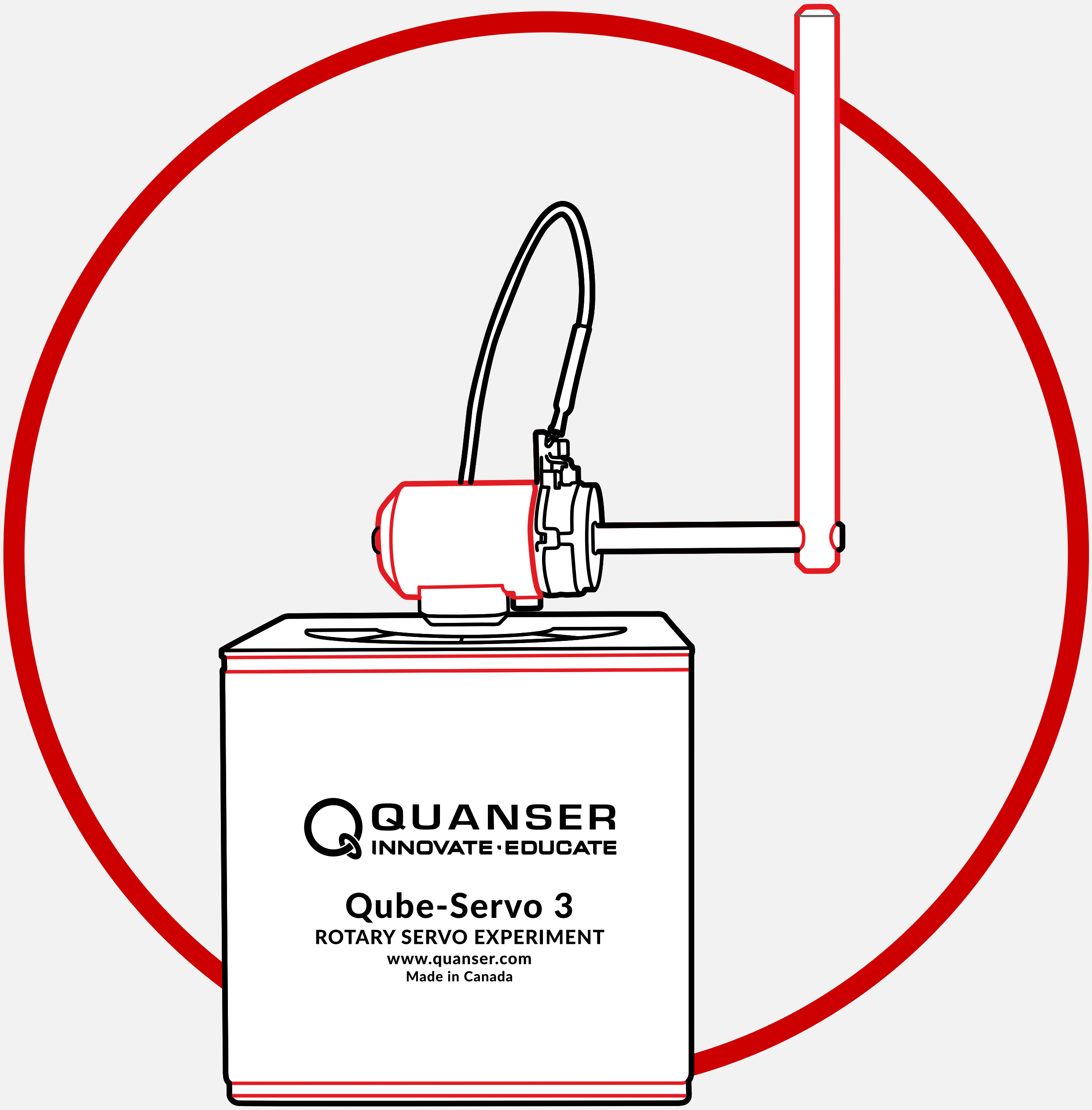

Qube-Servo 3

Swing-Up Control

V1.2 – 27th February 2025

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Caution

This equipment is designed to be used for educational and research purposes and is not intended for use by the public. The user is responsible for ensuring that the equipment will be used by technically qualified personnel only. Users are responsible for certifying any modifications or additions they make to the default configuration.

FCC Notice This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment.

Industry Canada Notice This Class A digital apparatus complies with CAN ICES-3 (A). Cet appareil numérique de la classe A est conforme à la norme NMB-3 (A) du Canada.
Japan VCCI Notice This is a Class A product based on the standard of the Voluntary Control Council for Interference (VCCI). If this equipment is used in a domestic environment, radio interference may occur, in which case the user may be required to take corrective actions.

この装置は、クラス A 情報技術装置です。この装置を家庭環境で使用すると電波妨害を引き起こすことがあります。この場合には使用者が適切な対策を講ずるよう要求されることがあります。 VCCI–A

Waste Electrical and Electronic Equipment (WEEE)
This symbol indicates that waste products must be disposed of separately from municipal household waste, according to Directive 2012/19/EU of the European Parliament and the Council on waste electrical and electronic equipment (WEEE). All products at the end of their life cycle must be sent to a WEEE collection and recycling center. Proper WEEE disposal reduces the environmental impact and the risk to human health due to potentially hazardous substances used in such equipment. Your cooperation in proper WEEE disposal will contribute to the effective usage of natural resources.

电子信息产品污染控制管理办法 (中国 RoHS)

中国客户Quanser Consulting Inc. 关于关于限制在电子电气设备中使用某些有害成分的指令 (RoHS)。

CE Compliance CE

This product meets the essential requirements of applicable European Directives as follows:
- 2014/30/EU; Electromagnetic Compatibility Directive (EMC)

Warning: This is a Class A product. In a domestic environment this product may cause radio interference, in which case the user may be required to take adequate measures.

Qube-Servo 3 – Application Guide
Swing-Up Control

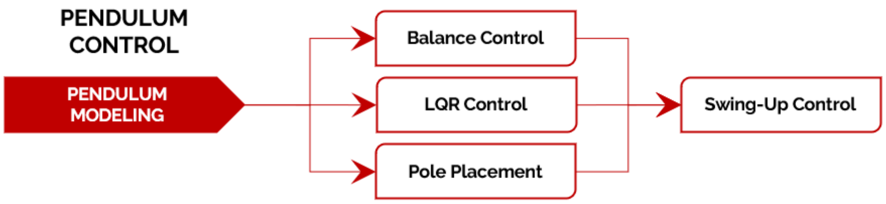
Why explore Swing-Up Control?

Swing-up and balance control is a complicated control problem. It can be broken down into two separate forms of control that are engaged under different conditions. Different controllers have certain strengths, which is why two separate controllers are used to solve this problem. Often when dealing with complex systems that need to be controlled, different forms of control will be needed to solve individual smaller problems that make up the whole system. In the case of swing-up and balance we focus on an energy controller for the swing-up action and an LQR controller for the balancing action.

Background

This lab is part of the Pendulum Control skills progression of the Qube-Servo 3. These labs are focused on understanding different ways to maintain balance of an inverted pendulum. This lab will use that knowledge to create an energy based controller to swing the pendulum up and then maintain the balance.

The lab progression is as follows:



Prior to starting this lab, please review the following concept reviews (should be located in Documents/Quanser/concept_reviews/),

- Concept Review – Modeling & IO → Pendulum Free Body Diagram (Energy Control Section)

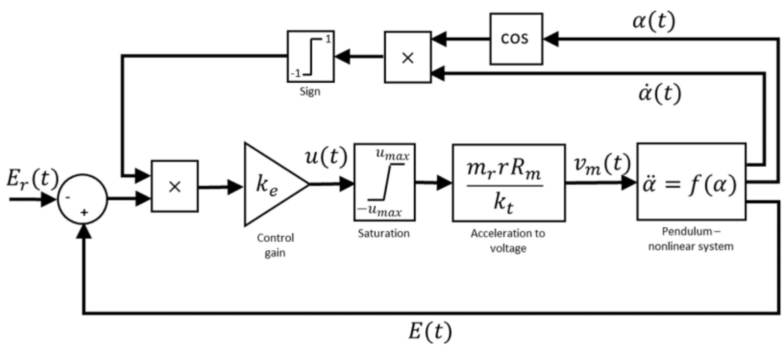
Hybrid Swing-Up Control

The energy swing-up control of the pendulum using proportional control law is $u = (E - E_r)\dot{\alpha}\cos\alpha$, as described in the concept review. It can be combined with a blaancing control such as the ones described in previous labs such as Balance, Pole Placement and LQR control labs to obtain a system that swings up the pendulum and then balances it.

Similarly as described in the Balance Control lab, the balance control is to be enabled when the pendulum is within ± 20 degrees. When it is not enabled, the swing-up control is engaged. Thus, the switching can be described mathematically by

$$\begin{cases} u_{bal} & if\ |\alpha| - \pi \leq 0.345\, rad \\ u_{swing\_up} & otherwise \end{cases}$$

The block diagram of the swingup nonlinear control is



Getting started

In this lab, you will explore the different inputs to the swing-up control system. This will develop the intuition behind adjusting different parameters and their effects on the system response. Then, you will tune the energy based controller to swing up the pendulum into the balance controller.

Ensure you have completed the following labs

- **SP5_ Pendulum Modeling Labs**
- **Any of the following: Pendulum Balance Control, LQR Balance or Pole Placement Control**

Before you begin this lab, ensure that the following criteria are met.

- If using a physical Qube-Servo 3, make sure it has been setup and tested. See the Qube-Servo 3 Quick Start Guide for details on this step.
- Make sure the pendulum attachment is set up and connected to the Qube-Servo 3 using the cable to the Encoder 1 port. Turn the plug to make sure the pendulum is centered around the front of the Qube at 0˚. The resistance from the cable will help keep it in the desired position.
- If using the virtual Qube-Servo 3, make sure you have Quanser Interactive Labs open in the Qube 3 - Pendulum → Pendulum Workspace.
- You are familiar with the basics of Simulink. See the Simulink Onramp for more help with getting started with Simulink.