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USER MANUAL

QUBE-Servo Experiment

Set Up and Configuration

CAPTIVATE. MOTIVATE. GRADUATE.

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1 PRESENTATION

The Quanser QUBE-Servo, 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 comes in three versions: the USB Interface, Direct I/O Interface, and NI myRIO Interface. The QUBE-Servo USB Interface has its own built-in power amplifier and data acquisition device. The QUBE-Servo Direct I/O Interface also has an integrated amplifier but allows an external data acquisition (DAQ) device to interface to its I/O. The QUBE-Servo myRIO Interface also has a built in amplifier, and allows a direct connection to the NI myRIO Expansion Port (MXP) connector.

For all versions, the system is driven using a direct-drive 18V brushed DC motor housed in a solid aluminum frame. Two add-on modules are supplied with the system: an inertial disc and a rotary pendulum. The modules can be easily attached or interchanged using magnets mounted on the QUBE-Servo module connector. Single-ended rotary encoders are used to measure the angular position of the DC motor and pendulum.

Main QUBE-Servo features:

- Compact and complete rotary servo system
- 18V direct-drive brushed DC motor
- Encoders mounted on DC motor and pendulum
- Built-in PWM amplifier
- Built-in USB data acquisition (DAQ) device (only for QUBE-Servo USB Interface)
- Inertial disc module
- Rotary pendulum module

Figure 1.1: Quanser QUBE-Servo

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

There are three QUBE-Servo models with different I/O interface options: the QUBE-Servo USB Interface, the QUBE-Servo Direct I/O Interface, and the QUBE-Servo myRIO Interface. The QUBE-Servo USB Interface provides a built-in data acquisition device and an integrated amplifier. The QUBE-Servo Direct I/O Interface and QUBE-Servo myRIO Interface both have an amplifier but do not have built-in DAQ systems. Instead, the QUBE-Servo Direct I/O Interface includes amplifier command and encoder ports that can be interfaced with an external DAQ device, and the QUBE-Servo myRIO Interface includes an MXP connector to interface directly with the NI myRIO.

The interaction between the different system components on the QUBE-Servo 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 is interfaced to the PC or laptop via USB link in the QUBE-Servo USB Interface. In the QUBE-Servo Direct I/O Interface and QUBE-Servo myRIO Interface systems, an external DAQ would be used to interface to the amplifier and encoders.

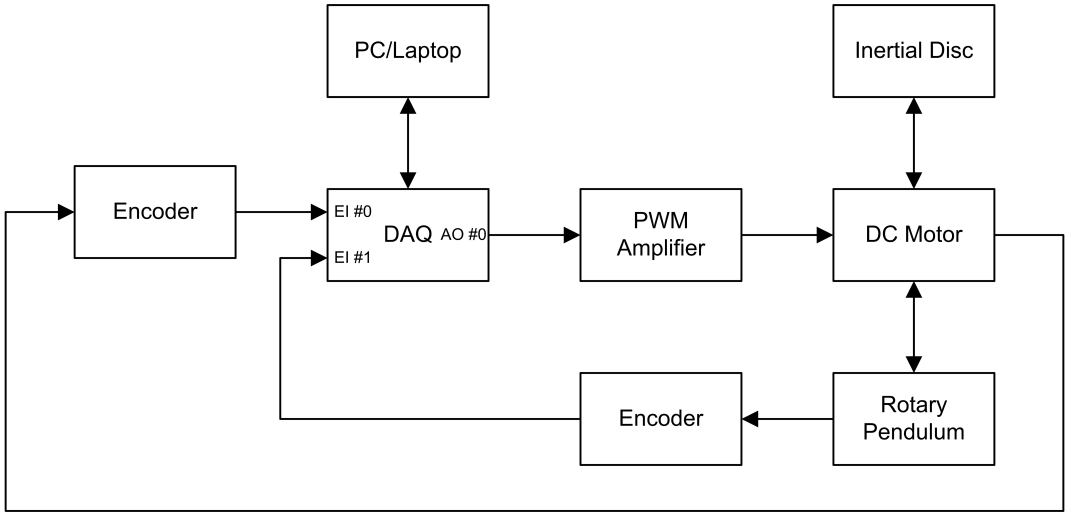


Figure 2.1: Interaction between QUBE-Servo components.

The schematic given in Figure 2.2 illustrates the main QUBE-Servo components and how they interact with a data acquisition (DAQ) device.

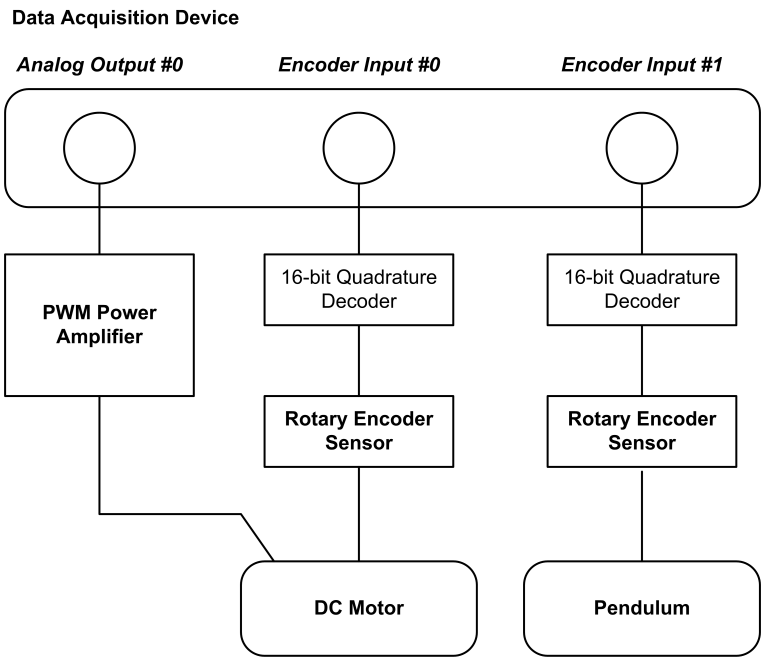


Figure 2.2: System schematic

2.2 Hardware Components

The main QUBE-Servo components - for the USB, Direct I/O, and NI myRIO interfaces - are listed in Table 2.1. The components on the QUBE-Servo USB Interface are labeled in Figure 2.3a, the components on the QUBE-Servo Direct I/O Interface are shown in Figure 2.3b, and the components on the QUBE-Servo myRIO Interface are in Figure 2.3c.

ESD Warning: The internal components are sensitive to electrostatic discharge. Before handling the QUBE-Servo, make sure you touch something metal to ground yourself.

ID	Component	ID	Component
1	Aluminum chassis	11	Rotary arm hub
2	Module connector	12	Rotary pendulum magnets
3	Module connector magnets	13	Pendulum encoder
4	USB DAQ connector†	14	DC motor
5	Module encoder connector	15	Motor encoder
6	Power connector	16	QUBE-Servo DAQ/amplifier board
7	Power LED	17	Encoder 0 connector*
8	Inertial disc	18	Encoder 1 connector*
9	Pendulum link	19	Amplifier Input 0 connector*
10	Rotary arm rod	20	NI myRIO MXP connector‡

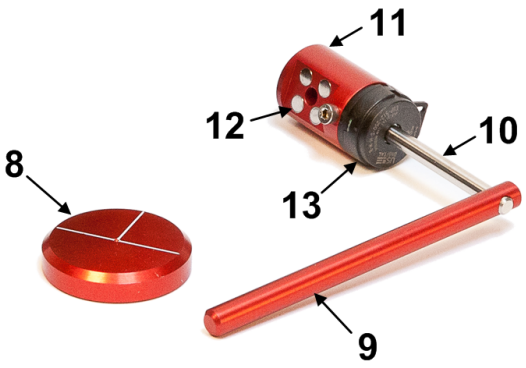
Table 2.1: QUBE-Servo Components
‡ only on QUBE-Servo myRIO Interface

† only on QUBE-Servo USB Interface
*only on QUBE-Servo Direct I/O Interface

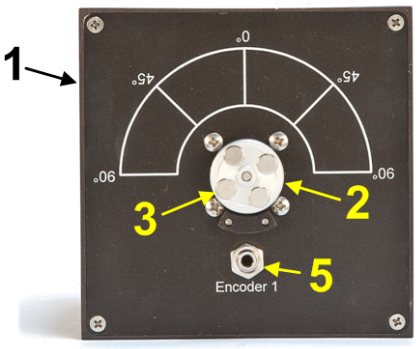
(a) QUBE-Servo USB Interface

(b) QUBE-Servo Direct I/O Interface

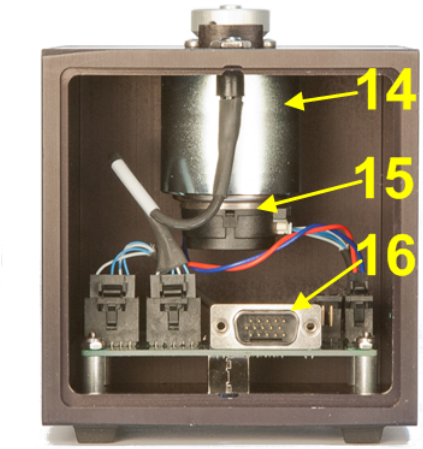
(c) QUBE-Servo myRIO Interface



(d) QUBE-Servo Modules



(e) QUBE-Servo Top View



(f) QUBE-Servo Interior

Figure 2.3: QUBE-Servo components

2.2.1 DC Motor

The QUBE-Servo includes a direct-drive 18V brushed DC motor housed in a solid aluminum frame. 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: 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 is a single-ended optical shaft encoder. It outputs 2048 counts per revolution in quadrature mode (512 lines per revolution).

The encoders used to measure the angular position of the DC motor and pendulum on the QUBE is the US Digital E8P-512-118 single-ended optical shaft encoder. The complete specification sheet of the E8P optical shaft encoder is given in E8P Data Sheet.

2.2.3 Data Acquisition (DAQ) Device

The QUBE-Servo USB Interface circuit board includes a USB data acquisition device with two 16-bit encoder channels with quadrature decoding and two PWM output channels. The DAQ is very similar to the Quanser Q2-USB board. See the Q2-USB User Manual [1] for more information. The QUBE-Servo Direct I/O Interface circuit board does not have the built-in USB DAQ (it does have the amplifier and encoder channels).

2.2.4 Power Amplifier

The QUBE-Servo 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 Amplifier Input Connector

The *Amplifier Input* RCA connector on the QUBE-Servo Direct I/O Interface is shown in Figure 2.3b. It is single-ended and has a range of ± 10V. As shown in Figure 2.2, it is connected to the amplifier command which then drives the motor.

2.2.6 Encoder Connector

The *Encoder 0* and *Encoder 1* 5-pin DIN connectors pictured on the QUBE-Servo Direct I/O Interface in Figure 2.3b output the measurements from the motor encoder and the add-on module (e.g., pendulum) encoder, respectively. The encoder connector pin-out is shown in Figure 2.4.

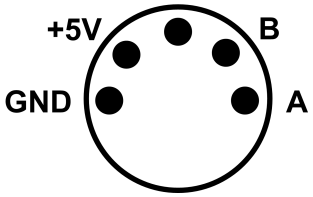


Figure 2.4: 5-pin DIN encoder pin-out

2.2.7 MXP Connector

The *myRIO Connector A/B* connector pictured on the QUBE-Servo myRIO Interface in Figure 2.3c is used to connect the amplifier command line, and encoder readings from the QUBE-Servo components to either of the two NI myRIO MXP connectors.

2.3 System Parameters

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

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	0.016 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)	0.176 deg/count
Amplifier		
	Amplifier type	PWM
	Peak Current	2 A
	Continuous Current	0.5 A
	Output voltage range	$\pm$10 V

Table 2.2: QUBE-Servo 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 system, you need the following components:

1. QUBE-Servo (USB, Direct I/O, or NI myRIO version; USB version shown in Figure 1.1)
2. Inertial disc module (shown in Figure 1.1)
3. Rotary Pendulum (ROTPEN) module (shown in Figure 1.1)
4. 15V 2.0 A power supply

   Note: Only the power supply provided should be used with the QUBE-Servo
5. Power cable
6. USB 2.0 A/B cable, an RCA cable and two 5-pin-DIN cables, or NI myRIO MXP interface cable provided with your QUBE-Servo depending on the version.

3.2 QUBE-Servo USB Interface Hardware Setup

To setup the QUBE-Servo USB Interface follow these steps:

1. Connect USB 2.0 cable from back cover of QUBE-Servo to an enabled USB 2.0 port on your desktop PC or laptop.
2. The QUBE-Servo USB Interface 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 to the power supply. Ensure the power supply is connected to a wall outlet using the appropriate power cable.
4. Attach the inertial disc or ROTPEN module to the motor hub using the magnets. The QUBE-Servo is shown with the inertial 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(connector shown in Figure 2.3e). The QUBE-Servo with the attached pendulum and connected cable is pictured in Figure 3.1b.

3.3 QUBE-Servo myRIO Interface Hardware Setup

To setup the QUBE-Servo myRIO Interface follow these steps:

1. Connect NI myRIO MXP interface cable from the back cover of QUBE-Servo to either of the two MXP connectors (A or B) on the NI myRIO.

(a) QUBE-Servo with Inertial Disc Module (b) QUBE-Servowith Pendulum Module

Figure 3.1: QUBE-Servo with different modules

2. Connect the **Power** connector on the QUBE-Servo to the power supply. Ensure the power supply is connected to a wall outlet using the appropriate power cable.
3. Attach the inertial disc or ROTPEN module to the motor hub using the magnets. The QUBE-Servo is shown with the inertial disc and ROTPEN modules setup in Figure 3.1.
4. **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(connector shown in Figure 2.3e). The QUBE-Servo with the attached pendulum and connected cable is pictured in Figure 3.1b.

3.4 QUBE-Servo Direct I/O Interface Hardware Setup

This section describes how to connect the QUBE-Servo Direct I/O Interface system to your data acquisition (DAQ) device. The connection procedure is given below, summarized in Table 3.1 and illustrated in Figure 3.2. In addition, the cables needed to connect the QUBE-Servo Direct I/O Interface are shown in Figure 3.3.

Follow these steps to connect the QUBE-Servo Direct I/O Interface to your data acquisition device:

1. Before proceeding make sure your data acquisition (DAQ) device has been setup and successfully tested. Refer to the documentation supplied with your DAQ 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 your DAQ or your PC.
3. Using the RCA cable, connect the *Analog Output #0* on the DAQ to the *Amplifier Input 0* socket on the QUBE-Servo.
4. Using the 5-pin-DIN to 5-pin-DIN cable, connect the *Encoder 0* connector on the QUBE-Servo to *Encoder Input #0* on the DAQ device. This carries the motor angle measurement.
5. Attach the inertial disc or ROTPEN module to the motor hub using the magnets. The QUBE-Servo is shown with the inertial disc and ROTPEN modules setup in Figure 3.1.

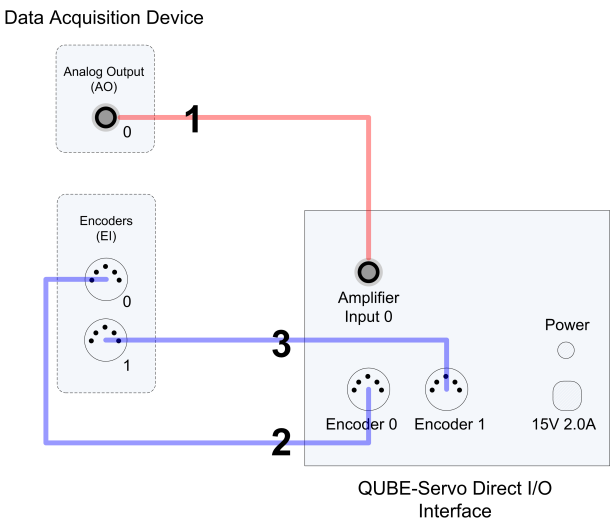


Figure 3.2: Connections between QUBE-Servo Direct I/O Interface and an external DAQ

6. **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 (connector shown in Figure 2.3e). The QUBE-Servo with the attached pendulum and connected cable is pictured in Figure 3.1b.

7. **ROTPEN Users:** Using the 5-pin-DIN to 5-pin-DIN cable, connect the *Encoder 1* connector on the QUBE-Servo to *Encoder Input #1* on the DAQ device.

Cable #	From	To	Signal
1	DAQ: **Analog Output #0**	QUBE-Servo **Amplifier Input #0** connector	Amplifier voltage command driving motor.
2	DAQ: **Encoder Input #0**	QUBE-Servo **Encoder #0** connector	Motor encoder measurement.
3	DAQ: **Encoder Input #1**	QUBE-Servo **Encoder #1** connector	Pendulum module encoder measurement.

Table 3.1: QUBE-Servo wiring summary

(a) Amplifier Input Cable: RCA to RCA (b) Encoder Cable: 5-pin-DIN to 5-pin-DIN

Figure 3.3: Cables used to connect QUBE-Servo Direct I/O Interface to a DAQ device

REFERENCES

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

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