Final Design Report Addendum

Helium-Filled Blimp Flight Control

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Certain modifications had to be made to the final code during the testing of the *LITEC Blimp*. The proportional and derivative gains had to be altered due to inherent differences in frictional factors between the lazy Susan and the blimp. The printf statements also had to be changed in order to get accurate results from the radio transmitter. The error correction term within the steer rudder function was also modified.

In the previous version of the code, two if statements within the steer rudder function corrected the magnitude of the error. Because the heading error cannot be greater than ±180°, the calculated error term must be changed so that the gondola will take the shortest path to achieve the desired heading. To accomplish this, the code must be able to read a negative error and then correct for it. The previous code implemented two if statements:

```
if (error < -1800)
      error = 3600 + error;
if (error > 1800)
      error = 3600 – error;
```

While the first statement is correct, the second will shift the error in the wrong direction. Instead of shifting error to some negative angle, the error ends up positive. The blimp responds by spinning in circles if it overshoots too much. In addition, this code caused the pulse widths for the fans to always be greater than the neutral pulse width. When it overshot, the blimp would rotate in only one direction. To correct for this inefficiency, the signs within the invalid statement were changed so that 3600 is subtracted from errors greater than 1800. For these errors, the error term becomes negative and corrects for big overshoots. The PD control was able to work properly because of this sign correction.

When collecting data for the blimp using SecureCRT, a significant amount of noise prevented the collection of accurate data. The reason for this occurrence was due to the fact that the code was trying to print out seven columns of data every second. Each quantity being printed was approximately 4 to 5 characters in length. The average time allotted per character was approximately 30 ms. To try and correct for this, the code was modified to only print four variables instead of seven. These variables were actual heading, actual altitude, rudder pulsewidth, and thrust pulsewidth. While interference still occurred in the data collection, it was greatly reduced.

From experimenting with the gondola on the lazy Susan, it was determined that a kp value of 3 and kd value of 100 were the ideal gains for steering control. As shown below, this held true during the actual testing of the blimp.

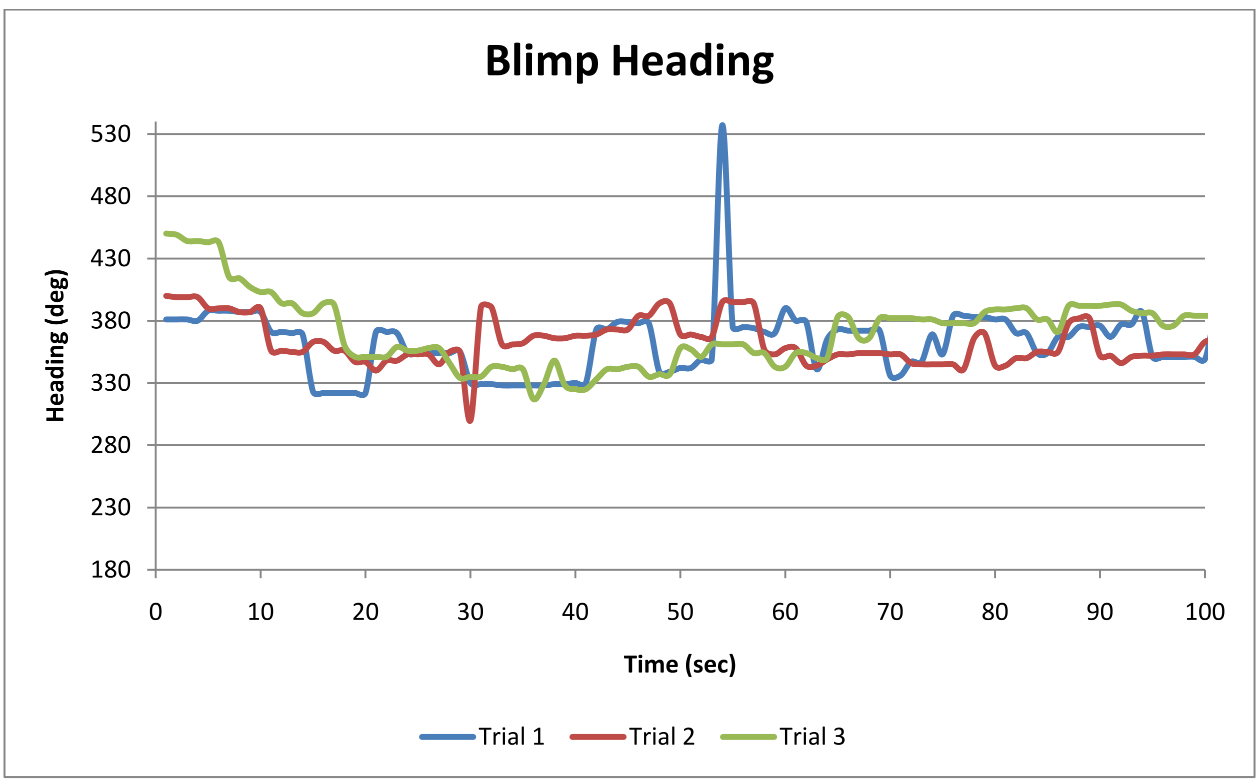

Figure 1 - Blimp Flight Headings

Although the proportional and derivative gains are the same, the most ideal result that matched our predictions from using the gondola was found in Trial 3. The gains worked excellently in achieving the desired heading because they adjust the heading quickly, minimize the degree of oscillation, and minimize the settling time. The blimp had a desired heading equal to the direction of north. The rudder fan overshoots the desired heading of 360°, but quickly corrects itself as the derivative gain dampens the system. The graphs from trials 1 and 2 show how the blimp stayed within a small tolerance of the desired heading, but did not output our desired predicted graph.

Three different sets of gains (see Table 1) were tested for the altitude.

Trial	Proportional Gain	Derivative Gain
1	50	750
2	50	210
3	20	510

Table 1 - Blimp Altitude Control Gains

The kp and kd values for the altitude were much larger than those for the heading. This is due to the fact that the error terms in the heading had a range of -1800 to 1800 while the error term for the altitude had a much smaller range from approximately -150 to 150. In order for the PD control algorithms to send an appropriate pulsewidth to the fans, the gains had to be much higher. The results for the trials are shown below.

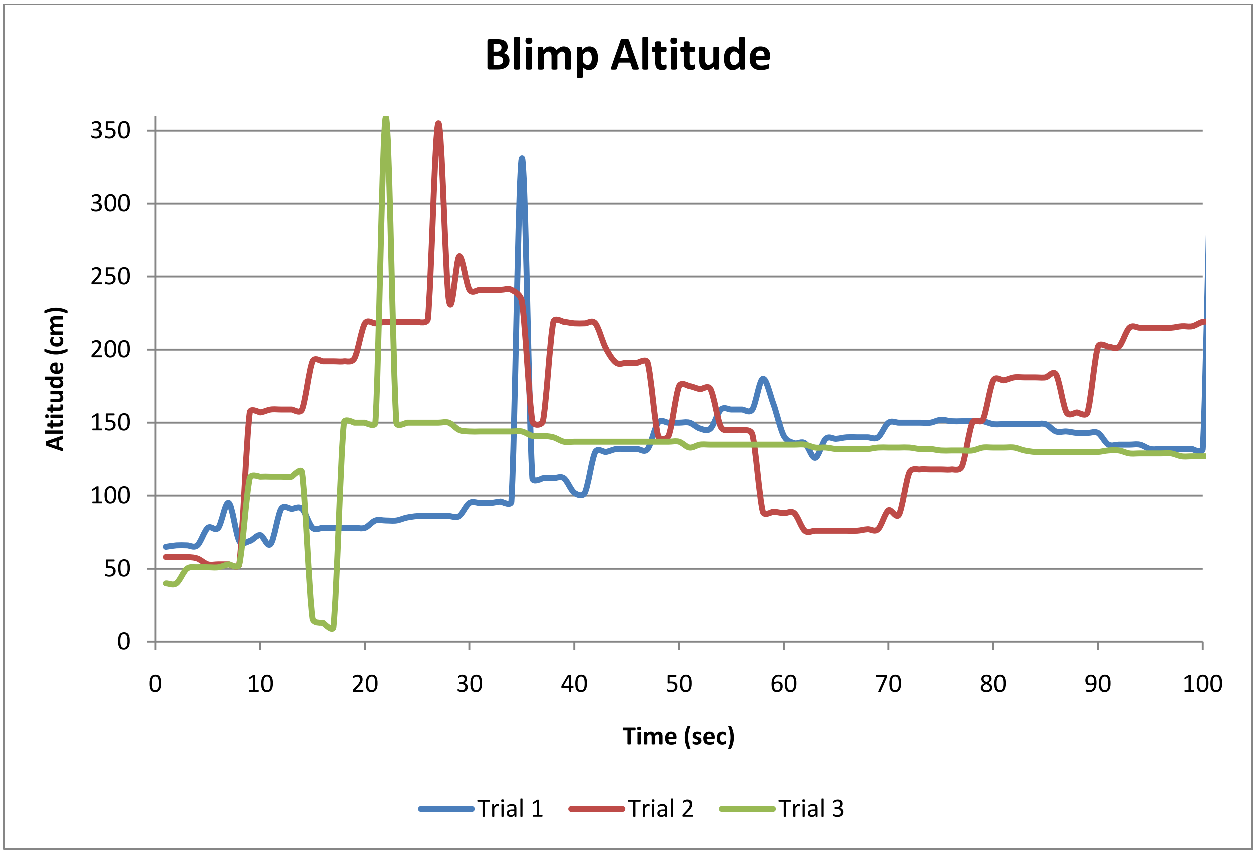

Figure 2 - Blimp Flight Altitudes

All the graphs show spikes at certain time locations. This error in the data is due to noise during the data collection using the radio frequency transmitter. For the purposes of this analysis these spikes are ignored. The data shows that the gains in trial 1 represent a critically damped system. The altitude starts around 60cm, increases and overshoots 150 by approximately 20cm and then settles to a range of 150cm. This was found to be the most ideal case. Trial 2 represents an under-damped system. The low derivative gain caused less dampening of the system while the high proportional gain caused the blimp to oscillate considerably. The altitude graph of trial 3 appears to have good gain settings, but in fact the blimp starting falling continuously after 30s. This is because the proportional gain was too low and the fans did not spin at any significant speed when the range was close to the desired range of 150cm. After analyzing each of these cases, it was concluded that trial 1 was the most ideal case and trial 2 was the worst case.

By altering the error correction term, reducing the number of variables being printed, and finding appropriate kp and kd gains through experimentation, a sufficient PD control algorithm was achieved for the blimp. Additional data for each trial regarding both steering and altitude control can be seen below.

Data and Observations

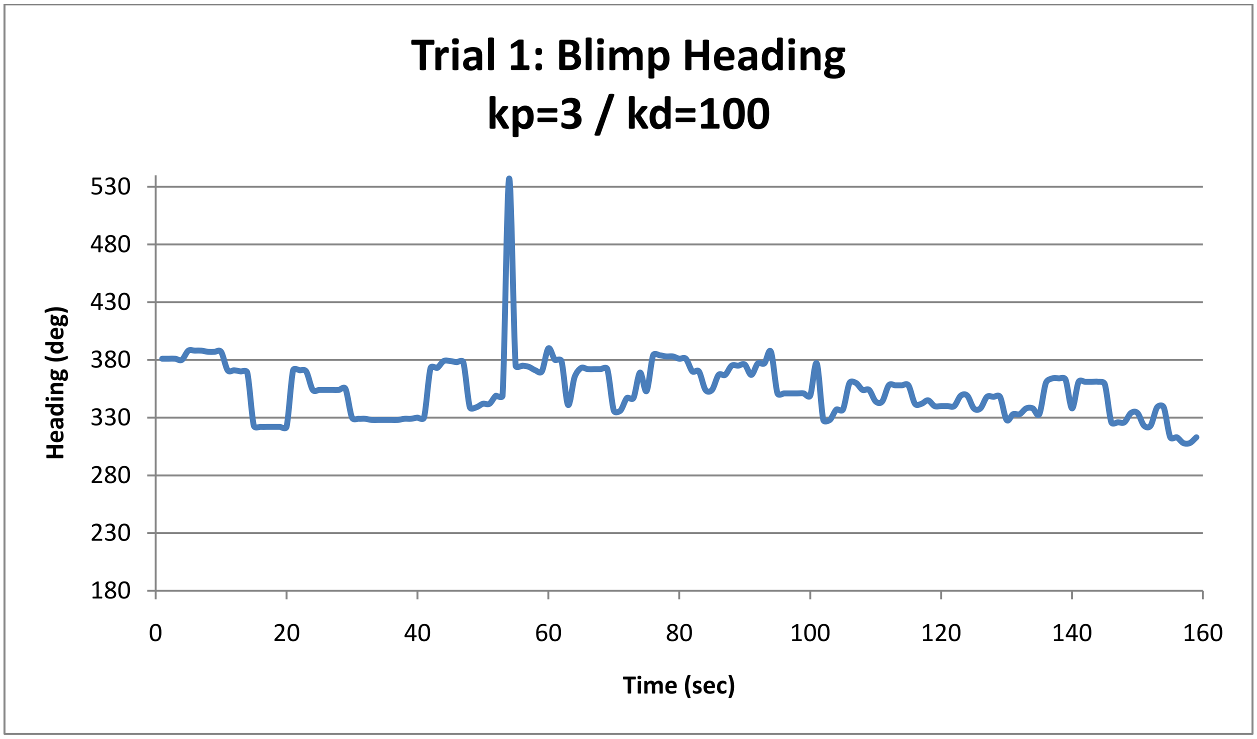

Figure 3 - Trial 1: Blimp Heading

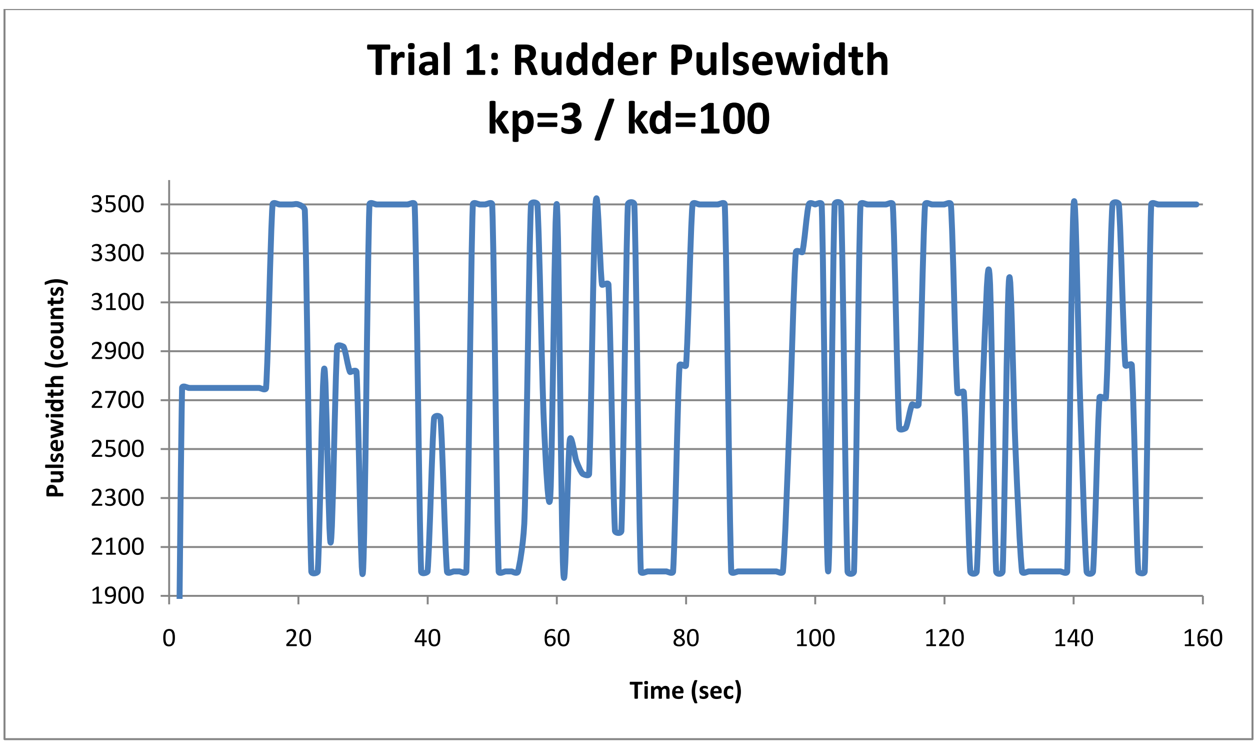

Figure 4 - Trial 1: Rudder Pulsewidth

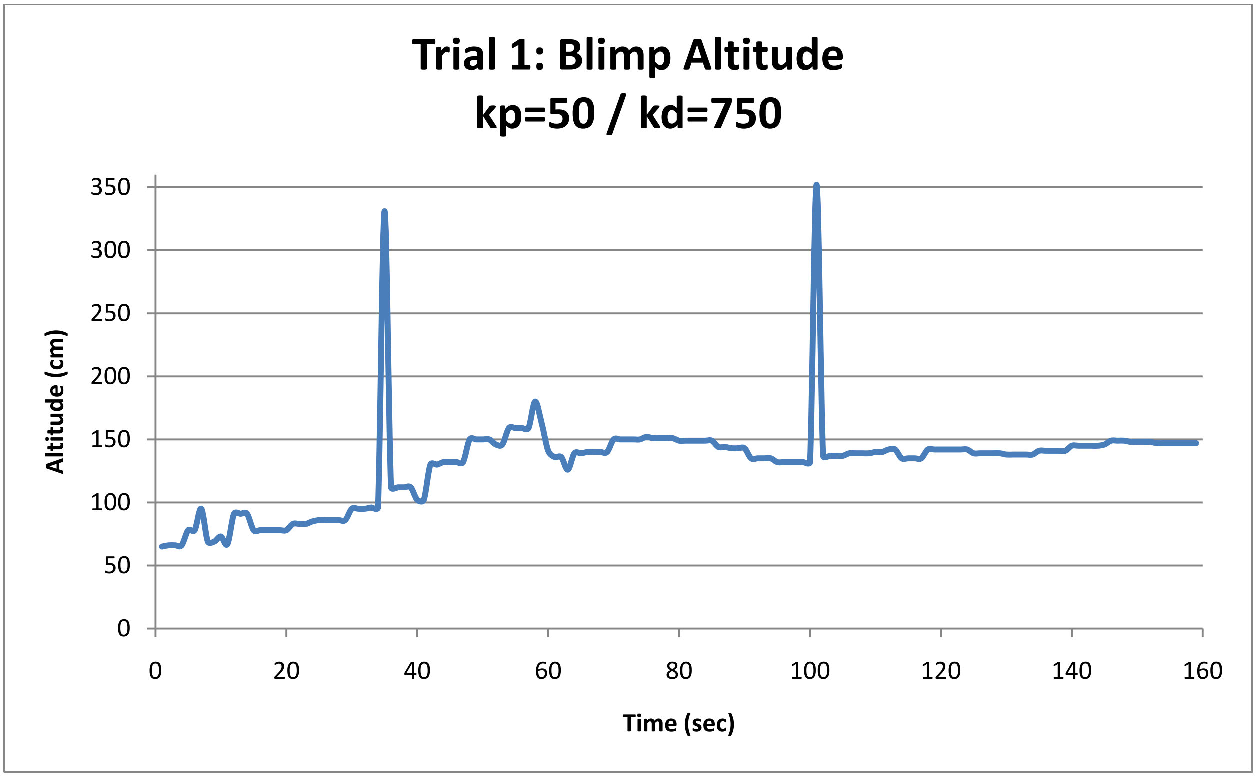

Figure 5 - Trial 1: Blimp Altitude

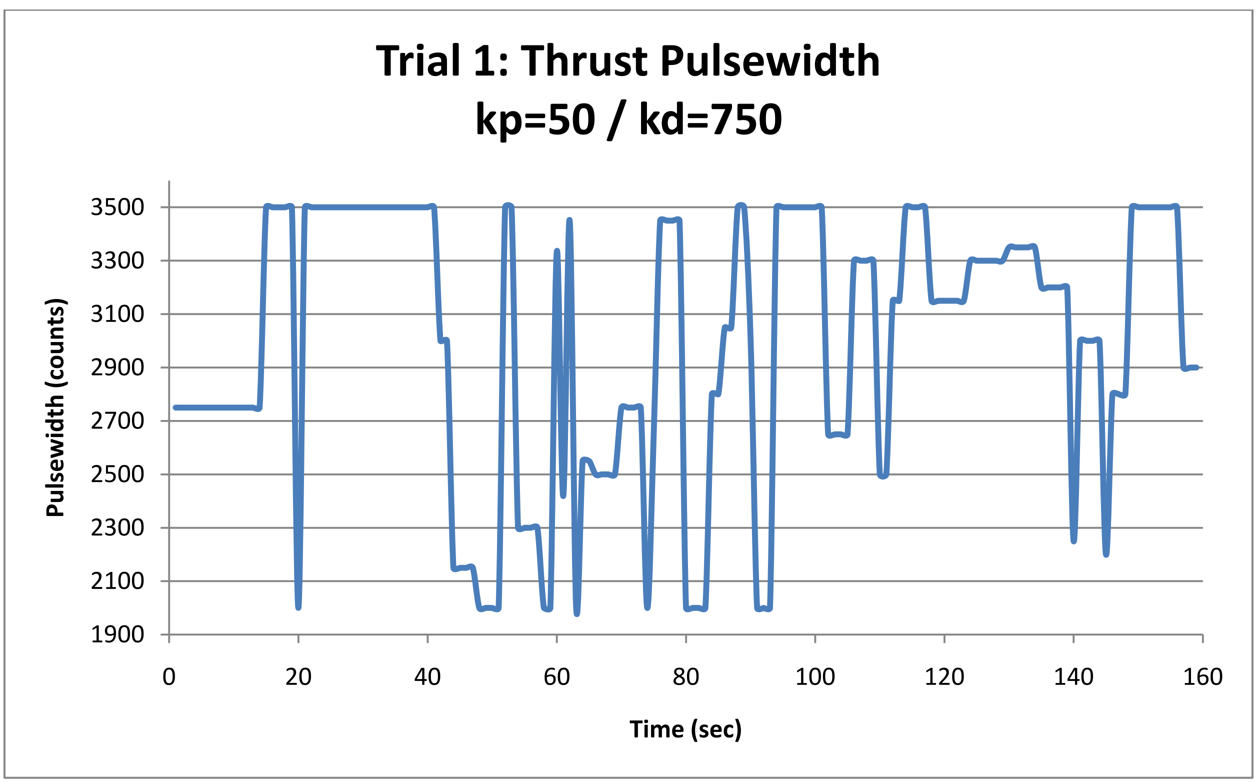

Figure 6 - Trial 1: Thrust Pulsewidth

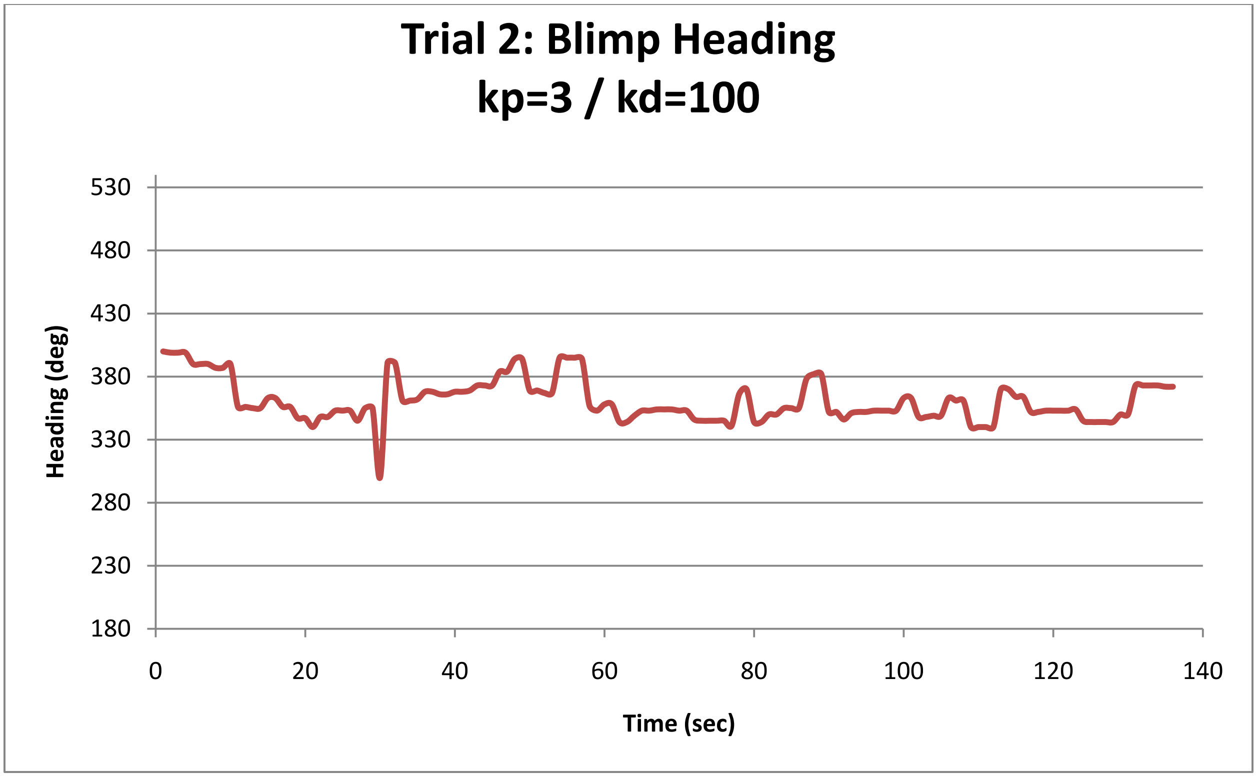

Figure 7 - Trial 2: Blimp Heading

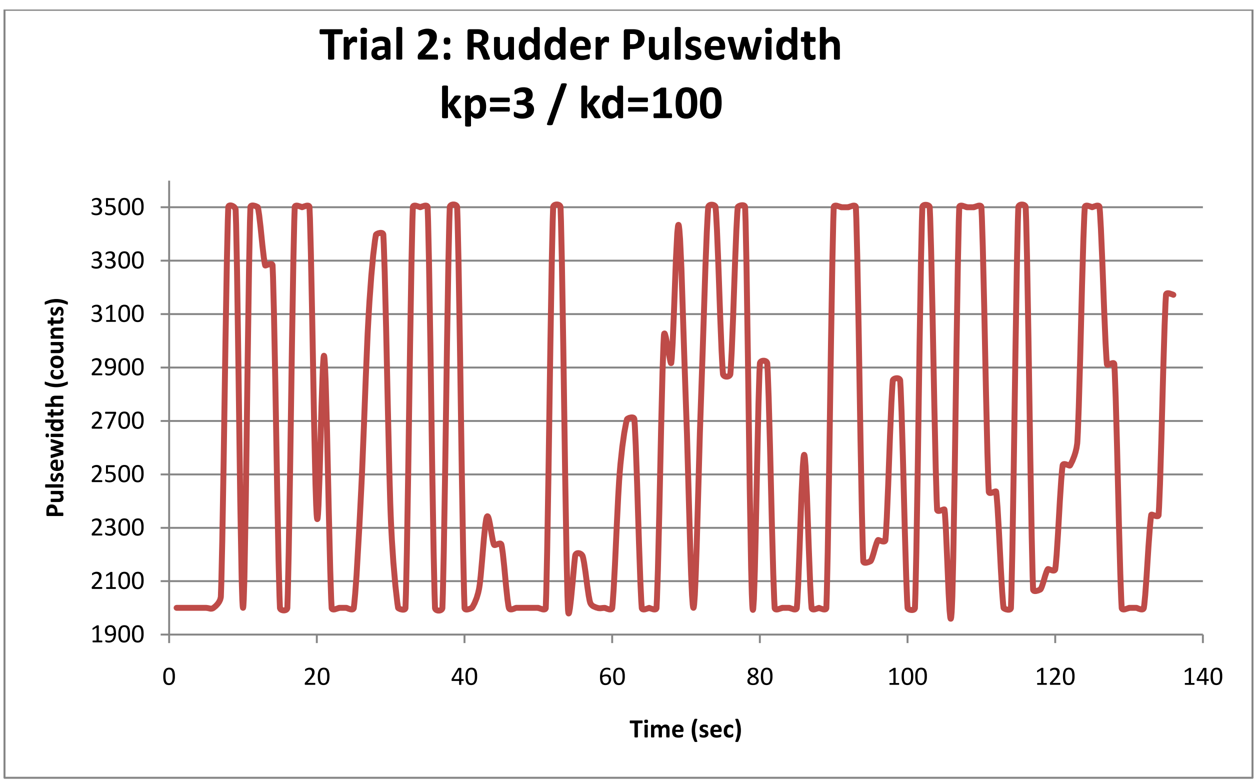

Figure 8 - Trial 2: Rudder Pulsewidth

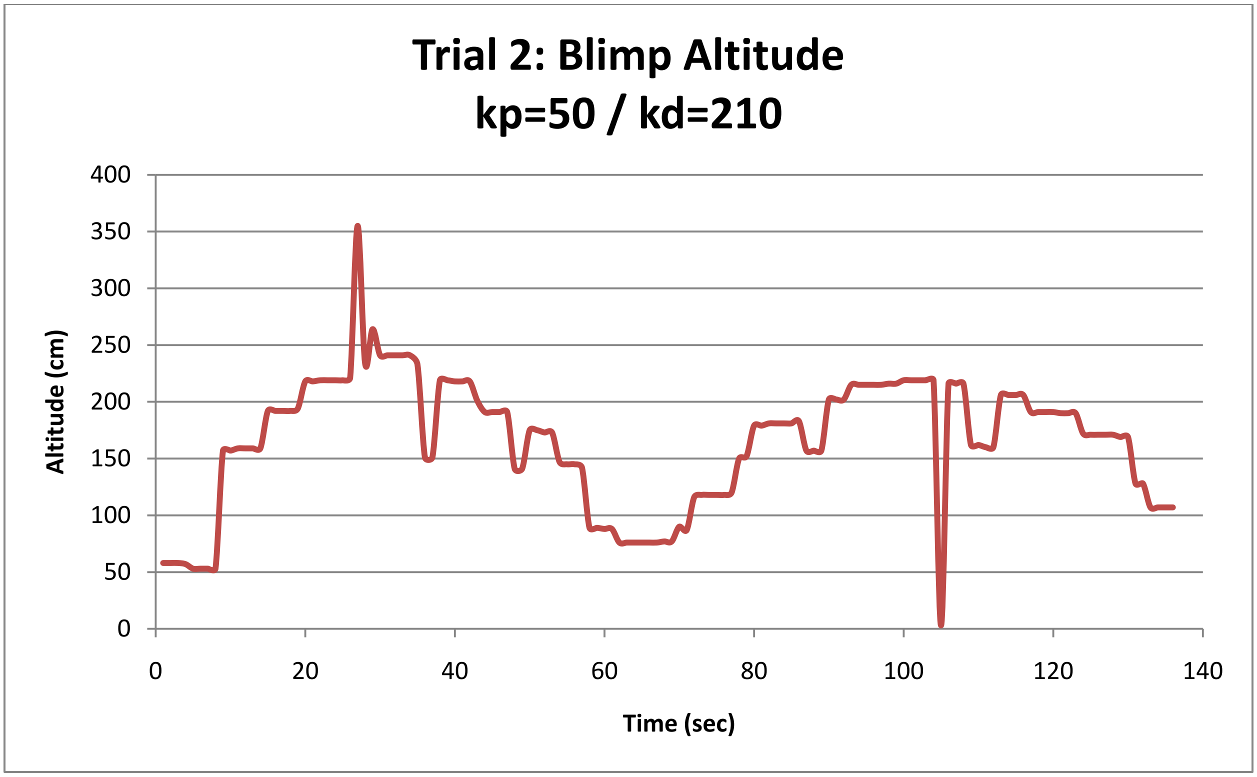

Figure 9 - Trial 2: Blimp Altitude

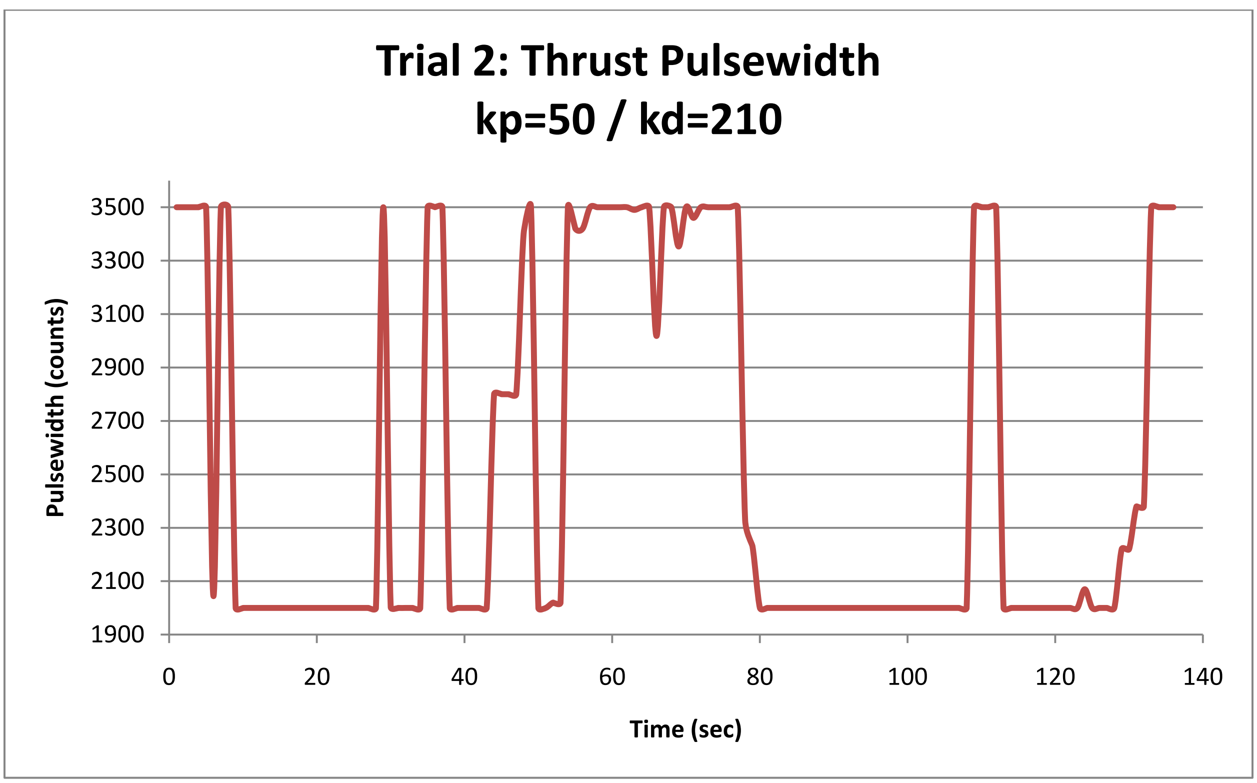

Figure 10 - Trial 2: Thrust Pulsewidth

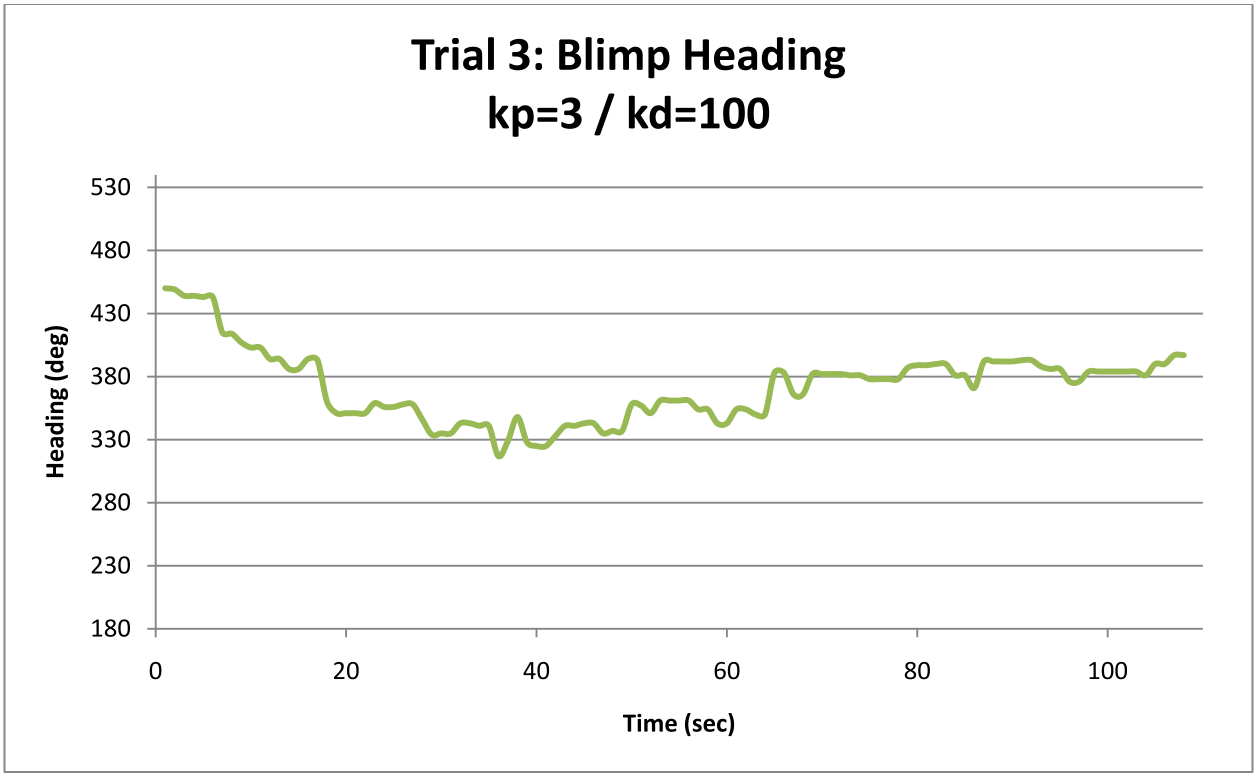

Figure 11 - Trial 3: Blimp Heading

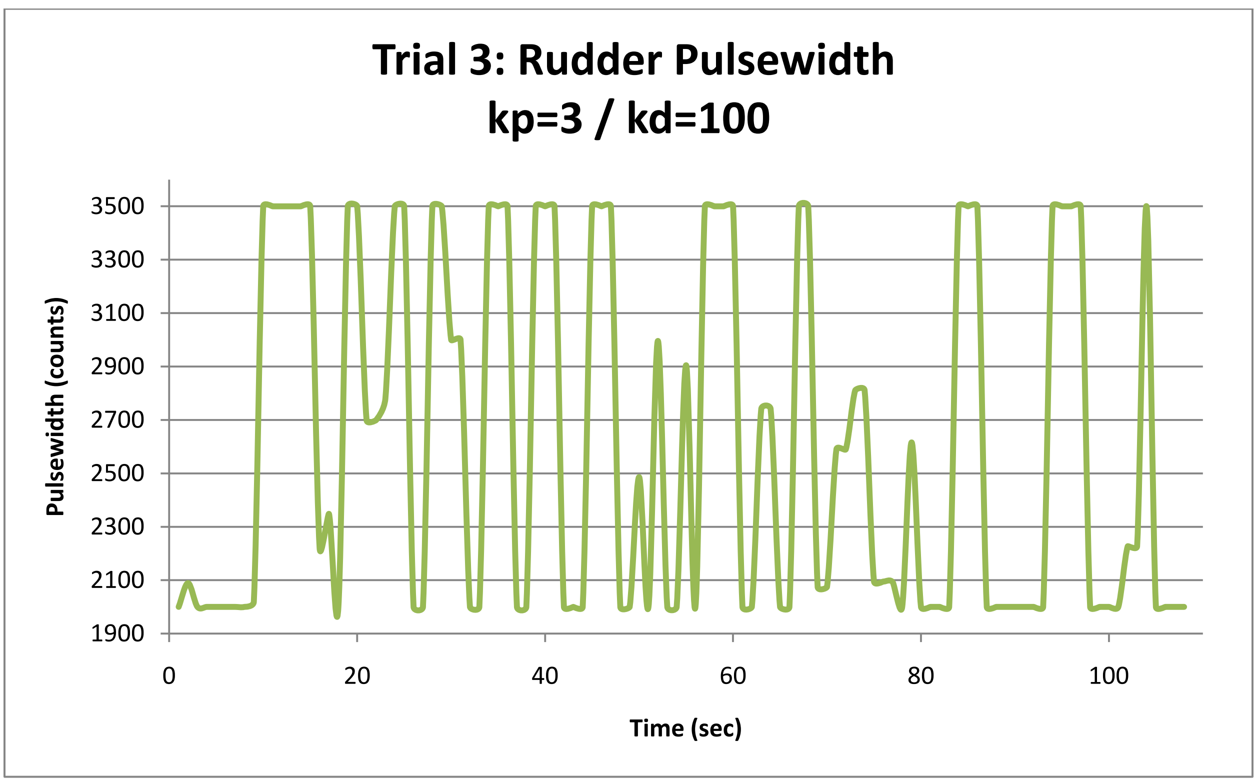

Figure 12 - Trial 3: Rudder Pulsewidth

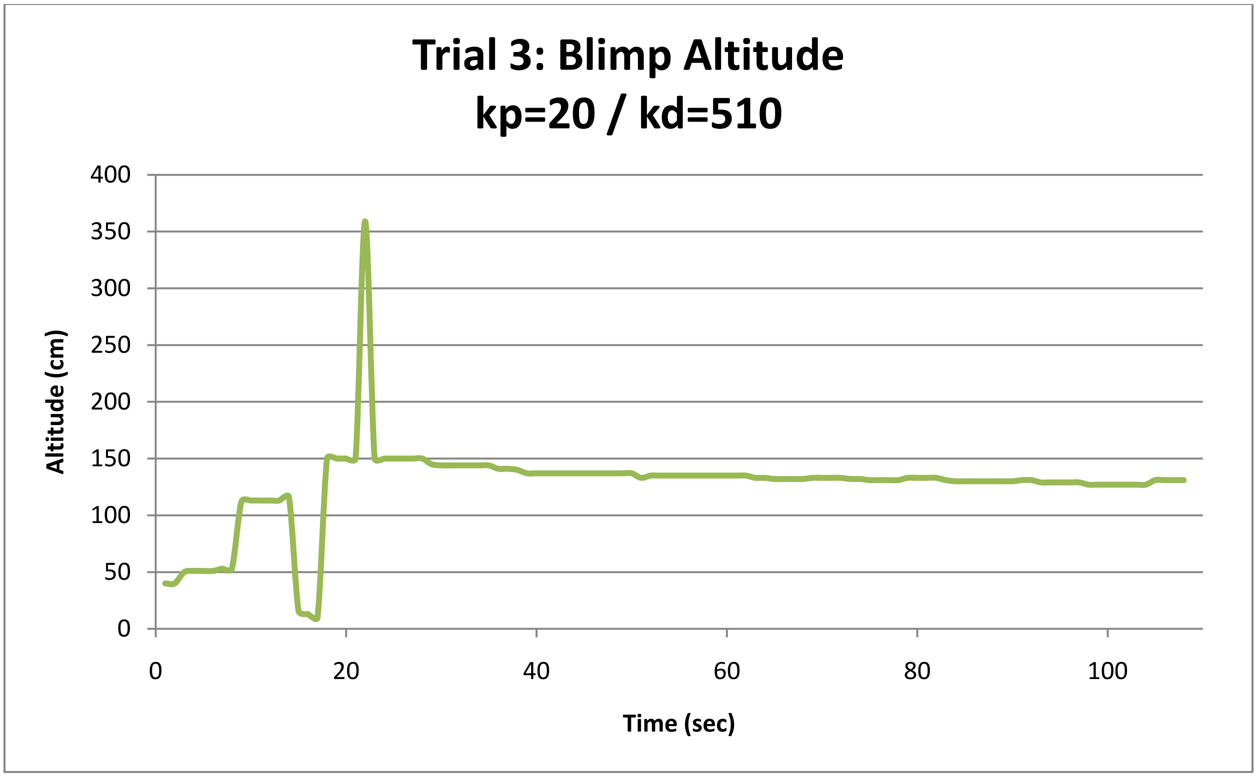

Figure 13 - Trial 3: Blimp Altitude

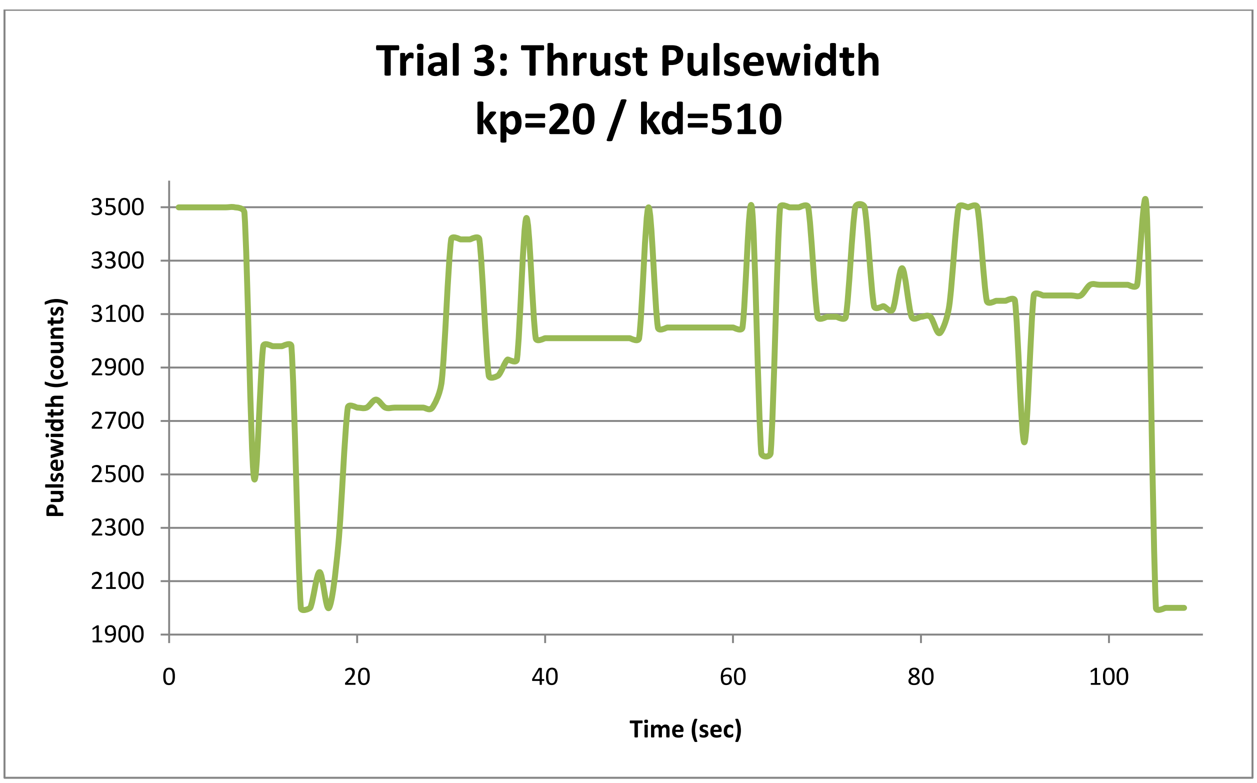

Figure 14 - Trial 3: Thrust Pulsewidth