

Qube-Servo 3

Swing-Up Control

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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)。

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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

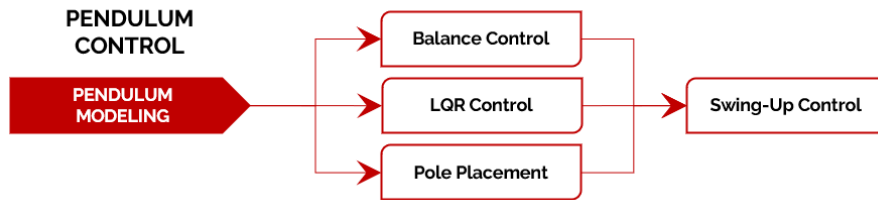
Why explore Swing-Up Control?

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)

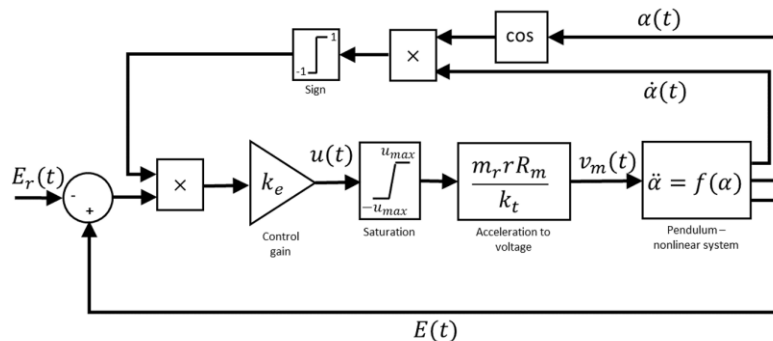
Hybrid Swing-Up Control

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 balancing 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

$$\begin{cases} u_{bal} & \text{if } |\alpha| - \pi \leq 0.345 \text{ rad} \\ u_{swing_up} & \text{otherwise} \end{cases}$$

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.