# Using the Filter Factor as Part of the PID Controller Design

Brad Gilkison, Aaron MidKiff, Alex Bush; Advisors: Dr. Yousef Sardahi, Dr. Almuatazbellah Boker

Marshall University

## Motivation

Proportional-integral-derivative (PID) controllers are used in many control system applications. However, most of these controllers do not use the filter factor as a design parameter. PID controllers should be tuned as four parameter systems using the filter factor as parameter instead of as a three parameter system.

## Introduction

When designing a feedback control loop, certain performance goals need to be met, such as percentage overshoot, peak time, rise time, or settling time when a step input is applied to the closed-loop system. A common feedback control loop is the PID controller. In most PID systems, only the proportional, integral, and derivative gains are tuned and the derivative filter factor is either set to a default value or determined experimentally. However, tuning this filter factor along with the three gains can improve the stability and response of the controller. We present a simple PID controller using this filter factor on a Quanser servo motor.



Figure 1: Quanser Rotary Servo Base Unit

## PID Control System

A typical parallel PID linear closed feedback system is shown in Figure 2. R(s) is the desired output and Y(s) is the actual output. The plant being controlled has transfer function G(s) and the sensor measuring the output has transfer function H(s). W(s) is the load disturbance and V(s) is the external measurement noise. The PI block denotes the proportional integral control and the FD block denotes the filtered derivative term.
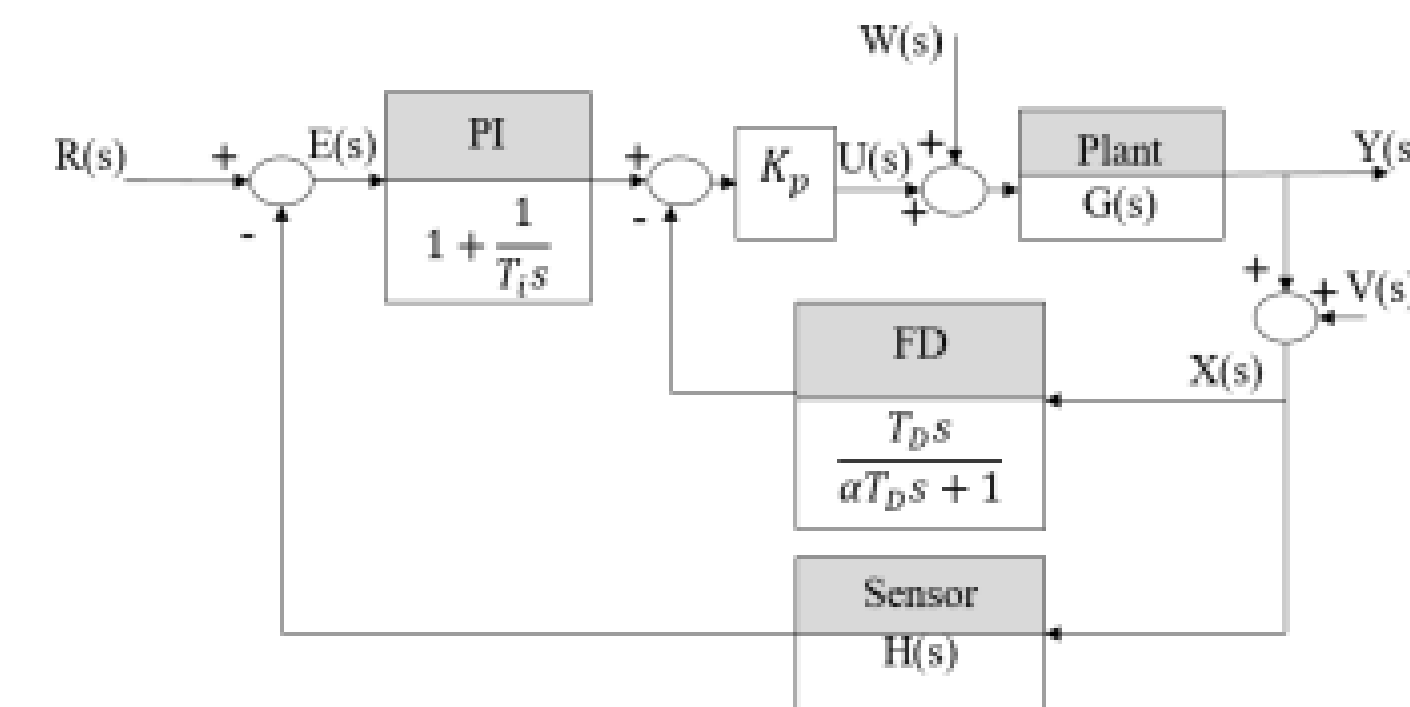


Figure 2: Parallel PID Feedback System

Equation (1) shows the PID control law. $K_p$, $T_i$, $T_D$, and $\alpha$ are the proportional gain, the integral time constant, the derivative time constant, and the filter factor, respectively. This shows that the system is affected by the filter factor.

$$U(s) = K_p\left[\left[1 + \frac{1}{T_i s}\right]E(s) - \frac{T_D s}{\alpha T_D s + 1}X(s)\right] \quad (1)$$

In addition, the filter factor is significant in controlling W(s) and V(s). For example, the load disturbance sensitivity transfer function is shown in Equation (2). F(s), which contains the filter factor, is shown in Equation (3). Therefore, the filter factor is essential in minimizing the effect of W(s) and V(s).

$$LDSTF = \frac{G(s)}{1 + C(s)G(s)F(s)} \quad (2)$$

$$F(s) = H(s) + \left(\frac{T_D s}{\alpha T_D s + 1}\right)\left(\frac{T_i s}{1 + T_i s}\right) \quad (3)$$

## Simulink Design

To show the effect of the filter factor, a PID controller was coded in Simulink. The Simulink file controlled the Quanser Rotary Servo Base Unit shown in Figure 1. Figure 3 shows the block diagram of the entire Simulink model. Figure 4 shows the actual PID controller, which includes the filter factor block.
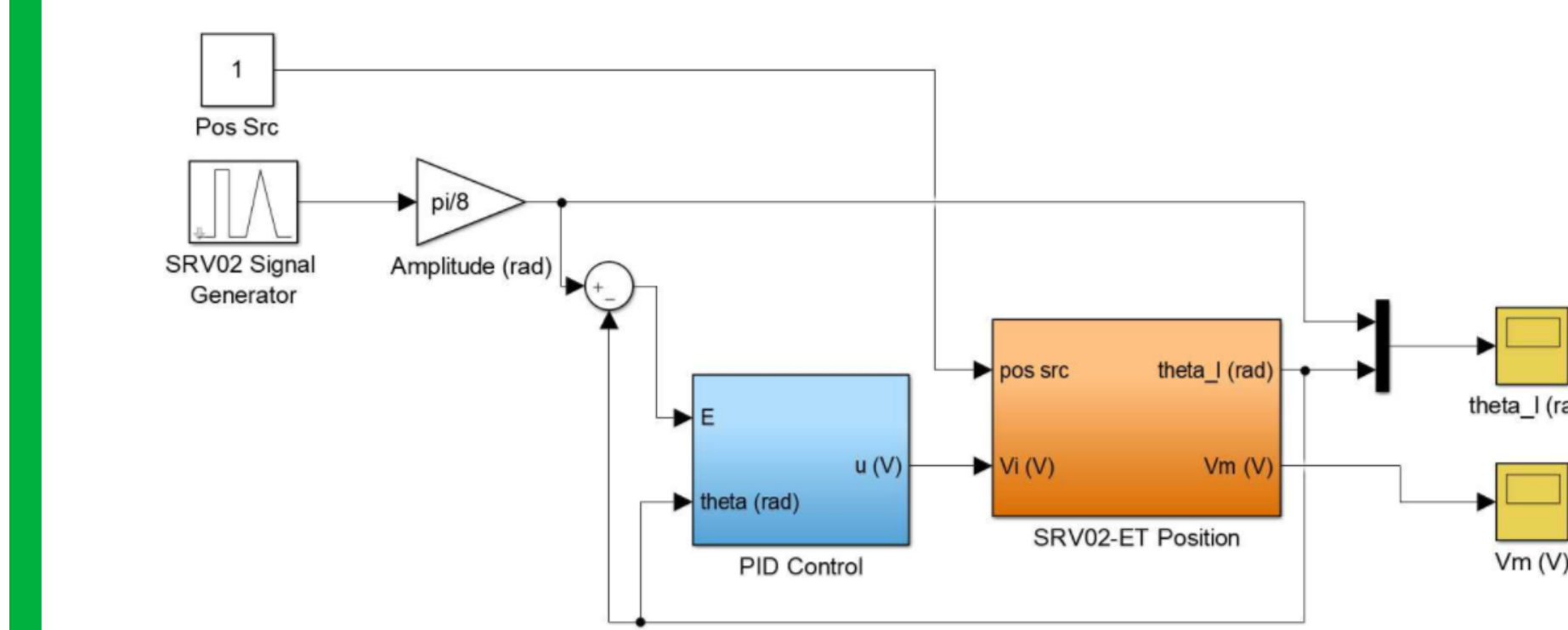


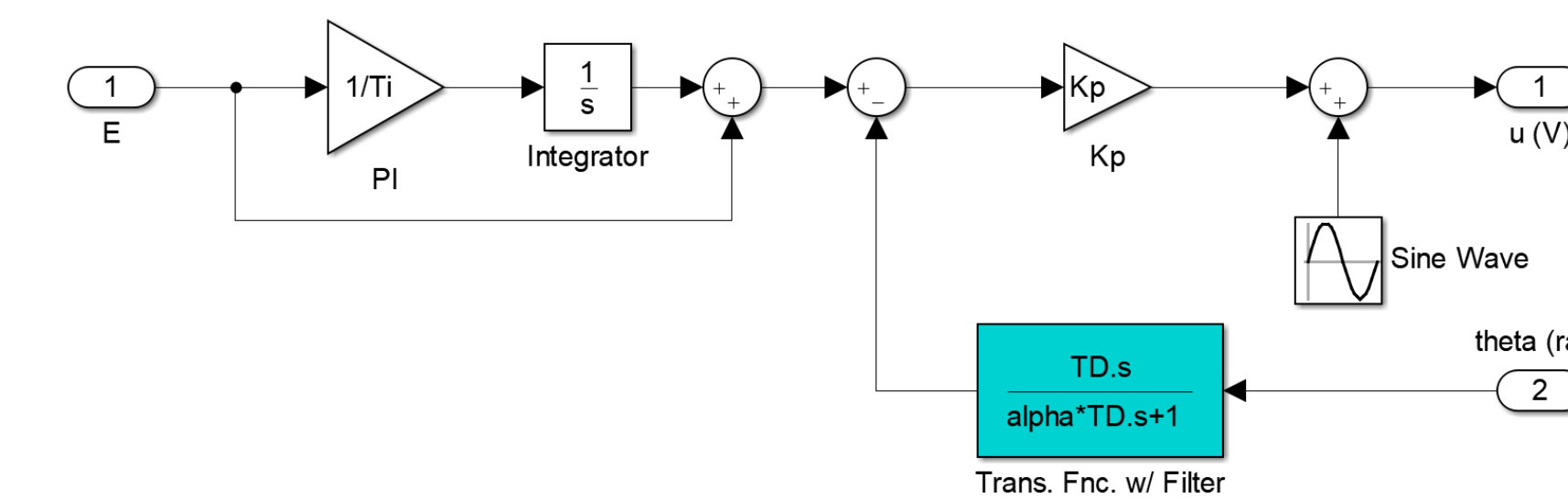Figure 3: Block Diagram of Quanser System



Figure 4: Block Diagram of PID Controller with Filter Factor

## Results

First, the simulation was ran without the filter factor. The output is shown in Figure 5. Next, the filter factor was added and the output is shown in Figure 6. Load disturbance, W(s), was simulated by adding a sine wave.
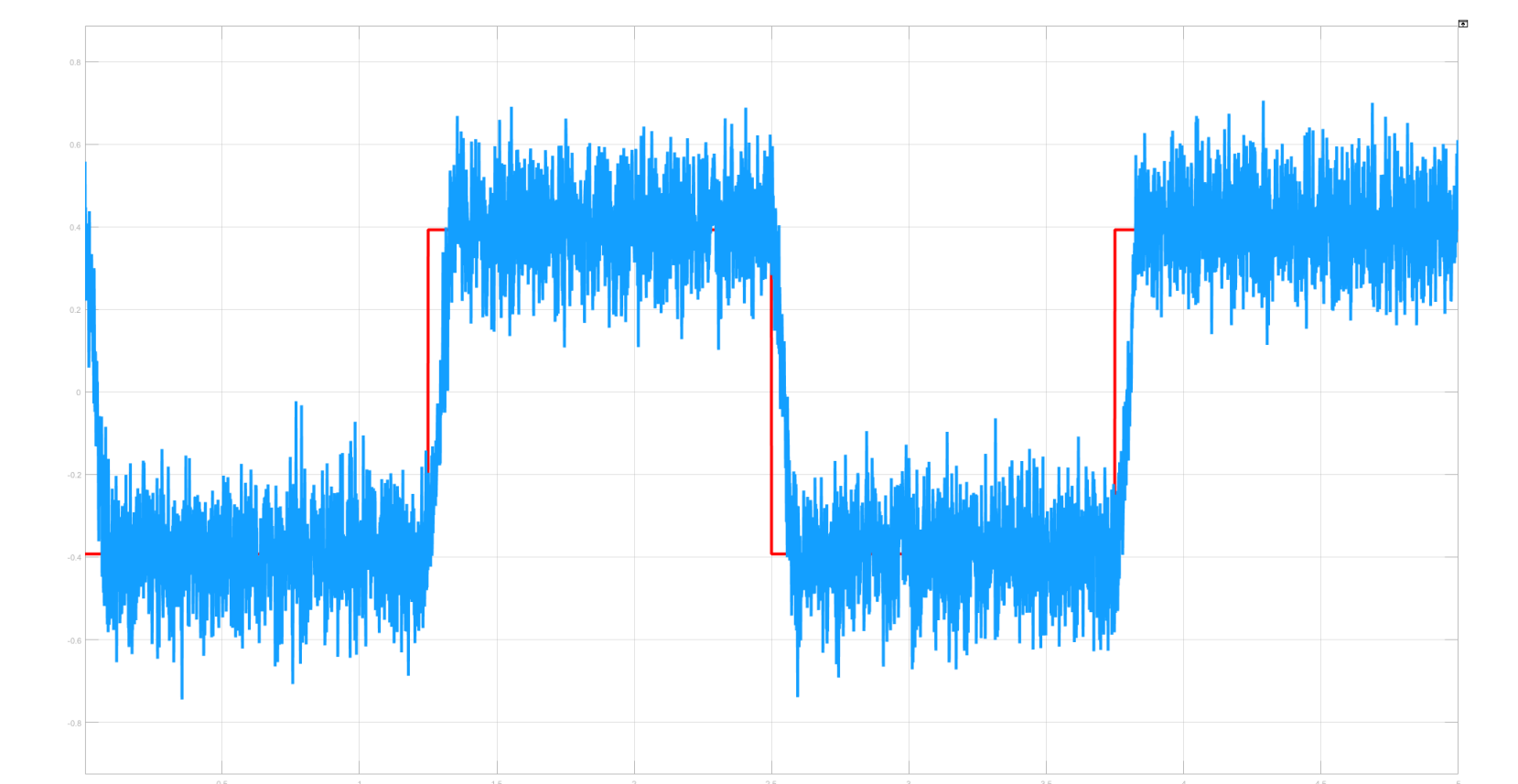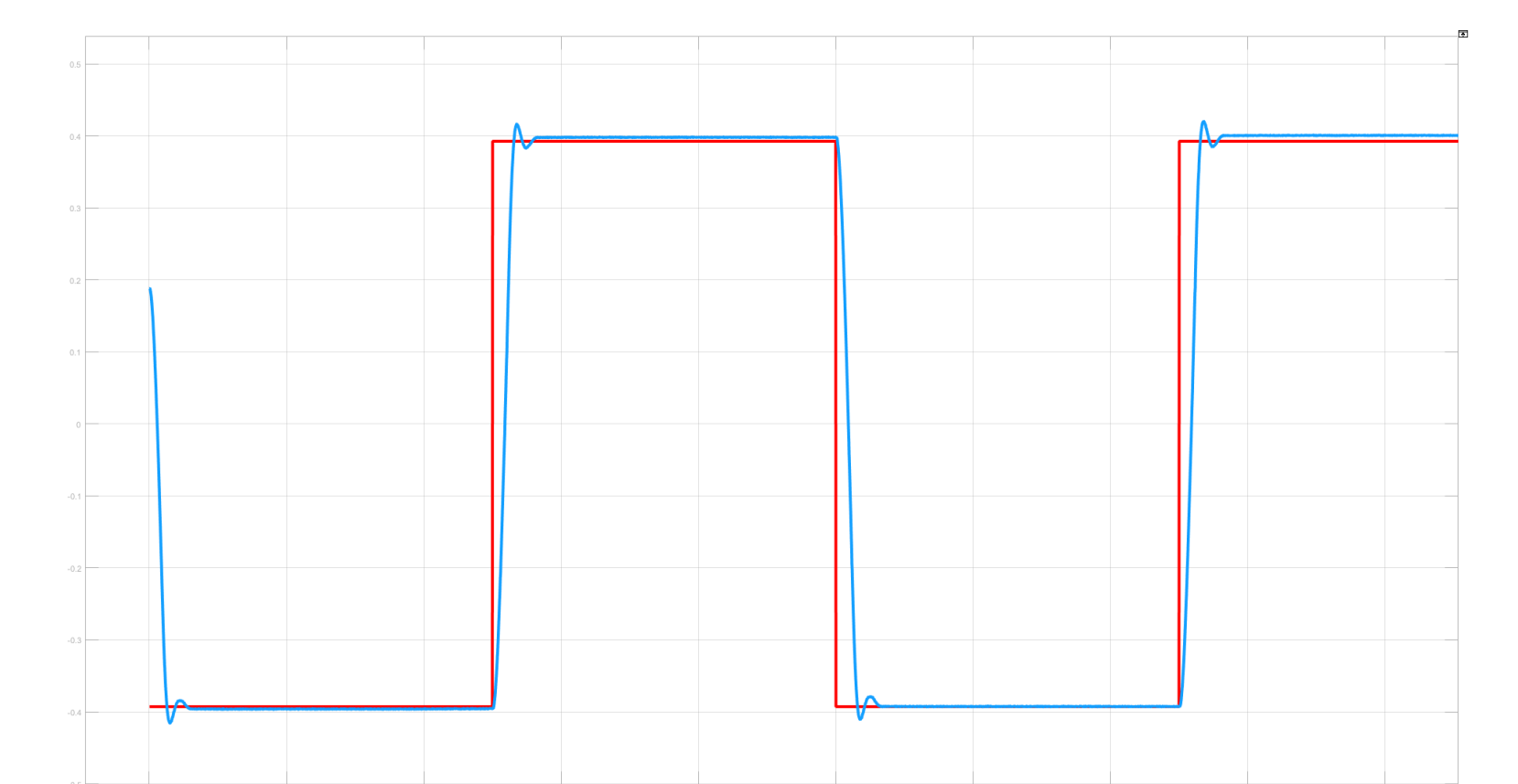


Figure 5: Output without Filter Factor



Figure 6: Output with Filter Factor

By comparing Figure 5 and 6, it is shown that adding the filter drastically reduces noise.

## Conclusion

This concept has many uses in industry. For example, the engine of a jet is extremely susceptible to noise. By designing a control system that accounts for the filter factor, this noise can be significantly reduced. Also, by optimizing all four factors in the PID controller, a system can be designed to decrease the offshoot while increasing the settling time. With the correct optimization, the most desired performance goals can be achieved.