIEW™ and Microsoft Windows® license needs to be purchased separately
2 Quanser QPIDe (PCIe-based data acquisition devices) is recommended when a deterministic real-time performance is required

BALL AND BEAM WORKSTATION

The Rotary Ball and Beam module is ideal to introduce various control concepts related to unstable closed loop systems. Students will learn how to break down a problem and design a cascade control to stabilize the ball.

When mounted on the Rotary Servo Base Unit, this experiment effectively demonstrates a real-life application of PD control and how it relates to stabilizing a ball on a track. It's useful in teaching basic control principles related to real-life challenges such as aircraft roll control.

HOW IT WORKS

The Ball and 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 track is effectively a potentiometer, outputting a voltage that's proportional to the position of the ball.

When coupled to the Rotary Servo Base Unit, the tilt angle of the beam can be controlled by changing the servo gear angle. The Ball and Beam module can be operated in stand-alone mode, and the ball position can be controlled via the user interface. The Ball and Beam module can also be paired with an additional Remote Sensor module, in which case the system operates in a Master/Slave mode where the ball on the beam will follow the reference ball position of the second Ball and Beam module.

"Thanks to the open-architecture design of Quanser equipment, we've customized experiments, and added new ones. Quanser's open architecture is a great plus for us."

Dr. Stephen Williams,

Associate Professor, Electrical Engineering and Computer Science Department, Milwaukee School of Engineering, USA

Aircraft roll control is a key real-world application of the Ball and Beam experiment.

WORKSTATION COMPONENTS BALL AND BEAM EXPERIMENT

Component	Description
Plant	• Servo Base Unit (SRV02) • Ball and Beam module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• ABET-aligned* instructor workbook** • ABET-aligned* student workbook** • User Manual** • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS BALL AND BEAM MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
- First-principles derivation
- Transfer function representation
- Linearization
- Model validation

Control Topics
- Multiple loops
- PID

FEATURES

- Optional Master/Slave Configuration with additional Ball and Beam module
- High quality aluminum chassis with precision-crafted parts
- High quality precision-crafted parts
- Robust machined aluminum casing with stainless steel rod
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Calibrated Base Dimensions (L x W)	50 x 22.5	cm
Beam Length	42.5	cm
Lever Arm Length	12	cm
Support Arm Length	16	cm
Beam Sensor Measurement Range	±5	V
Ball Position Sensor Bias Power	±12	V
Ball Position Measurement Range	±5	V
Ball and Beam Module Mass	0.65	kg
Ball Mass	0.064	kg

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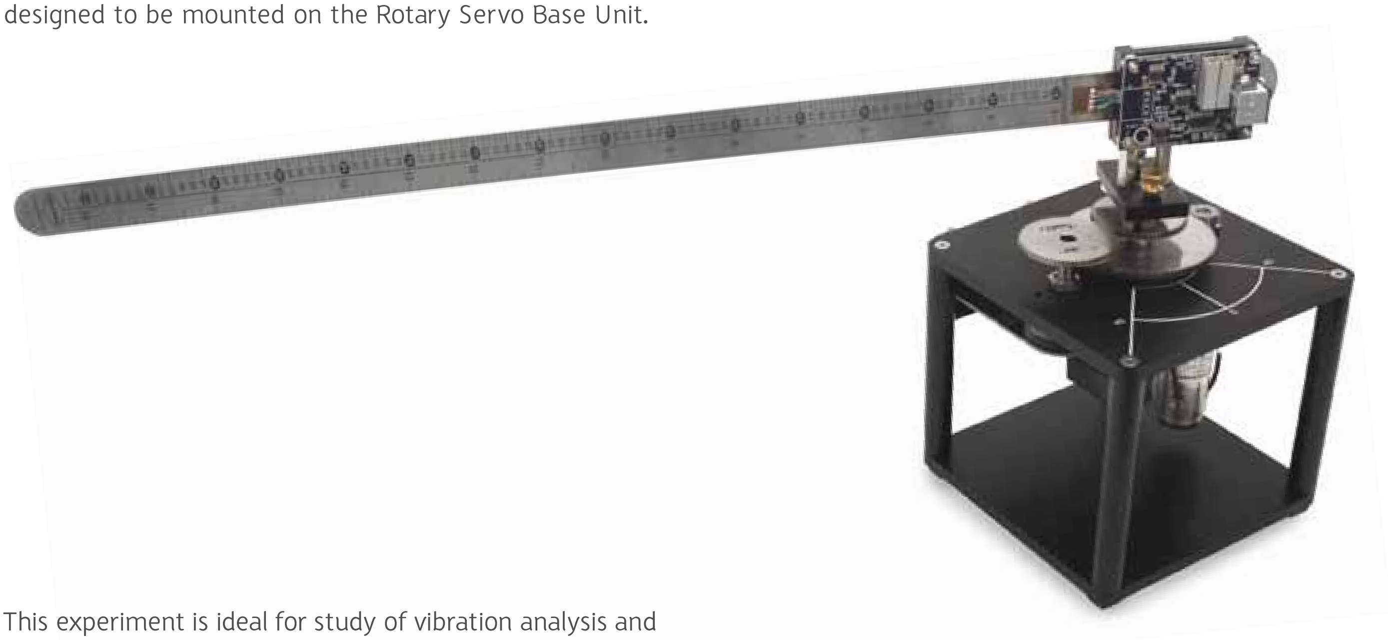
ROTARY FLEXIBLE LINK WORKSTATION

The Rotary Flexible Link module is designed to help students perform flexible link control experiments. The module is designed to be mounted on the Rotary Servo Base Unit.



This experiment is ideal for study of vibration analysis and resonance and allows to mimic real-life control problems encounteredin large, lightweight structures that exhibit flexibilities and require feedback control for improved performance. The experiment is also useful when modelling a flexible link on a robot or spacecraft.

"Quanser's turn-key solution allowd us to get started very quickly. And now I want to add on different modules."

Dr. Kelly Cohen,
Associate Professor, Aerospace Engineering and Engineering Mechanics,
University of Cincinnati, USA

HOW IT WORKS

The Rotary Flexible Link consists of a strain gage which is held at the clamped end of a thin stainless steel flexible link. The DC motor on the Rotary Servo Base Unit is used to rotate the flexible link from one end in the horizontal plane.

The motor end of the link is instrumented with a strain gage that can detect the deflection of the tip. The strain gage outputs an analog signal proportional to the deflection of the link.

In this experiment, students learn to find the stiffness experimentally, and use Lagrange to develop the system model. This is then used to develop a feedback control using a linear-quadratic regulator, where the tip of a beam tracks a desired command while minimizing link deflection.

The Rotary Flexible Link experiment will introduce students to such real world challenges as the flexibility in the Canadarm Shuttle Remote Manipulator System.

www.quanser.com/products/rotary_flexible_link

THE PLANTS PICTURED HERE ARE NOT TO SCALE. FOR DIMENSIONS AND SYSTEM SPECIFICATIONS, EMAIL INFO@QUANSER.COM

WORKSTATION COMPONENTS ROTARY FLEXIBLE LINK EXPERIMENT

Component	Description
Plant	• Servo Base Unit (SRV02) • Rotay Flexible Link module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• ABET-aligned* instructor workbook** • ABET-aligned* student workbook** • User Manual** • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW™? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS ROTARY FLEXIBLE LINK MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
- Lagrange derivation
- State-space representation
- Model validation
- Parameter estimation

Control Topics
- Linear-quadratic regulator
- Vibration control

FEATURES

- High quality aluminum chassis with precision-crafted parts
- High resolution strain gage to sense link deflection
- Rotay Flexible Link module easily attaches to the Rotary Servo Base Unit
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Module Dimensions (L x H)	48 x 2	cm
Main Arm Length (straingage to tip)	41.9	cm
Strain Gage Bias Power	±12	V
Strain Gage Measurement Range	±5	V
Strain Gage Calibration Gain	2.54	cm/V
Flexible Link Mass	0.065	kg
Flexible Link Rigid Body Inertia	0.0038	kg.m²

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ROTARY FLEXIBLE JOINT WORKSTATION

The Rotary Flexible Joint module is ideal for modeling a flexible joint on a robot when mounted on the Rotary Servo Base Unit. It is also useful in the study of vibration analysis and resonance.

"Hands-on experiments seem to be particularly effective for teaching basic concepts in dynamics and control. The experiments show the students how theory and real world are interconnected."

Dr. Shirley Dyke,

Professor of Mechanical Engineering and Civil Engineering, School of Civil Engineering
Purdue University, West Lafayette, Indiana, USA

This experiment uses a sensor to measure joint deflection, to address the control problems encountered in large, geared robot joints where flexibility is exhibited in the gearbox.

Students will learn how to model the system using state-space and design a feedback controller with pole-placement.

HOW IT WORKS

The Rotary Flexible Joint module consists of a free arm attached to two identical springs. The springs are mounted to an aluminum chassis which is fastened to the Rotary Servo Base Unit load gear. The module attaches to a DC motor on the Servo Base Unit that rotates a beam mounted on a flexible joint.

The Rotary Flexible Joint module is supplied with three distinct pairs of springs, each with varying stiffness. It comes with three base and three arm anchors for the springs, and allows to obtain a wide variety of joint stiffness. The module is also supplied with a variable arm load that can be mounted at three distinct anchor positions to change the length of the load.

With the Rotary Flexible Joint experiment, students will learn to solve real-world control problems encountered in large-geared robot joints found in some industrial robotic equipment.

WORKSTATION COMPONENTS ROTARY FLEXIBLE JOINT EXPERIMENT

Component	Description
Plant	• Servo Base Unit (SRV02) • Rotay Flexible Joint module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• ABET-aligned* instructor workbook** • ABET-aligned* student workbook** • User Manual** • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS ROTARY FLEXIBLE JOINT MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
- Lagrange derivation
- State-space representation
- Model validation
- Parameter estimation

Control Topics
- Pole placement
- Vibration control

FEATURES

- High quality aluminum chassis with precision-crafted parts
- High resolution encoder to sense arm position
- Variable load length and spring anchors to change system parameters
- Variable spring stiffness
- Rotary Flexible Joint module easily attaches to Rotary Servo Base Unit
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Module Dimensions (L x W x H)	10 x 8 x 5	cm
Main Arm Length	30	cm
Load Arm Length	15.6	cm
Module Body Mass	0.3	kg
Main Arm Mass	0.064	kg
Load Arm Mass	0.03	kg
Encoder Resolution	4096	counts/rev.
Spring # 1 Stiffness	187	N/m
Spring # 2 Stiffness	313	N/m
Spring # 3 Stiffness	565	N/m

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ROTARY INVERTED PENDULUM WORKSTATION

The Rotary Inverted Pendulum module offers the student a hands-on opportunity to grasp the classic pendulum problem by learning to balance a vertical rod by rotating or changing the angle at the base.

The Inverted Pendulum module attaches to the Rotary Servo Base unit. This experimental set up exposes students to two different control challenges: Inverted Pendulum (i.e., the Furuta Pendulum) and Self-erecting Inverted Pendulum.

Students will use this module to learn practical problem-solving skills for mechanical and aerospace engineering while designing controllers that balance a vertical rod in the upright position by rotating or changing the angle at the base (Inverted Pendulum), and swing the pendulum up and maintain it in the upright position. A classic application is the two-wheeled Segway self-balancing electric vehicle. A widely used teaching tool, the Inverted Pendulum experiment is extremely versatile and offers you an excellent opportunity to stretch your budget.

HOW IT WORKS

The Rotary Inverted Pendulum consists of a flat arm with a pivot at one end and a metal shaft on the other end. The pivot-end is mounted on top of the Rotary Servo Base Unit load gear shaft. The pendulum link is fastened onto the metal shaft and the shaft is instrumented with a high resolution encoder to measure its angle. The result is a horizontally rotating arm with a pendulum at the end.

The dynamics of the Segway self-balancing electric vehicle are similar to the classic control problem of the inverted pendulum.

"We decided to go with Quanser because Quanser equipment was modular and flexible. You can add different modules to each SRV02 Base Unit and create new experiments out of it."

Dr. Keyvan Hashtrudi-Zaad,
Associate Professor, Department of Electrical and Computer Engineering,
Queen's University, Canada

WORKSTATION COMPONENTS ROTARY INVERTED PENDULUM EXPERIMENT

Component	Description
Plant	• Servo Base Unit (SRV02) • Rotary Inverted Pendulum module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• ABET-aligned* instructor workbook** • ABET-aligned* student workbook** • User Manual** • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW™? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS ROTARY INVERTED PENDULUM MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
- State-space representation
- Linearization

Control Topics
- Hybrid control
- Pole placement
- Energy-based/non-linear control

FEATURES

- High quality aluminum chassis with precision-crafted parts
- High resolution encoders to sense rod and shaft angles
- Rotary Inverted Pendulum module easily attaches to the Rotary Servo Base Unit
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Coupled Arm Length	21.6	cm
Coupled Arm Mass	0.257	kg
Pendulum Link Length	33.7	cm
Pendulum Link Mass	0.127	kg
Encoder Resolution	4096	count/rev.

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ROTARY DOUBLE INVERTED PENDULUM WORKSTATION

The Rotary Double Inverted Pendulum module is ideal to introduce intermediate and advanced control concepts, taking the classic single inverted pendulum challenge to the next level of complexity. Students will learn to balance two vertical rods by manipulating the angle of the base.

The Rotary Double Inverted Pendulum module attaches to the Rotary Servo Base Unit. You can use this setup to demostrate real-world control challenges related, for example, to takeoff stabilization of a multi-stage rocket, or modeling the human posture system.

HOW IT WORKS

The Rotary Double Inverted Pendulum is composed of a rotary arm that attaches to the Rotary Servo Base Unit, a short 7-inch bottom blue rod, an encoder hinge, and the top 12-inch blue rod. The balance control computes a voltage based on the angle measurements from the encoders. This control voltage signal is amplified and applied to the servomotor. The rotary arm moves accordingly to balance the two links and the process repeats itself.

The Rotary Double Inverted Pendulum experiment is similar to control of the human posture system.

"The robust, modular design of Quanser's rotary control experiments offers a very good solution to the challenge of balancing costs and having a system that can endure heavy student usage."

Dr. Tong Guofeng,

Associate Professor, Institute of Artificial Intelligence and Robotics, Northeastern University, China

www.quanser.com/products/rotary_double_pendulum

WORKSTATION COMPONENTS ROTARY DOUBLE INVERTED PENDULUM EXPERIMENT

Component	Description
Plant	• Servo Base Unit (SRV02) • Rotay Double Inverted Pendulum module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• Laboratory Guide* • User Manual* • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q8-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW™? This experiment can also be configured with NI CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS ROTARY DOUBLE INVERTED PENDULUM MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
- First-principles derivation
- Experimental derivation
- Transfer function representation
- Frequency response representation
- Model validation

Control Topics
- PID
- Lead Compensator

FEATURES

- High resolution encoders sense rotary arm and pendulum link angles
- Double pendulum is comprised of a 7-inch aluminum link connected to a 12-inch link
- Rotary Double Inverted Pendulum module easily attaches to the Rotary Servo Base Unit
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Rotary Arm: Length from Pivot to Tip	21.59	cm
Rotary Arm: Mass	0.2570	kg
Short Pendulum: Mass (w/T-fitting)	0.097	kg
Short Pendulum: Length from Pivot to Tip	20.0	cm
Medium Pendulum: Mass (w/T-fitting)	0.127	kg
Medium Pendulum: Length from Pivot to Tip	33.65	cm
Mass of Encoder Hinge located between the Lower and Upper Pendulum	0.1410	kg

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GYRO/STABLE PLATFORM WORKSTATION

A gyroscope is used for measuring or maintaining orientation (providing stability or maintaining a reference direction), based on principles of conservation of angular momentum.

The Gyro/Stable Platform module provides an excellent opportunity to study gyroscopic properties along with control experiments that resemble real-life applications of the gyro. It represents an ideal way to teach rotational dynamics principles.

Using the Gyro/Stable Platform, you can prepare students for control navigation challenges such as those encountered in instruments mounted on ships. Students will also learn concepts for real-world satellite navigation as they design a feedback controller that measures the gyro deflection and maintains the line of sight of the gyro frame.

HOW IT WORKS

The Gyro/Stable Platform module attches to the Rotary Servo Base Unit. The gyroscope module itself consists of a rotating disk mounted inside a frame. It is actuated about its center through a DC motor. An internal 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 measures the angle of the blue frame as it rotates about the shafts, i.e., it measures the disc tilt angle.

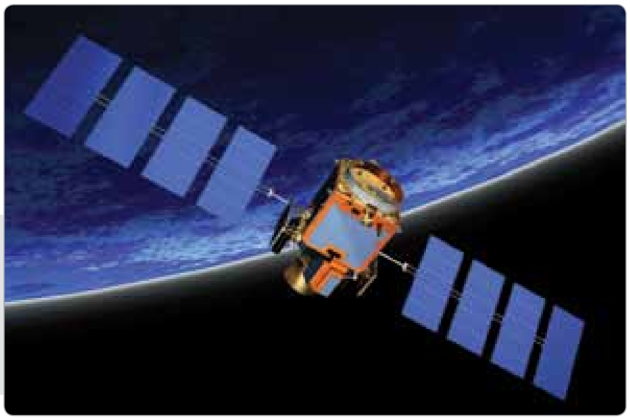
The Rotary Servo Base Unit is mounted on a 2-plate structure. The plates are mounted on top of each other and are free to rotate. This allows the gyroscope structure to be manually rotated relative to a fixed surface in order to simulate external disturbance to the gyroscope system.

When the gyroscope controller is running, the Rotary Servo Base Unit keeps its heading as you rotate the bottom plate – without any direct position measurement of the base plate.

"The robustness and solid construction of the Quanser products has been excellent, with experiments still functioning perfectly after eight years without problems."

Dr. Victor Becerra,

Lecturer, School of Systems Engineering, University of Reading, United Kingdom



Space satellite orientation is one of many real-world control challenges your students can experience with the Gyro/Stable Platform workstation.

www.quanser.com/products/rotary_gyroscope

THE PLANTS PICTURED HERE ARE NOT TO SCALE. FOR DIMENSIONS AND SYSTEM SPECIFICATIONS, EMAIL INFO@QUANSER.COM

WORKSTATION COMPONENTS GYRO/STABLE PLATFORM EXPERIMENT

Component	Description
Plant	• Servo Base Unit (SRV02) • Gyro/Stable Platform module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• Instructor workbook* • Student workbook* • User Manual* • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS GYRO/STABLE PLATFORM MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
- First-principles derivation
- Transfer function representation

Control Topics
- Observer design
- PID

FEATURES

- Large inertial disc is actuated by a DC motor
- High resolution encoder measures the disc tilt angle
- SRV02 mounts on a rotatable two-plate structure to simulate disturbance
- Gyro/Stable Platform module easily attaches to the Rotary Servo Base Unit
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Motor Torque Constant	0.02	N.m/A
Motor Armature resistance	5.3	Ω
Armature Inductance	0.580	mH
Motor Nominal Voltage	12	V
Motor Armature Inertia	1.4×10^{-6}	$kg.m^2$
Motor Nominal Current	0.23	A
Flywheel Radius	0.0508	m
Flywheel Mass	0.8	kg
Flywheel Inertia about Spin Axis	1.0323	$kg.m^2$
Gyro Module Inertia about Input Axis	0.002	$kg.m^2$
Spring Stiffness	1.909	N/m
Gear Mechanism Ratio	¼	
Encoder Resolution (in quadrature mode)	4096	counts/rev.
	0.0879	deg/count

* Hard copies are not included. Documentation is supplied in electronic format on a CD
[1] MATLAB®/Simulink®, LabVIEW™ and Microsoft Windows® license needs to be purchased separately
[2] Quanser QPIDe (PCIe-based data acquisition devices) is recommended when a deterministic real-time performance is required

2 DOF ROBOT WORKSTATION

The Two Degrees of Freedom (2 DOF) Robot module helps students learn the fundamentals of robotics. When mounted on two Rotary Servo Base Units, you obtain a four-bar linkage robot. Students can learn real-world robotic concepts such forward and inverse kinematics, and end effector planar position control.

The 2 DOF Robot is particularly suitable for teaching intermediate robotic principles. It can be expanded to allow teaching of the 2 DOF Inverted Pendulum experiment. Applications of the 2 DOF Robot typically are pick-and-place robots used in manufacturing lines, such as PCB printing.

"My students use Quanser modules as a rapid prototype to choose and analyze different control scenarios. They start doing experiments very quickly."

Dr. Roxana Saint-Nom,
Electrical Engineering Department Chair,
CAERCEM Researcher,
Buenos Aires Institute of Technology, Argentina

HOW IT WORKS

The 2 DOF Robot module is connected to two Rotary Servo Base Units, which are mounted at a fixed distance and control a 4-bar linkage system: two powered arms coupled through two non-powered arms. The system is planar and has two actuated and three unactuated revolute joints.

The goal of the 2 DOF Robot experiment is to manipulate the X-Y position of a four-bar linkage end effector. Such a system is similar to the kinematic problems encountered in the control of other parallel mechanisms that have singularities.

A popular application of the 2 DOF Robot experiment is the pick-and-place robot used in manufacturing lines.

WORKSTATION COMPONENTS 2 DOF ROBOT EXPERIMENT

Component	Description
Plant	• 2 x Servo Base Unit (SRV02) • 2 DOF Robot module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• Instructor workbook* • Student workbook* • User Manual* • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X2
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW™? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS 2 DOF ROBOT MODULE

CURRICULUM TOPICS PROVIDED

Model Topics
- Transfer function representation
- Kinematics

Control Topic
- PD

FEATURES

- 4-bar precision-crafted aluminum linkage system
- Can mount the 2 DOF Inverted Pendulum module for additional experiments (sold separately)
- 2 DOF robot module easily attaches to the Rotary Servo Base Unit
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Mass of 4-bar Linkage Module	0.335	kg
Mass of Single Link	0.065	kg
Length of Link	0.127	m
Link Moment of Inertia about Cog	8.74×10^{-5}	$kg.m^2$
Link Moment of Inertia about Pivot	3.49×10^{-4}	$kg.m^2$
2 DOF Robot Overall Dimensions (L x W x H)	40 x 30 x 20	cm
2 DOF Robot Total Mass	4.0	kg

* Hard copies are not included. Documentation is supplied in electronic format on a CD
[1] MATLAB®/Simulink®, LabVIEW™ and Microsoft Windows® license needs to be purchased separately
[2] Quanser QPIDe (PCIe-based data acquisition devices) is recommended when a deterministic real-time performance is required

2 DOF INVERTED PENDULUM WORKSTATION

Based on the Two Degrees of Freedom (2 DOF) Robot workstation, the 2 DOF Inverted Pendulum module is ideal to introduce students to more advanced robotics concepts.

Mounted on the 2 DOF Robot (i.e. two Rotary Servo Base Units with a 4-bar linkage system), the setup is reconfigurable for two experiments: the 2 DOF Inverted Pendulum and the 2 DOF Gantry. Students will learn concepts for aerospace engineering applications, such as rocket stabilization, while designing a controller that maintains the pendulum upright using the two servo motors.

HOW IT WORKS

The 2 DOF Inverted Pendulum module consists of an instrumented 2 DOF joint, to which a 12-inch rod is mounted. The rod is free to swing about two orthogonal axes.

The module is attached to the 2 DOF Robot, i.e. two Rotary Servo Base Units with servomotor output shafts coupled through a four-bar linkage. The 2 DOF Joint is attached to the end effector of the robot arms.

The goal of the 2 DOF Inverted Pendulum workstation is to command the position of the 2 DOF Robot end effector to balance the 2 DOF Inverted Pendulum module. By measuring the deviations of the vertical pendulum, a controller can be used to rotate the servos such that the position of the end effector balances the pendulum.

In the 2 DOF Gantry setup, the challenge is to design a feedback controller that dampens out the swinging of a single pendulum load suspended from a 2 DOF joint.

"Students like Quanser experiments very much. They start with solving the problems in the Quanser course material, which is provided with every experiment, and then gradually move from simple to more complicated and more exciting problems."

Dr. Yongpeng Zhang

Assistant Professor, Department of Engineering Technology, Prairie View A and M University, Texas, USA

With the 2 DOF Inverted Pendulum experiment, you can demonstrate real-world control challenges encountered in aerospace engineering applications, such as rocket stabilization during takeoff.

WORKSTATION COMPONENTS 2 DOF INVERTED PENDULUM EXPERIMENT

Component	Description
Plant	• 2 × Servo Base Unit (SRV02) • 2 DOF Joint module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• Laboratory Guide* • User Manual* • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q8-USB
Amplifier	• Quanser VoltPAQ-X2
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW™? This experiment can also be configured with NI CompactRIO. For details contact Quanser@NI.com

SYSTEM SPECIFICATIONS 2 DOF INVERTED PENDULUM MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
• State-space representation

Control Topic
• Linear-quadratic regulator

FEATURES

- 2 DOF Joint allows the pendulum to rotate in both orthogonal axes
- Inverted pendulum mounts at the end of the 2 DOF Robot linkage arms
- High resolution encoders to sense pendulum link angles
- Configurable for two experiments: 2 DOF Inverted Pendulum (mounted on top) and 2 DOF Gantry (mounted on bottom)
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Mass of 4-bar Linkage Module	0.335	kg
Mass of Single Link	0.065	kg
Length of Link	0.127	m
Mass of Pendulum (with T-fitting)	0.127	kg
Mass of 2 DOF Hinge with 2 Encoders	0.30	kg
Full Length of Pendulum: from Pivot to Tip	0.3365	m
Link Moment of Inertia about Cog	8.74×10^{-5}	$kg.m^2$
Link Moment of Inertia about Pivot	4.41×10^{-4}	$kg.m^2$
Encoder sensitivity on 2 DOF Joint	0.0879	deg/count

* Hard copies are not included. Documentation is supplied in electronic format on a CD
[1] MATLAB®/Simulink®, LabVIEW™ and Microsoft Windows® license needs to be purchased separately
[2] Quanser QPIDe (PCIe-based data acquisition devices) is recommended when a deterministic real-time performance is required

MULTI-DOF TORSION WORKSTATION

With the Rotary Multi-DOF Torsion module, you can teach principles of robotics and torsional dynamics. Students will learn about modeling a torsional system and how to control it by minimizing the amount of vibration.

The Torsion module attaches to the Rotary Servo Base Unit for teaching 1 DOF torsional dynamics. Adding one or more (up to seven) torsion modules in series allows you to expand the complexity of the experiments to study 2 DOF or Multi-DOF torsional dynamics.

Applications that include high-gear ratio harmonic drives and lightweight transmission shafts may have joint flexibilities and torsional compliance, all of which can be emulated with this system.

"The modularity of Quanser equipment was very useful for us. We could build a sophisticated lab from scratch incrementally."

Dr. YangQuan Chen,

Associate Professor, Department of Electrical Engineering, Utah State University, USA

HOW IT WORKS

The Torsion Module is a rotary torsional system that consists of an instrumented bearing block, which is mounted in a cubic aluminum frame. A shaft is free to spin inside the bearing block and its angle is measured using an encoder. The shaft can be fitted with either a torsional load or a flexible coupling.

The assembly made of one Rotary Torsion module coupled to a Rotary Servo Base Unit constitutes a one Degree of Freedom (1 DOF) torsional system. The Rotary Servo Base 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. Up to seven torsion modules can be coupled in series to allow for multi-dimensional control problems.

The Multi-DOF Torsion experiment can help your students learn about the effect of flexible coupling between the actuator and the load in complex industrial processes.

WORKSTATION COMPONENTS MULTI-DOF TORSION EXPERIMENT

Component	Description
Plant[1]	• Servo Base Unit (SRV02) • Multi-DOF Torsion module
Controller Design Environment[2]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• Instructor workbook* • Student workbook* • User Manual* • Quick Start Guide
Real-Time Targets[2]	• Microsoft Windows®
Data Acquisition Board[3]	• Quanser Q2-USB
Amplifier	• Quanser VoltPAQ-X1
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

Using LabVIEW™? This experiment can also be configured with NI myRIO and CompactRIO. For details contact Quanser@NI.com**

SYSTEM SPECIFICATIONS MULTI-DOF TORSION MODULE

CURRICULUM TOPICS PROVIDED

Modeling Topics
- First-principles derivation (1 DOF Torsion)
- Lagrange derivation (2 DOF Torsion)
- State-space representation (1 and 2 DOF Torsion)
- Model validation (1 and 2 DOF Torsion)
- Parameter estimation (1 and 2 DOF Torsion)

Control Topics (1 and 2 DOF Torsion)
- Linear-quadratic regulator
- Vibration control

FEATURES

- High resolution encoders are used to sense the torsion shaft angle
- Can mount multiple torsion modules for multi degree of freedom torsion system
- Variable disc position to achieve different inertia
- Multi-DOF Torsion module easily attaches to the Rotary Servo Base Unit
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

TORSION MODULE

SPECIFICATION	VALUE	UNITS
Disk Weight Mass	0.0022	kg
Disk Weight Diameter	3.80	cm
Flexible Coupling Stiffness	1.0	N.m./rad
Load Support Bar Length	4.4	cm
Load Support Bar Mass	0.21	kg
Overall Dimensions of Torsion Module (L x W x H)	21 x 13 x 13	cm
Total Mass of Torsion Module	1.2	kg

* Hard copies are not included. Documentation is supplied in electronic format on a CD
** 1 DOF Torsion setup only
[1] Up to seven Multi-DOF Torsion modules can be used
[2] MATLAB®/Simulink®, LabVIEW™ and Microsoft Windows® license needs to be purchased separately
[3] Quanser QPIDe (PCIe-based data acquisition devices) is recommended when a deterministic real-time performance is required

2 DOF BALL BALANCER WORKSTATION

The Two Degrees of Freedom (2 DOF) Ball Balancer module is a vision-based control experiment designed to teach intermediate to advanced control concepts. The Ball Balancer system allows students to gain practical experience using camera-based sensor analysis to stabilize the position of a ball on a plate.

Students can take what they learned in the one-dimensional Ball and Beam experiment, and apply it to the X-Y planar case. They can learn how to design and implement a control system that stabilizes the ball on a plane, either at a fixed point of reference or by making it track a determined path.

New challenges include camera sensor calibration to achieve the correct ball position and the increased difficulty of stabilizing a free-moving, unrestricted ball in two dimensions.

Applications include helping new developments in the field of vision-based motion platforms. Current applications range from disposal robotic vehicles to pan-tilt cameras and visual servoing.

HOW IT WORKS

The 2 DOF Ball Balancer module consists of a plate on which a ball can be placed and is free to move. Two Rotary Servo Base Units are connected to the sides of the plate using 2 DOF gimbals. The plate can swivel about in any direction. By controlling the position of the servo load gears, the tilt angle of the plate can be adjusted to balance the ball to a desired planar position.

The digital camera mounted overhead captures two-dimensional images of the plate and tracks the coordinates of the ball in real time. Images are transferred quickly to the PC via a FireWire connection. With the controller provided, students can make the ball track various trajectories (a circle, for example), or even stabilize the ball when it is thrown onto the plate.

"Quanser equipment gives students good insight into real control."

Dr. Ben Cazzolato,

Associate Professor, School of Mechanical Engineering, University of Adelaide, Australia

Real-world applications for the 2 DOF Ball Balancer experiment include pan and tilt security cameras.

WORKSTATION COMPONENTS 2 DOF BALL BALANCER EXPERIMENT

Component	Description
Plant	• 2 × Servo Base Unit (SRV02) • 2 DOF Ball Balancer module
Controller Design Environment[1]	• Quanser QUARC® add-on for MATLAB®/Simulink® • Quanser RCP Toolkit add-on for NI LabVIEW™
Documentation	• Instructor workbook* • Student workbook* • User Manual* • Quick Start Guide
Real-Time Targets[1]	• Microsoft Windows®
Data Acquisition Board[2]	• Quanser Q2-USB
Amplifier[3]	• Quanser VoltPAQ-X2
Others	• Complete dynamic model • Simulink® pre-designed controllers • LabVIEW™ pre-designed controllers

SYSTEM SPECIFICATIONS 2 DOF BALL BALANCER MODULE

CURRICULUM TOPICS PROVIDED

Model Derivation
- First-principles

Modeling Topics
- First-principles derivation
- Transfer function representation
- Linearization

Control Topics
- PID
- Multiple loops

Control-related Topic
- Sensor analysis

FEATURES

- Chassis is precision-crafted and constructed of durable ABS plastic
- Plate is mounted on a 2 DOF gimbal, which allows the plates to swivel about both axes
- High-resolution encoders for accurate sensing and positioning of table plate in 2D plane
- High resolution, high quality, fast frame rate CCD digital camera with FireWire connection to allow quick real-time sensing of object position in 2D plane
- Quanser image processing software and Simulink® library provided
- Easy-connect cables and connectors
- Fully compatible with MATLAB®/Simulink® and LabVIEW™
- Fully documented system models and parameters provided for MATLAB®, Simulink®, LabVIEW™ and Maple™
- Open architecture design, allowing users to design their own controller

DEVICE SPECIFICATIONS

SPECIFICATION	VALUE	UNITS
Calibrated Base Dimensions (W x D)	41.75 x 41.75	cm
Camera Support Height	69.5	cm
Table Dimensions (L x W)	27.5 x 27.5	cm
Lever Arm Length	9.7	cm
Support Arm Length	14.6	cm
Camera Specification	IIDC 1394-based Digital Camera	v 1.31
Camera Standard Resolution	640 x 480	
Camera Frame Rate (at full resolution, Y8 format)	30	FPS
Camera Pixel Format	Y8 in BGR format	

* Hard copies are not included. Documentation is supplied in electronic format on a CD
[1] MATLAB®/Simulink®, LabVIEW™ and Microsoft Windows® license needs to be purchased separately
[2] Quanser QPIDe (PCIe-based data acquisition devices) is recommended when a deterministic real-time performance is required
[3] Two VoltPAQ-X1 units can also be used to run this experiment

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YOU CAN RELY ON QUANSER TO ADVANCE CONTROL EDUCATION

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