Vehicle Cruise Control

Topics Covered

- Basic data gathering using QUARC®
- PI speed control of a DC motor

Prerequisites

- The QUBE-Servo 2 has been setup and tested. See the QUBE-Servo 2 Quick Start Guide for details.
- Inertia disc load is on the QUBE-Servo 2.
- You are familiar with the basics of Simulink®.

Note: This workbook contains a single independent laboratory experiment as an introduction to the QDS platform. If you are interested in the complete QDS platform, please contact info@quanser.com

1 Background

1.1 Quanser® HIL Driving Simulator

The Quanser® HIL Driving Simulator (QDS) is a modular and expandable Simulink® model of a car driving on a closed track. The model is intended as a platform for the development, implementation and evaluation of a variety of control systems. The QDS consists of a variety of components that are integrated together to create a representation of a vehicle being driven on a track. One possible configuration is shown in Figure 1.1. The model utilizes the QUARC® environment to facilitate hardware-in-the-loop interfacing (HIL). The Quanser® Visualization block is also used to create an immersive visual environment for testing and evaluating controllers. Students are expected to observe and think critically about the effects of system parameters on not just the discrete plant, but the overall system.

Figure 1.1: Quanser® Driving Simulator

Some examples of the real-world control problems that can be addressed using the QDS include parking assist systems, radar guided cruise control, active suspension, traction control and autonomous navigation.

1.2 Electronic Throttle Control

Electronic throttle control (ETC), traction control and cruise control have become standard features on modern cars. More recently, with the advent of radar-guided cruise control, and pre-crash systems electronic vehicle control units have begun to play an increasingly critical role in the real-time control of vehicle speed. Though the implementation of these systems can be complex, the essential system can be viewed as a closed-loop speed controller that sends throttle commands to the engine, shown in Figure 1.2.

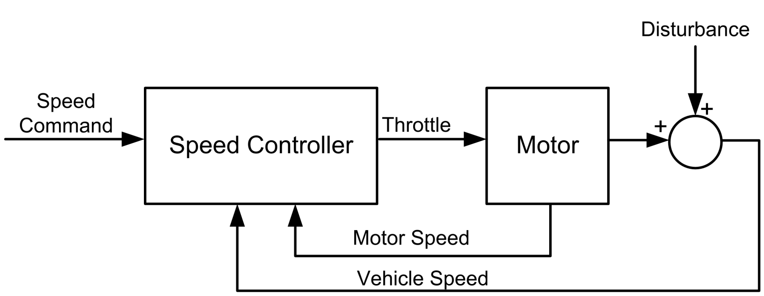

Figure 1.2: ETC controller

1.3 DC Motor Speed Control

For this laboratory, you will use the QDS in conjunction with a QUBE-Servo 2 to develop a Proportional-Integral (PI) speed controller to regulate the speed of the simulated vehicle. This exercise is analogous to developing an ETC for an electric vehicle, shown in Figure 1.3. In this case, the disturbance to the speed of the vehicle is the slope of the road, which is converted into a voltage and added to the control command. The controller that you will design takes the actual speed of the QUBE-Servo 2 motor as the derivative of the encoder measurements, and the commanded speed from the internal driver controller in the QDS. The PI controller then outputs the motor voltage V_m, which is added to the slope of the road and sent to the QUBE-Servo 2. The slope of the road is provided by the sensors inside the QDS.

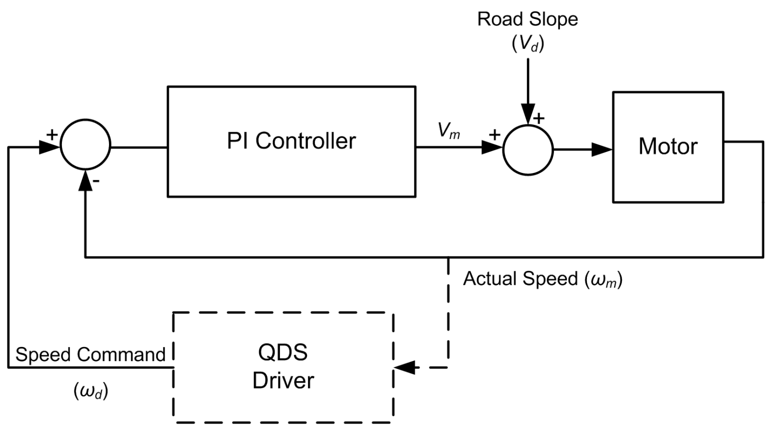

Figure 1.3: QDS speed controller

1.4 PI Control

The PI controller is one of the most common control algorithms. It combines the error reduction of proportional control, with the offset elimination of integral control. The proportional term tracks the instantaneous error, while the integral term controls the offset by tracking the total error over time. The longer there is error in the system, the more the integral term tries to compensate. Though the lack of a derivative term can cause overshoot and a longer settling time, for systems with simple dynamics the algorithm can provide near-optimal performance with no steady-state error.

In the time-domain, the linear behavior of a PI controller can be described by:

$$u(t) = k_p(r(t) - y(t)) + k_i \int_0^t (r(t) - y(t))dt \tag{1.1}$$

where u(t) is the control signal, r(t) is the reference, and y(t) is the measured process output.

2 In-Lab Exercise

1. Open the Quanser Driving Simulator model `speed_model_qds.mdl`.
2. Open the Engine Dynamics subsystem shown in Figure 2.1.

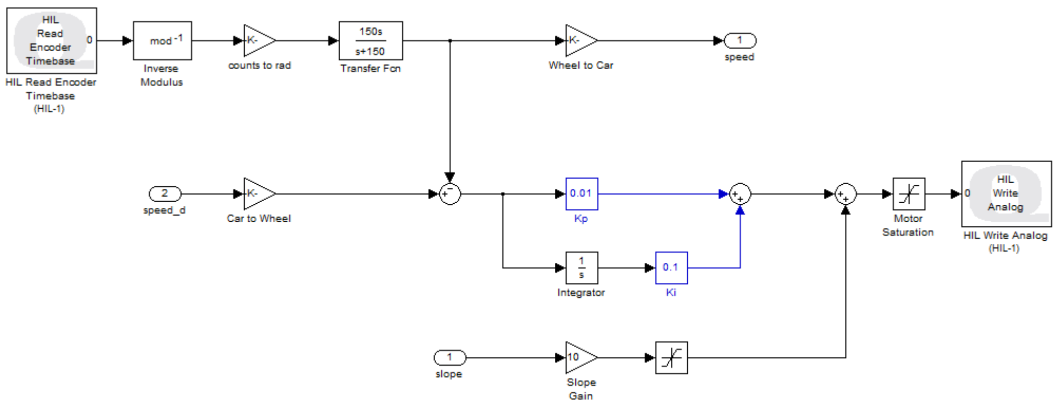

Figure 2.1: QDS speed control subsystem

3. If the car has 18 in rims and 1 in tires, derive the value of *Car to Wheel* in the Speed Control subsystem block diagram. This gain converts the car speed in $\mathrm{m/s}$ to wheel rotational speed in $\mathrm{rad/s}$.
4. Enter a k_p gain of 0.3 into the Kp *Slider Gain* block, and a value of 0 into the Ki *Gain* block.
5. Build and run the QUARC® controller.
6. Observe the performance of the car as it makes a lap of the track.
7. Set $k_p = 0.08$ and $k_i = 0.56$ and run the simulation.
8. What do you observe about the performance of the vehicle in both cases?
9. Add a Scope to the subsystem to plot the controller error (desired vs. actual speed).
10. Rebuild and run the simulation.
11. Is the controller able to track the desired speed effectively?
12. Change the gain of the slope disturbance in the Slope Gain block to 0.
13. How well is the controller able to track the speed command if the disturbance is eliminated?
14. Delete the connection between the desired speed signal input speed_d and the Car to Wheel block. Replace the desired speed command with a constant value of 50 m/s.
15. Reset the Slope Gain block back to the original gain of 10. Rebuild and re-run the simulation.
16. How well is the controller able to compensate for the slope disturbance? How does this compare to the setpoint tracking performance?
17. If necessary, re-tune the controller gains to achieve the desired performance.
18. Record the final control gains and response plots.
19. Stop the QUARC® controller.
20. Power *OFF* the QUBE-Servo 2.

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