DAC Testing using xPC Target
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Concerns recently raised about the poor tracking performance of the VxWorks controller implementation has led us to pursue testing the controller with a) more similar Simulink controller diagrams with the two controller environments (xPC Target and VxWorks), and b) exchanging i/o hardware between the two to detect differences (if any) in the closed-loop controller behavior.

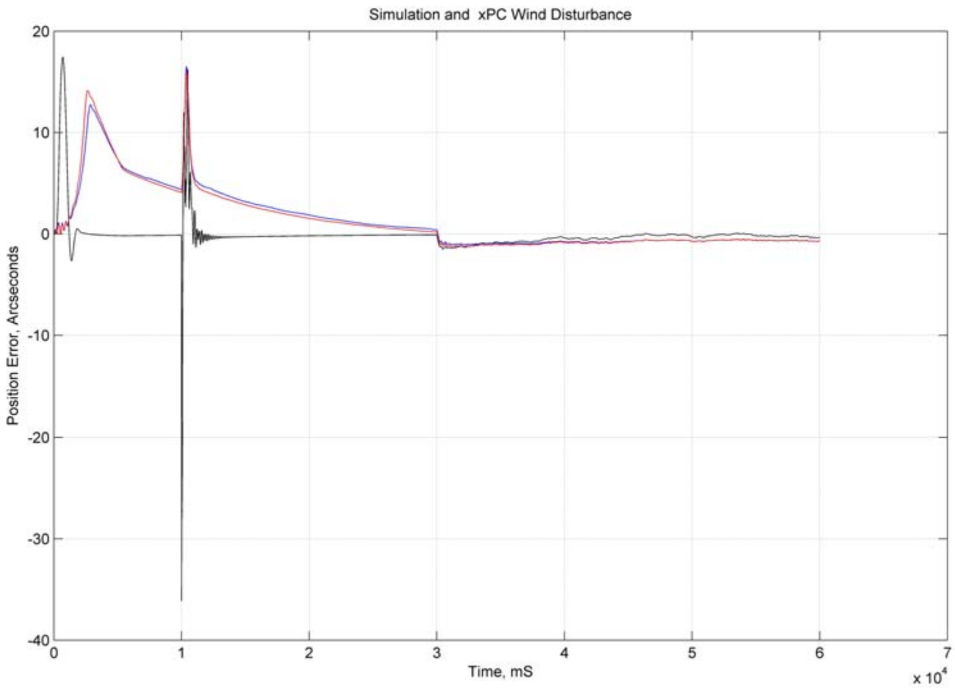
As an initial step, the controller was first constructed in simulation-only mode on both the downtown VxWorks machine and the xPC Target machine using a controller diagram as close as possible to that used in the VxWorks implementation. The loop was closed on the Eln4s10 identified open-loop model, with the HO (high-order) rolloff filter removed. The controller was set up in simulation to begin closed-loop operation 5s after the controller code was started, with a 0.01° step command applied at 10s, and a simulated wind disturbance summed into the DAC signal path at 30s, for a total of 60s of runtime. The reader is referred to Trebisky's discussion of these simulation results at: http://cholla.mmto.org/mmt/servos/wind/ -- the remainder of this report will focus on running the controller on the telescope hardware with xPC Target.

The next move was to test the DAC signal path on the telescope amplifier interface hardware to ensure no noise or other issues had negative effects on the controller output. Both DACs were installed in the xPC machine and were connected to the interface system via the standard test interface panel hardware, and the servo interface bridge connection. Using the test panel electronics, the signal path out of the mount interface electronics with the IP-230 DAC, the measured noise on the amplifier BNC connection was ~25mV RMS, with about 60mV of DC offset. Most of the noise appears to be switching feedthrough from the isolation amplifiers used for galvanic isolation of the DAC outputs and the amplifiers. Using the PCI-DAC6703, we measured ~15mV of noise and ~25mV of offset. We also measured the servo bridge connection with the IP-230 connector populated, with similar results. We can safely conclude that the DAC signal path is of sufficient quality to drive the system properly.

We also successfully closed the servo loop with the full set of test connectors on the servo bridge panel (which provides a way to connect not only the IP-230 or the PCI-DAC6703 but also the IP-Quadrature or the LM628s, so it can be used for either test computer).

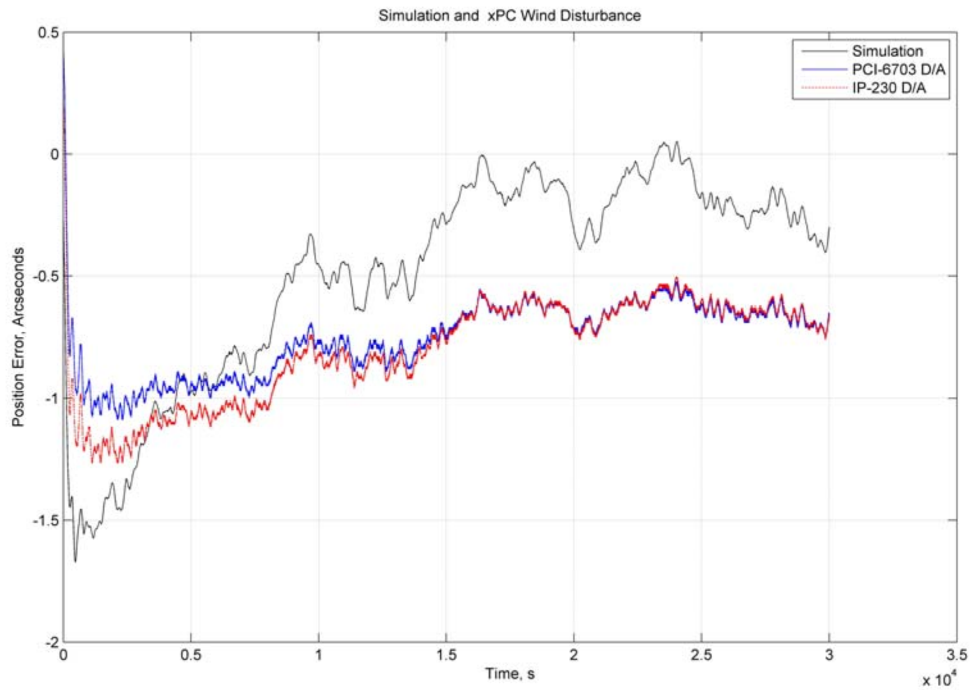
Moving on to closed-loop tests to verify the simulation results, the simulation-only controller was changed to add the hardware i/o blocks, and the HO filter was re-inserted in the output signal path. For the purposes of testing with xPC Target, the "Latched Absolute" signal was used as the commanded position for all time during the tests. This signal is the absolute encoder position acquired at startup via a transparent latch and added to the tape encoder outputs to form the feedback signal for the controller. As was done in simulation, a 0.01° step was added to this command position at time 10s, and the wind signal was applied at time 30s. We discovered that the 5s startup time was too long to close the servo loop due to a small unbalance torque on the telescope, so the controller was set to come out of reset-mode at 0.25s after startup to prevent an annoying “walk-off” of the telescope during the time between manually releasing the brakes and turn-on of the amplifiers and actually starting the controller.

The simulation controller has been adjusted to reflect these operational changes: the reset time was reduced to 0.25s and -10mV of offset has been added to the DAC signal path to simulate the unbalance torque.



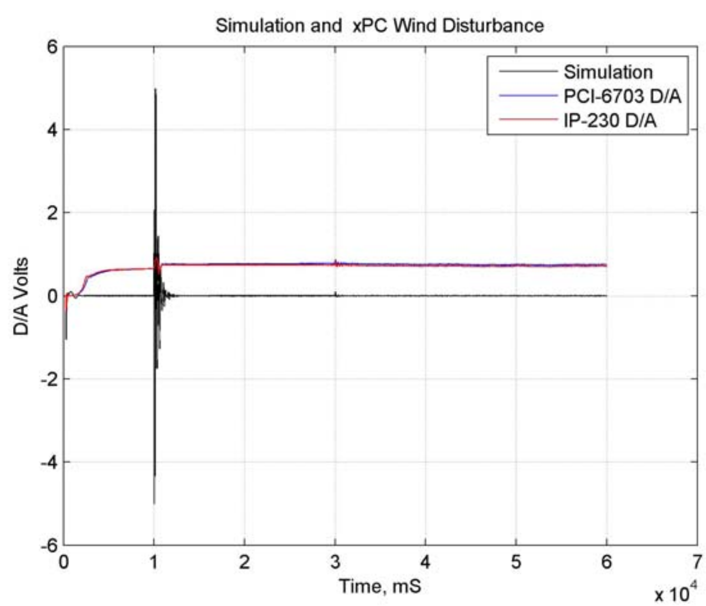
Above, we have the position error signal from the controller, with the simulation in black, the IP-230 based controller in blue, and the PCI-DAC6703 based controller in red. The two DACs give practically identical results, with the differences mainly due to the time between manual turn-on and starting the controller. The simulation shows a significant difference in the startup and step command period due mainly to the fact that the simulation is a strictly linear arrangement; we know that friction and motor windup are present on the real hardware, and the position error signal indeed shows much more damping that predicted by pure simulation. While not cause for alarm, we should remain cautious when evaluating simulation results with this knowledge in mind.

Focusing on the simulated wind response, we have:

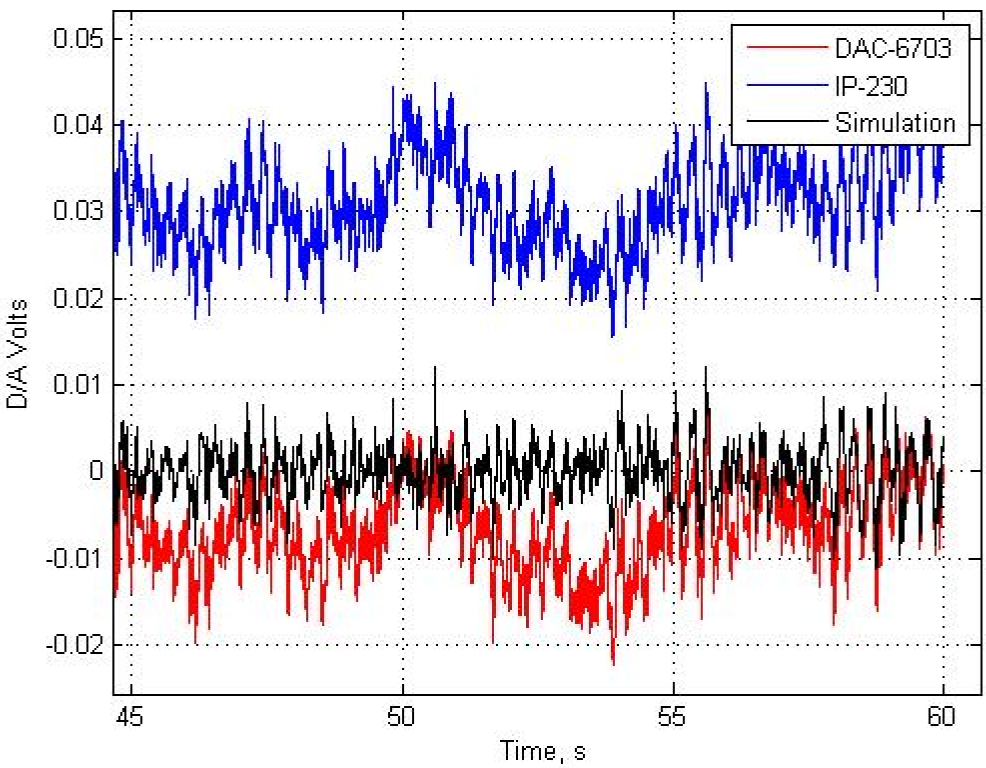


The X-axis is mislabeled, it's actually time in mS. However, the two DAC outputs are nearly identical, with more damping present than that predicted in simulation, while the simulation does predict the overall shape of the response. The simulated wind was $6^{m}/_{s}$, with 10% wind-gust component. As can be seen, the simulation overstates somewhat the actual telescope response – adjustment of the simulated torque with alleviate this, but the resultant standard deviations of the closed-loop error signals are 46mas (milliarcseconds) for the 6703 DAC and 51mas for the IP-230, well within a desired 100mas RMS value – simulation predicts 382mas of error for this test.

Additional comparative insight can be gained by looking at the DAC signal during the tests and the simulation results:



Clearly, the motor windup and friction are present in the telescope data, while the wind response signals are quite similar when the DC offset is removed:



Pure simulation appears to capture much of the closed-loop telescope performance, and the two DACs in the xPC Target environment also give nearly identical results. We can eliminate issues with the DAC hardware and the signal interface electronics as suspects in the difficulties with the VxWorks implementation. Trebisky has a forthcoming report comparing the simulations with the closed-loop VxWorks outputs to complete this latest round of detective work.