QUANSER
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USER MANUAL

QUBE-Servo 2 Experiment

Set Up and Configuration

CAPTIVATE. MOTIVATE. GRADUATE.

Quanser Inc.
119 Spy Court
Markham, Ontario
L3R 5H6
Canada
info@quanser.com
Phone: 1-905-940-3575
Fax: 1-905-940-3576

Printed in Markham, Ontario.

For more information on the solutions Quanser Inc. offers, please visit the web site at:
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CONTENTS

1 PRESENTATION

The Quanser QUBE-Servo 2, pictured in Figure 1.1, is a compact rotary servo system that can be used to perform a variety of classic servo control and inverted pendulum based experiments. The QUBE-Servo 2 can be configured with either the QFLEX 2 USB or QFLEX 2 Embedded interface modules. The QFLEX 2 USB allows control by a computer via USB connection. The QFLEX 2 Embedded allows for control by a microcontroller device such as an Arduino via a 4-wire SPI interface.

For all versions, the system is driven using a direct-drive 18V brushed DC motor. The motor is powered by a built-in PWM amplifier with integrated current sense. Two add-on modules are supplied with the system: an Inertia disc and a Rotary pendulum. The modules can be easily attached or interchanged using magnets mounted on the QUBE-Servo 2 module connector. Single-ended rotary encoders are used to measure the angular position of the DC motor and pendulum, and the angular velocity of the motor can also be measured using an integrated software-based tachometer.

Main QUBE-Servo 2 features:

- Compact and complete rotary servo system
- 18V direct-drive brushed DC motor
- Encoders mounted on DC motor and pendulum
- DC motor tachometer output
- Built-in PWM amplifier with integrated current sense
- Built-in data acquisition (DAQ) device
- Inertia disc module
- Rotary pendulum module
- Tri-color LED indicator lights

Figure 1.1: Quanser QUBE-Servo 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 SYSTEM HARDWARE

2.1 System Schematic

The QUBE-Servo 2 can be configured with one of two different I/O interfaces: the QFLEX 2 USB, and the QFLEX 2 Embedded. The QFLEX 2 USB provides a USB interface for use with a computer. The QFLEX 2 Embedded provides a 4-wire SPI interface for use with an external microcontroller board.

The interaction between the different system components on the QUBE-Servo 2 is illustrated in Figure 2.1. On the data acquisition (DAQ) device block, the motor and pendulum encoders are connected to the Encoder Input (EI) channels #0 and #1. The Analog Output (AO) channel is connected to the power amplifier command, which then drives the DC motor. The DAQ Analog Input (AI) channel is connected to the PWM amplifier current sense circuitry. The DAQ also controls the integrated tri-colour LEDs via an internal serial data bus. The DAQ can be interfaced to the PC or laptop via USB link in the QFLEX 2 USB, or to an external microcontroller via SPI in the QFLEX 2 Embedded.

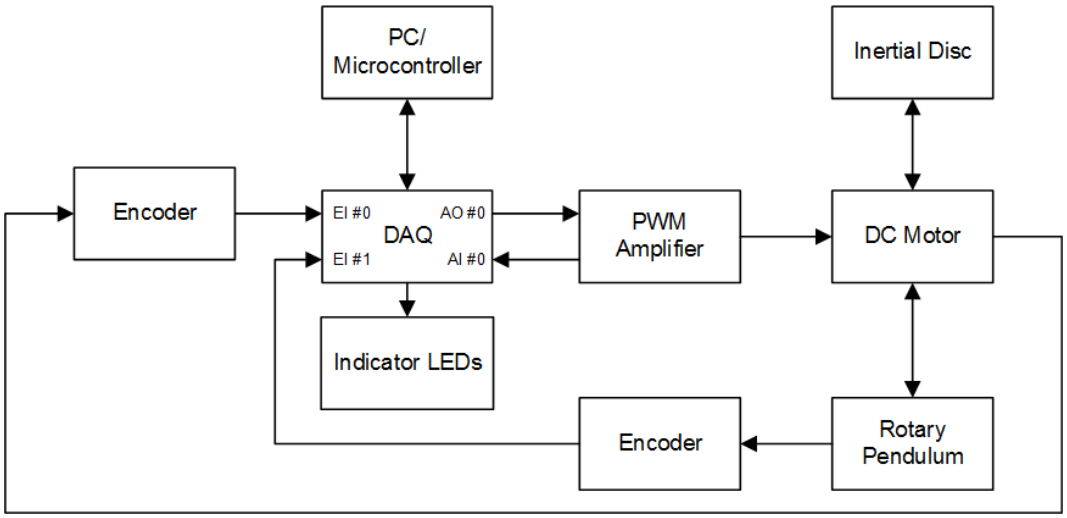


Figure 2.1: Interaction between QUBE-Servo 2 components.

2.2 Hardware Components

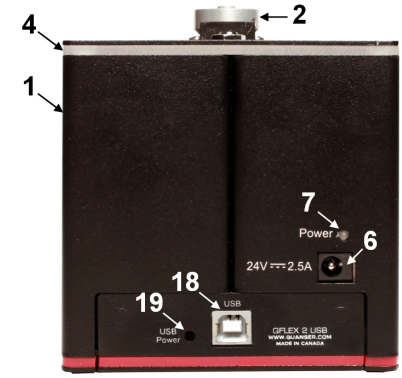
The main QUBE-Servo 2 components - for the USB and SPI embedded interfaces - are listed in Table 2.1. The components on the QFLEX 2 USB are labeled in Figure 2.2a, and the components on the QFLEX 2 Embedded are shown in Figure 2.2b.

ESD Warning: QUBE-Servo 2 internal components are sensitive to electrostatic discharge. Before handling the QUBE-Servo, ensure that you have been properly grounded.

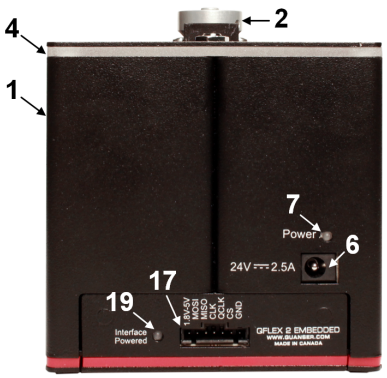
ID	Component	ID	Component
1	Chassis	11	Rotary arm hub
2	Module connector	12	Rotary pendulum magnets
3	Module connector magnets	13	Pendulum encoder
4	Status LED strip	14	DC motor
5	Module encoder connector	15	Motor encoder
6	Power connector	16	QUBE-Servo 2 DAQ/amplifier board
7	System power LED	17	SPI Data Connector*
8	Inertia disc	18	USB connector†
9	Pendulum arm	19	Interface power LED
10	Rotary arm rod	20	Internal data bus

Table 2.1: QUBE-Servo 2 Components

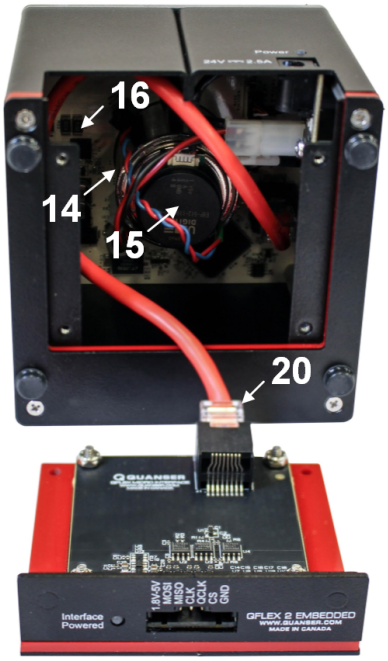
† only on QFLEX 2 USB
*only on QFLEX 2 Embedded



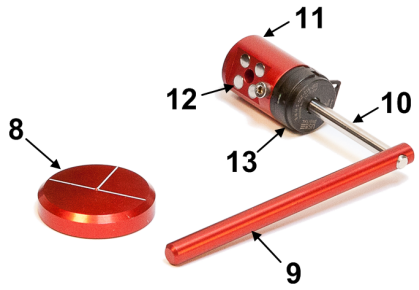
(a) QUBE-Servo 2 with QFLEX 2 USB



(b) QUBE-Servo 2 with QFLEX 2 Embedded



(c) QUBE-Servo 2 Interior



(d) QUBE-Servo 2 Modules

(e) QUBE-Servo 2 Top View

Figure 2.2: QUBE-Servo 2 components

2.2.1 DC Motor

The QUBE-Servo 2 includes a direct-drive 18V brushed DC motor. The motor specifications are given in Table 2.2.

The QUBE incorporates an Allied Motion CL40 Series Coreless DC Motor model 16705. The complete specification sheet of the motor is included at: http://alliedmotion.com/Products/Series.aspx?s=29.

Caution: Max motor input ± 10 V, 2 A peak, 0.5 A continuous.

Caution: Exposed moving parts.

Caution: Holding the motor in a stalled position for a prolonged period of time at applied voltages of over 5V can result in permanent damage.

2.2.2 Encoder

The encoders used to measure the angular position of the DC motor and pendulum on the QUBE-Servo 2 are US Digital E8P-512-118 single-ended optical shaft encoders. They output 2048 counts per revolution in quadrature mode (512 lines per revolution). A digital tachometer is also available for angular speed in counts/sec on channel 14000. The complete specification sheet of the E8P optical shaft encoder is given in the E8P Data Sheet.

2.2.3 Data Acquisition (DAQ) Device

The QUBE-Servo 2 includes an integrated data acquisition device with two 24-bit encoder channels with quadrature decoding and one PWM analog output channel. The DAQ also incorporates a 12-bit ADC which provides current sense feedback for the motor. The current feedback is used to detect motor stalls and will disable the amplifier if a prolonged stall is detected.

2.2.4 Power Amplifier

The QUBE-Servo 2 circuit board includes a PWM voltage-controlled power amplifier capable to providing 2 A peak current and 0.5 A continuous current (based on the thermal current rating of the motor). The output voltage range to the load is between ± 10 V.

2.2.5 Embedded System Connector

The SPI data connector pictured on the QFLEX 2 Embedded in Figure 2.2b allows an external microcontroller to set motor voltage and LED brightnesses, read and set encoder counters, and read motor speed and current flow. See the QFLEX 2 Embedded data sheet for information on connecting the SPI interface.

2.3 Environmental

The QUBE-Servo 2 is designed to function under the following environmental conditions:

- Standard rating
- Indoor use only
- Temperature 5°C to 40°C
- Altitude up to 2000 m
- Maximum relative humidity of 80% up to 31°C decreasing linearly to 50% relative humidity at 40°C
- Pollution Degree 2
- Mains supply voltage fluctuations up to $\pm$ 10% of nominal voltage
- Maximum transient overvoltage 2500 V

- Marked degree of protection to IEC 60529: Ordinary Equipment (IPX0)

2.4 System Parameters

Table 2.2 lists and characterizes the main parameters associated with the QUBE-Servo 2.

Symbol	Description	Value
DC Motor		
V_{nom}	Nominal input voltage	18.0 V
τ_{nom}	Nominal torque	22.0 mN-m
ω_{nom}	Nominal speed	3050 RPM
I_{nom}	Nominal current	0.540 A
R_m	Terminal resistance	8.4 Ω
k_t	Torque constant	0.042 N-m/A
k_m	Motor back-emf constant	0.042 V/(rad/s)
J_m	Rotor Inertia	4.0×10^{-6} kg-m^2
L_m	Rotor inductance	1.16 mH
m_h	Module attachment hub mass	0.0106 kg
r_h	Module attachment hub radius	0.0111 m
J_h	Module attachment moment of Inertia	0.6×10^{-6} kg-m^2
Inertia Disc Module		
m_d	Disc mass	0.053 kg
r_d	Disc radius	0.0248 m
Rotary Pendulum Module		
m_r	Rotary arm mass	0.095 kg
L_r	Rotary arm length (pivot to end of metal rod)	0.085 m
m_p	Pendulum link mass	0.024 kg
L_p	Pendulum link length	0.129 m
Motor and Pendulum Encoders		
	Encoder line count	512 lines/rev
	Encoder line count in quadrature	2048 lines/rev
	Encoder resolution (in quadrature, deg)	0.176 deg/count
	Encoder resolution (in quadrature, rad)	0.00307 rad/count
Amplifier		
	Amplifier type	PWM
	Peak Current	2 A
	Continuous Current	0.5 A
	Output voltage range (recommended)	$\pm$10 V
	Output voltage range (maximum)	$\pm$15 V

Table 2.2: QUBE-Servo 2 System Parameters

3 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.

3.1 Components

To setup the QUBE-Servo 2 system, you need the following components:

1. QUBE-Servo 2 (USB or Embedded version)
2. Inertia disc module (shown in Figure 3.1a)
3. Rotary Pendulum (ROTPEN) module (shown in Figure 3.1b)
4. Power supply with the following ratings:
   - Input Rating: 100-240 V AC, 50-60 Hz, 1.4 A
   - Output Rating: 24 V DC, 2.71 A

   Note: Only the power supply provided (AC-DC adapter by Adapter Technology Co Ltd, model ATS065-P241) should be used with the QUBE-Servo 2
5. Power cable

   Note: Only the power cable provided should be used with the QUBE-Servo 2

   Note: Make sure that the power cable's plug is accessible for disconnection in case of emergency

   Caution: Precaution must be taken during the connection of this equipment to the AC outlet to make sure the grounding (earthing) is in place, and that the ground wire is not disconnected
6. USB 2.0 A/B cable (for QFLEX 2 USB) or jumper wires (for QFLEX 2 Embedded)

(a) QUBE-Servo 2 with Inertia Disc Module (b) QUBE-Servo 2 with Pendulum Module

Figure 3.1: QUBE-Servo 2 with different modules

3.2 QFLEX 2 USB Hardware Setup

To setup the QFLEX 2 USB follow these steps:

1. Connect USB 2.0 cable from back cover of QUBE-Servo 2 to an enabled USB 2.0 port on your desktop PC or laptop.
2. The QFLEX 2 USB driver should install automatically. If not, then you may not have installed all the required software to support the device including either QUARC® or Quanser Rapid Control Prototyping Toolkit®.
3. Connect the **Power** connector on the QUBE-Servo 2 to the power supply. Ensure the power supply is connected to a wall outlet using the appropriate power cable.
4. Attach the Inertia disc or ROTPEN module to the motor hub using the magnets. The QUBE-Servo 2 is shown with the Inertia disc and ROTPEN modules setup in Figure 3.1.
5. **ROTPEN Users:** If you are using the pendulum attachment, connect the encoder cable from the pendulum module encoder to the **Encoder 1** connector on the top panel of the QUBE-Servo 2(connector shown in Figure 2.2e). The QUBE-Servo 2 with the attached pendulum and connected cable is pictured in Figure 3.1b.

3.3 QFLEX 2 Embedded Hardware Setup

This section describes how to connect the QFLEX 2 Embedded to an external microcontroller board. The connection procedure is given below, and summarized in Table 3.1. The wires required to connect the QFLEX 2 Embeddedare not included with the unit, connections may be made with jumper wires or a custom wiring solution dependent on the external controller being used. See the QFLEX 2 Embedded data sheet for information on wiring and communication.

Follow these steps to connect the QFLEX 2 Embedded to your microcontroller device.

1. Before proceeding make sure your microcontroller device has been setup and successfully tested. Refer to the documentation supplied with your control system for set up and testing instructions.
2. Make sure the everything is powered off before making any of these connections. This includes turning off the external microcontroller board.
3. Connect the GND pin on the QFLEX 2 Embedded to a digital ground connection on the microcontroller board.
4. Connect the MOSI, MISO, and CLK pins on the QFLEX 2 Embedded to the microcontroller board as outlined in the SPI interface documentation for your controller.
5. Connect the CS pin on the QFLEX 2 Embedded to a digital output on the microcontroller board.
6. Connect the 1.8V-5V pin on the QFLEX 2 Embedded to a signal level power pin on the microcontroller board in the 1.8V to 5V range.

   Caution: Applying voltages in excess of 5V to the 1.8V-5V input on the QFLEX 2 Embedded may result in damage to the QFLEX 2 Embedded.
7. **ROTPEN Users:** If you are using the pendulum attachment, connect the encoder cable from the pendulum module encoder to the **Encoder 1** connector on the top panel of the QUBE-Servo 2 (connector shown in Figure 2.2e). The QUBE-Servo 2 with the attached pendulum and connected cable is pictured in Figure 3.1b.

3.4 Exchanging QFLEX 2 Panels

Follow these steps to install the QFLEX 2 USB or QFLEX 2 Embedded panel in your QUBE-Servo 2.

Cable #	From Microcontroller	To QFLEX 2 Embedded	Signal
1	VCC/VDD(1.8V-5V)	1.8V-5V	QFLEX 2 Embedded interface power.
2	MOSI/SDO/SO	MOSI	SPI master out, slave in data line.
3	MISO/SDI/SI	MISO	SPI master in, slave out data line.
4	SCLK/SCK	CLK	SPI clock line.
5	Digital output line	CS	SPI slave select line.
6	GND/DGND	GND	SPI digital signal ground.

Table 3.1: QFLEX 2 Embedded wiring summary

1. Disconnect the 24VDC power input from the QUBE-Servo 2.
2. Disconnect any connections between the currently installed QFLEX panel and the computer or microcontroller board.

ESD Warning: The interior of the QUBE-Servo 2 contains components which are sensitive to electrostatic discharge. Before opening the QUBE-Servo 2 case, ensure that both you and the workspace are properly grounded.

3. Remove the four screws at the corners of the QFLEX panel to release the panel from the QUBE chassis. Figure 3.2 shows the QUBE-Servo 2 with the screws removed

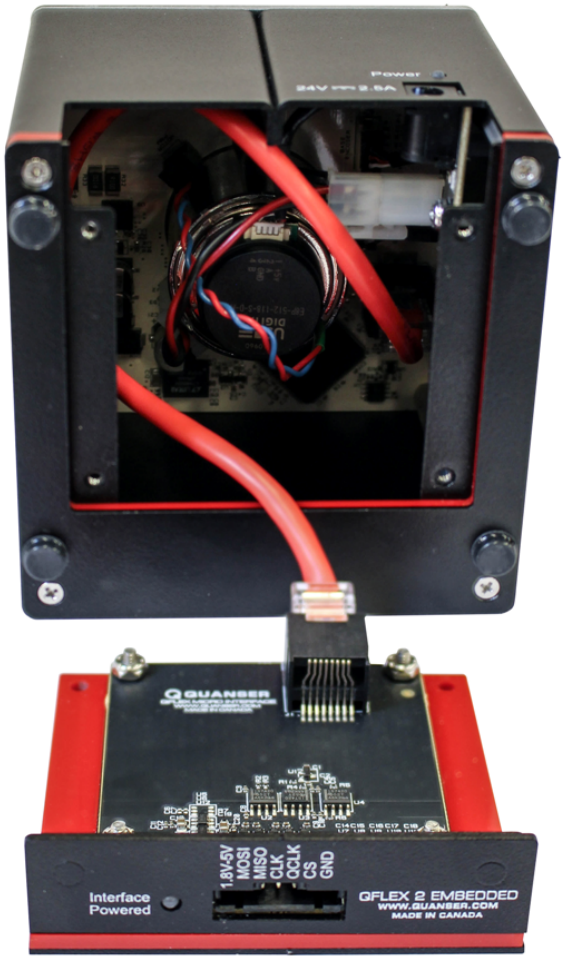


Figure 3.2: Changing the QFLEX panel

4. Disconnect the QUBE internal data cable from the QFLEX panel by depressing the latching tab.
5. Connect the QUBE internal data cable to the QFLEX panel to be installed, pressing the connector into the socket until a click is heard and the connector latches in place.
6. Anchor the QFLEX panel in place using the four screws removed earlier.

Caution: Ensure that the QUBE-Servo 2 is completely reassembled, with all screws in place before connecting power or attempting operation.

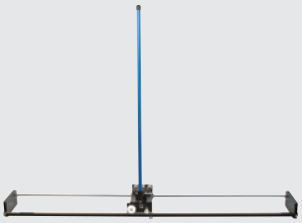
Other experiments for teaching fundamental control concepts and for advanced research

Rotary Servo Base Unit

Rotary Inverted Pendulum

IMDU Torsion

Linear Servo Base Unit with Inverted Pendulum



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