# Backhoe Vibrations

**Problem:**

The backhoe vibrates violently when feedback control is sending a positive command to the valves & directing flow into the 'A' workports. Motion is smooth in the opposite direction. Although this problem is observed for all four functions, it is by far worst in the swing and boom joints, where mass in motion is greatest. This problem does not occur when the valves are actuated manually.

**Action:**

(a)     Measure true voltage at valve control input pins. Check if D/A card is actually producing commanded voltage.

(b)     Investigate open-loop response. Check if open-loop commands produce oscillations also.

(c)     Test the backhoe's ability to follow a trenching reference in free space.

**Results:**

(a)     The output wires from the D/A card to the swing and boom valves were connected back to the A/D card in order to measure the actual voltage being sent to the valve.
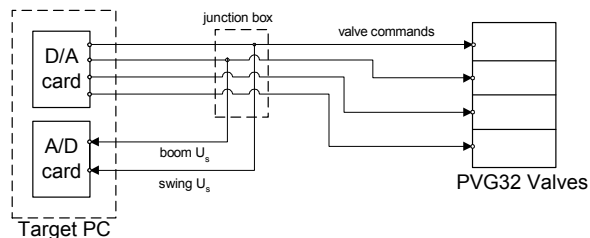


Data collected is illustrated in Figure 1 below, showing the violent oscillations. The data also shows that although the swing I/O channels have a discrepancy of about 0.05V, the D/A card is producing the voltages commanded by the controller for both the swing and boom valves. The stick and bucket valves oscillate much less and were not measured. Note that we have a 0.55V offset in our controller, which depends on the sign of the command, to compensate for the deadband in the valves. Oscillations also occurred in earlier tests before the offset was added to the controller.

(b)     The valves were given open-loop square wave commands of 0.8V at 0.7Hz. Data collected is illustrated in Figure 2 below. The data shows that the backhoe does not oscillate under open-loop control. Motion is smooth in all directions for all valves using open-loop commands.

(c)     Figure 3 shows the backhoe tracking a trenching trajectory.

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> **CONCLUSION: Valve oscillations are somehow linked to closed-loop feedback control. The question is—how?**
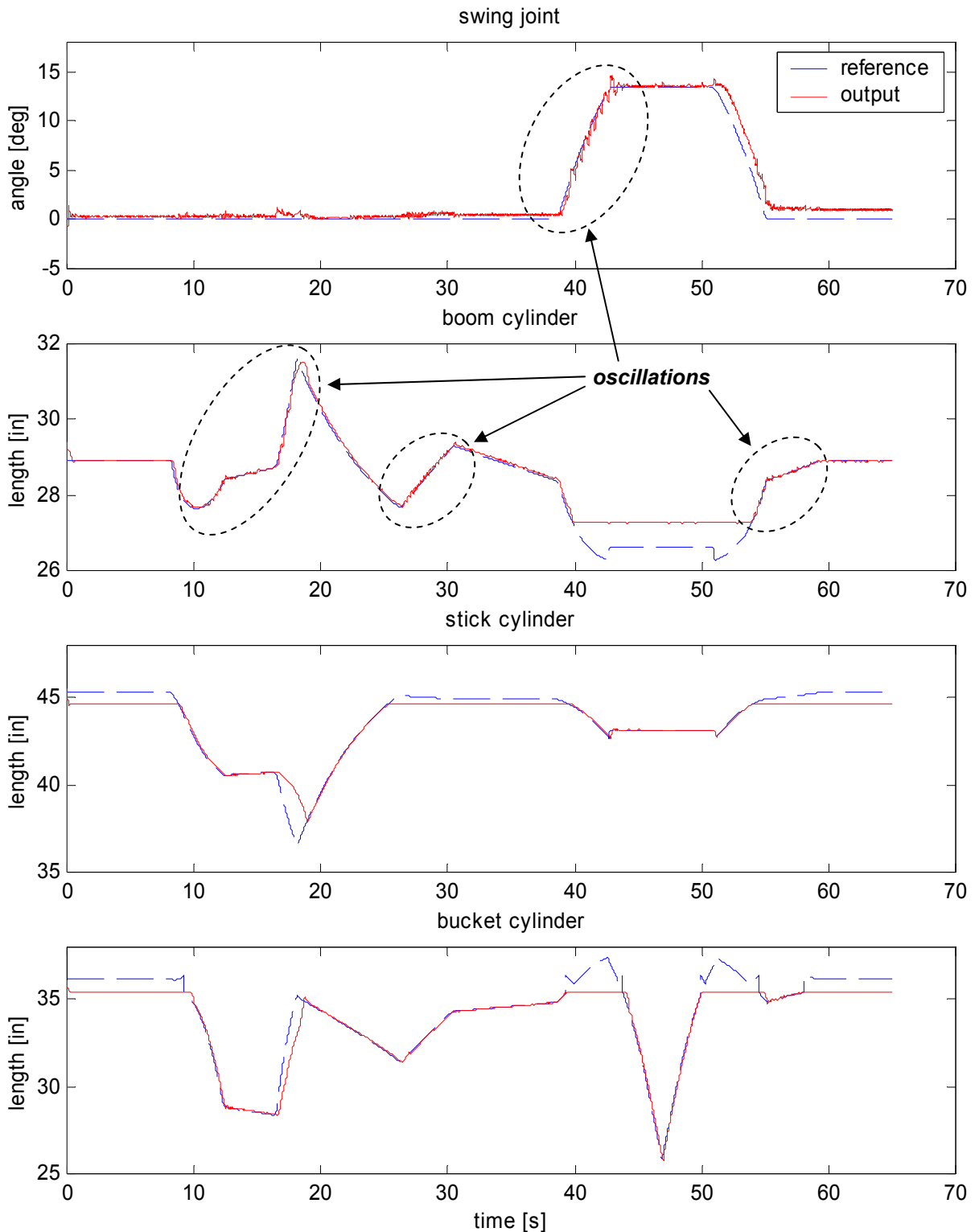
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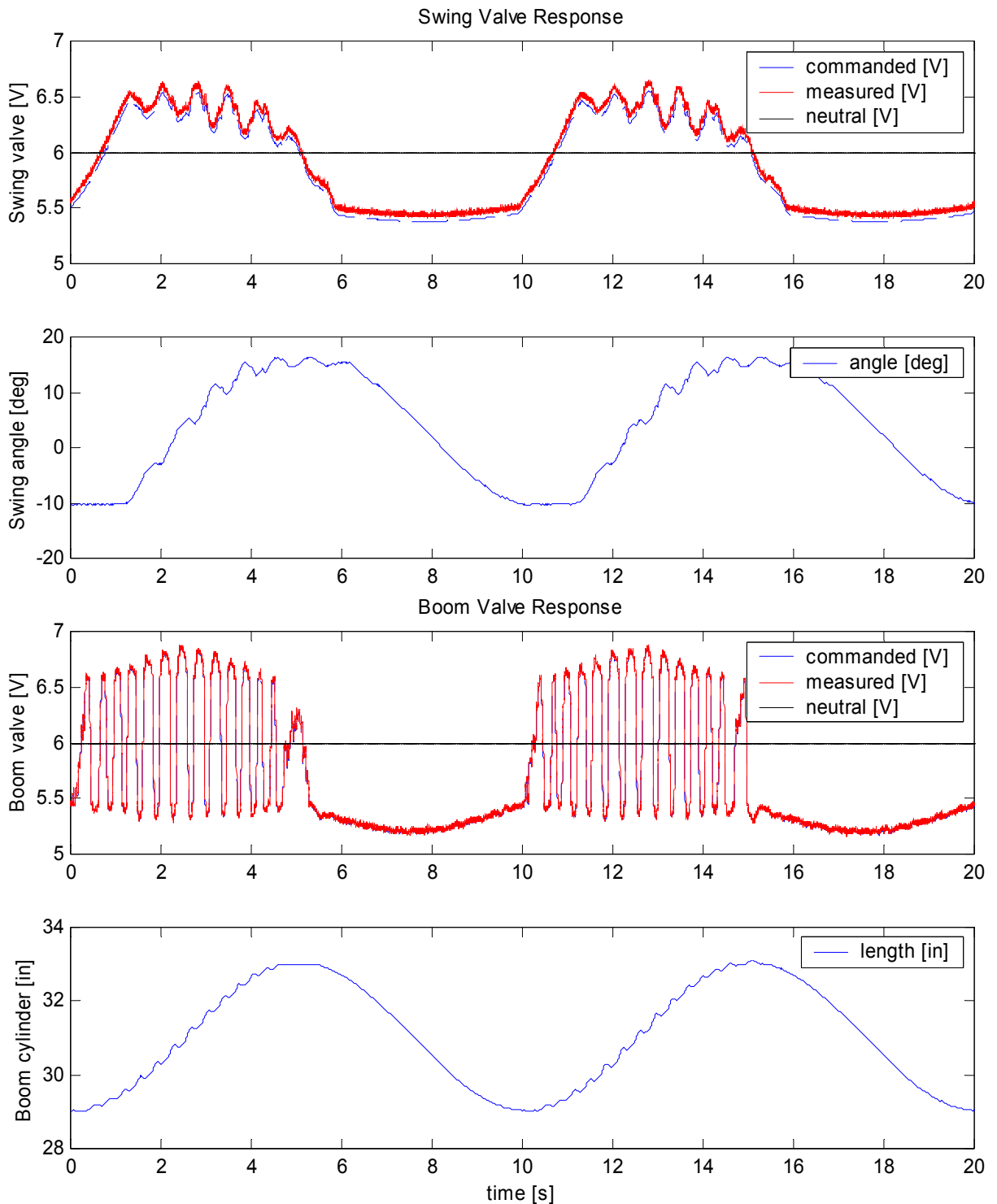
**Figure 1: Commanded vs. measured voltage**

The swing and boom oscillate violently when the controller is sending a positive signal to the valves. However, the D/A card is producing the requested signal.

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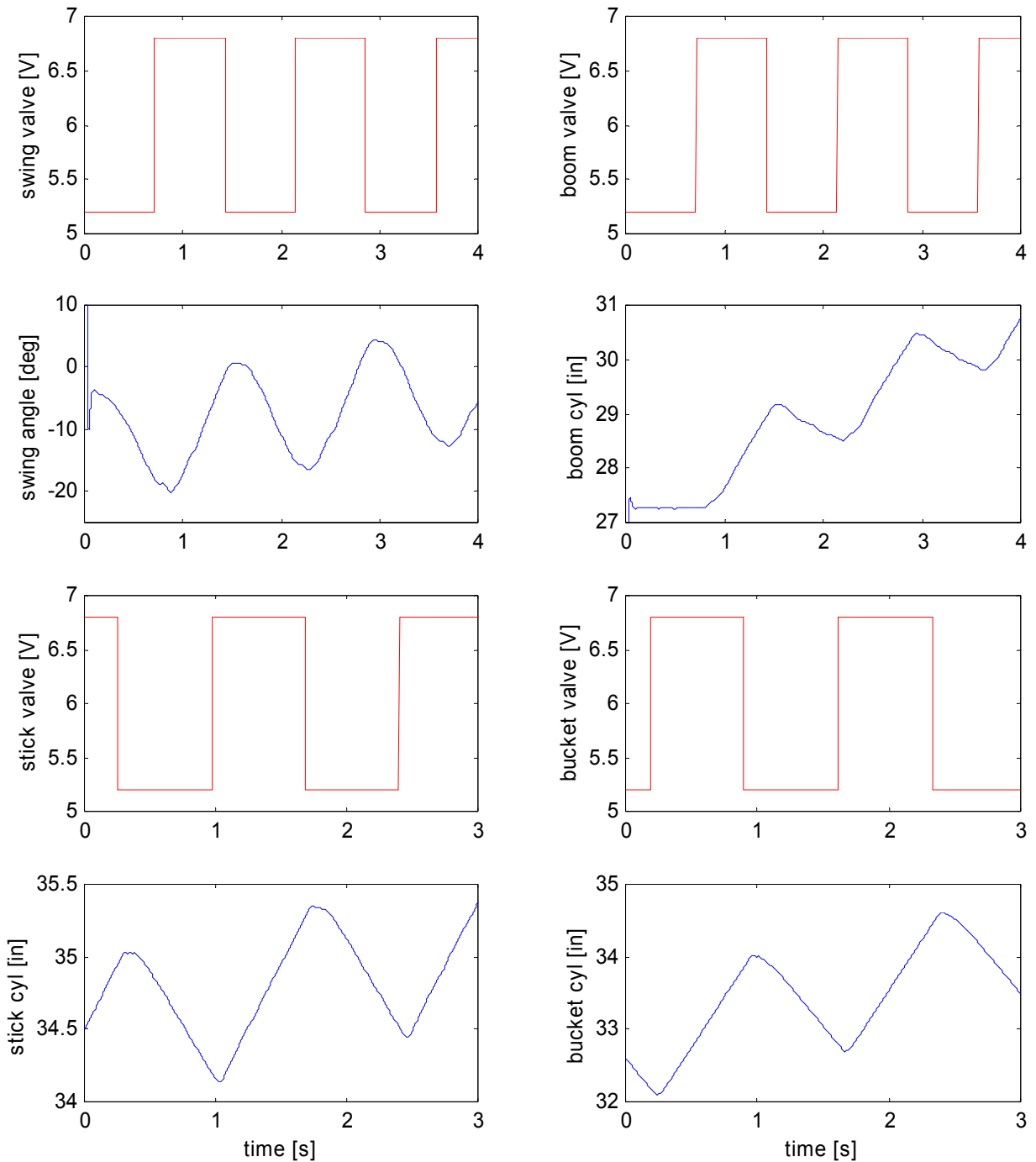
**Figure 2: Open-loop response**

All four valves respond smoothly to open-loop square wave commands. Drift is primarily due to unequal cap- and rod-side areas.

**Figure 3: Trenching trajectory tracking**

Backhoe tracking a digging trajectory in free space. Oscillations occur in the swing and boom when the angle / length respectively is increasing. Note that although some references lie outside the reachable workspace, tracking is fairly good, even with the oscillations.

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