2010 LM628 Closed-loop Response

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Introduction

This is the first in a series of reports documenting the test results from before the MMT Shutdown/Aluminization performed on the telescope azimuth axis. Among the first experiments done during the June testing period was to measure the closed-loop disturbance response of the LM628 output while the azimuth servo was commanded to hold a constant position. This helps document the performance of the existing servo system for archival purposes, as well as provide additional insight on the tracking jitter issues experienced during operation. This had not been done since the first tests reported in 2003, and also helps confirm the results reported then.

Test Setup

A modified version of the IP-Servo interface board was made that replaces the “normal” input isolation amplifiers with a standard inverting op-amp circuit to provide a summing junction with the LM628’s 12-bit DAC output. The DSA (Dynamic Signal Analyzer) sine chirp signal output was applied to the summing junction, while the output variable was the LM628’s DAC signal. This allows for direct input of a disturbance input signal and collection of coherent output responses of the closed-loop servo.

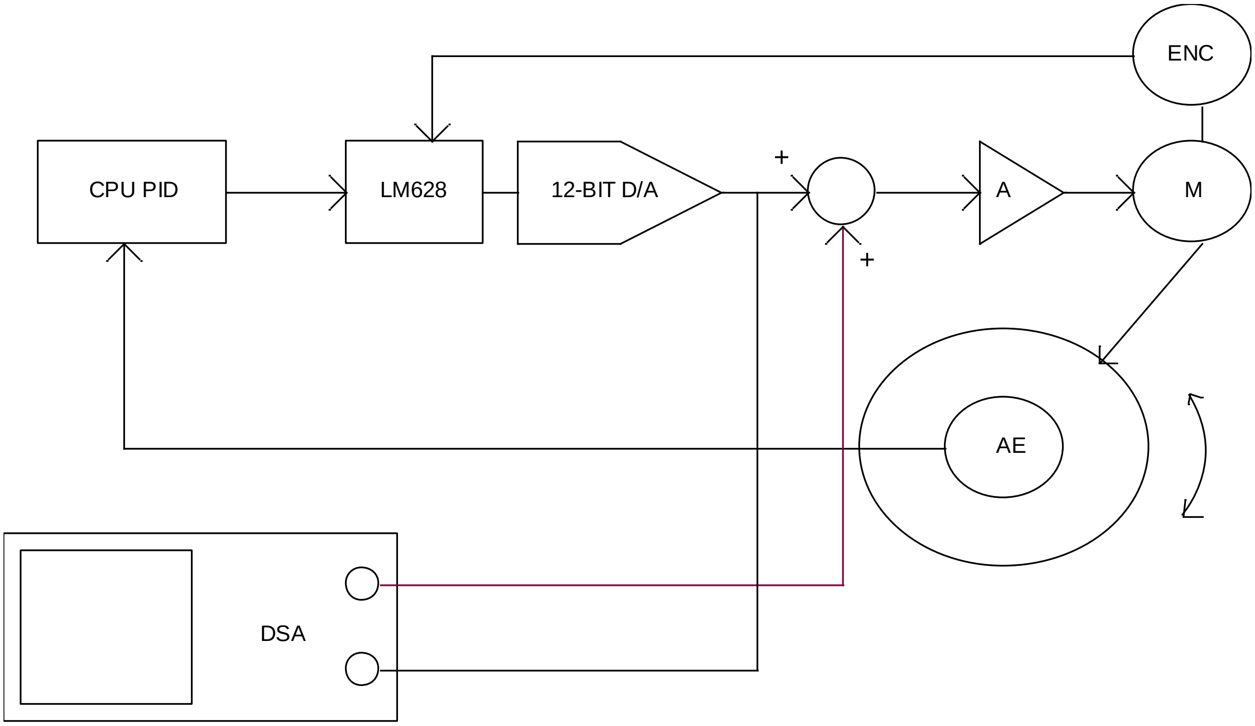

Figure 1. Servo Block Diagram with DSA Test Connections.

The block diagram shows the relationship amongst the various parts of the system. The summing junction outputs the LM628 velocity-loop command added to the disturbance chirp signal. The azimuth amplifiers then output a torque signal to the four drive motors, one of which has the RON905 shaft encoder for feedback to the LM628 unit. The telescope axis feeds the absolute encoder value to the

CPU-based PID loop, which in turn supplies a velocity command to the LM628. The DSA accepts the resultant DAC signal as the output signal.

With this setup, the ideal response would completely suppress the input chirp signal; small phase lag through the control loop and a perfectly stiff mechanical drive system would give out an input/output Bode plot with exactly 0db gain and 180° phase shift, meaning the input chirp is completely subtracted from the control loop and the only signal left is whatever control effort is required for the demanded position from the mount computer system.

Output Responses

Three tests were run, all at the same input amplitude (0.2V peak), were run from 0.2Hz out to 25Hz, 100Hz, and 200Hz. The DSA automatically calculates the required frequency signal resolution for each test – the default is 402 lines/sweep. The lower-range test naturally gives higher resolution for the lowest stop frequency; the higher stop frequency misses the low-frequency gain peaking seen in the high-resolution tests, but gives more data on the output response at higher rates while maintaining reasonable test durations.

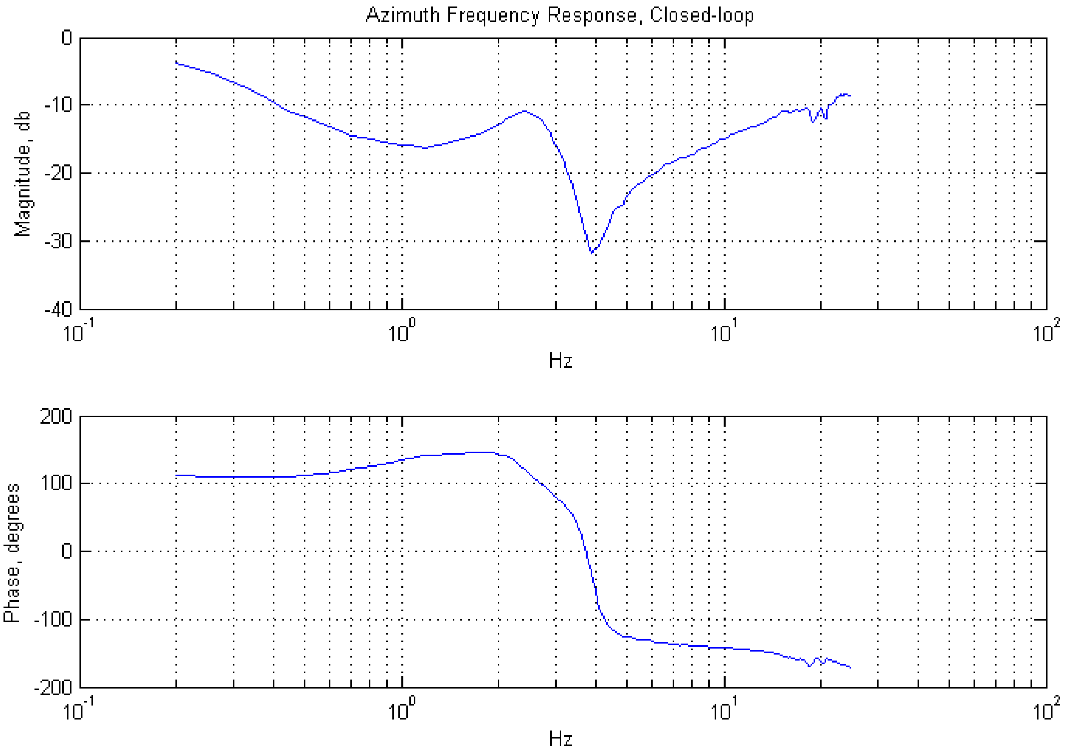

Figure 2. High-resolution Response 0.2 to 25Hz.

Here we see that the LM628 loop exhibits a highly non-linear output response. At very low frequencies (< 0.1Hz), it probably suppresses more of the input power. There is clearly gain peaking at ≈2.5Hz, followed by the known anti-resonance from the drive train at 3.8Hz. The gain then greatly increases towards 30Hz. So clearly, the LM628 loop fails at suppression of the input chirp at nearly all frequencies.

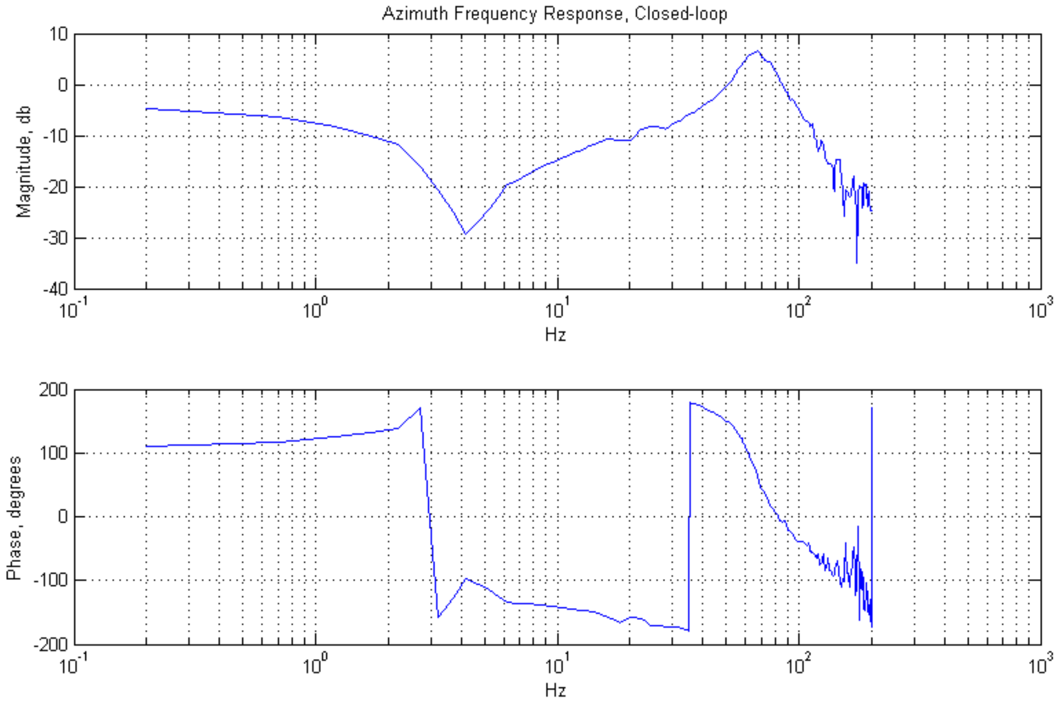

Figure 3. Lower-resolution Response out to 200Hz.

Here we see that the LM628 output has positive gain peaking at about 65Hz – it is *amplifying* the input disturbance signal. At about 125Hz, the output data become noisy, probably due to approaching the derivative sampling period in the LM628 controller and passing through the Nyquist limit, combined with interaction with the base 100Hz rate in the position loop. Again, due to the lower resolution, we miss the low-frequency gain peaking.

Conclusion

The gain peaking and poor disturbance rejection properties of the LM628-based servo loop reported in earlier Technical Memoranda are again confirmed here. The servo loop outputs need to be compared to open-loop measurements and combined into a complete model to confirm that any candidate control loop model correctly predicts these results. In this way, we can be confident that the telescope model used for control-design is sufficient for control system development.

More reports based on the 6/10 testing reports are forthcoming – these include open-loop chirp responses, motor tachometer outputs, and drive-friction measurements.