Direct Digital Down-Conversion for LIGO Wavefront Sensors, SURF Progress Report 2 (7/18/2003)

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1. INTRODUCTION

Over the last month, I have focused on testing a digital down-converter (DDC) in an actual control servo at the LIGO 40-meter lab. I continued to explore design details and learn about digital signal processing using the Altera Stratix DSP Development Kit. This progress report describes the DDC test in the Pre-Mode Cleaner (PMC) servo at the 40-meter lab.

Material presented in this progress report is a portion of the material that I will present in my final report, which will be entitled *Direct Digital Down-Conversion for LIGO Applications*.

2. PMC SERVO TEST

In order to determine whether or not DDC could be feasible in LIGO applications, we decided to replace the analog mixer in the PMC servo with an equivalent design programmed in the Stratix Development Kit. Although we could implement additional functions of the PMC servo in the Stratix Kit, our main goal was to test DDC.

After programming a simple mixer onto the Stratix Kit, we then inserted it in place of the analog mixer section of the PMC servo board. The schematic of the PMC servo board is in the Appendix. We sent the LO INPUT and PD INPUT signals directly to the Stratix Board, and sent the output of the Stratix Board to the FP1 TEST on the PMC servo. Then, using the PMC servo control screen, we enabled FP1 TEST, effectively replacing the analog mixer with the digital mixer programmed on our Stratix Kit. Using standard locking procedures, we then successfully locked the PMC.

3. TEST RESULTS

Having accomplished our goal of locking the PMC using a digital mixer, we then wanted to take at least one measurement in order to compare the performance of the analog and digital mixers. Using an SR785 Dynamic Signal Analyzer, we measured the closed-loop transfer function of the PMC servo using both the analog and the digital mixers. Figure 1 is a plot of the results.

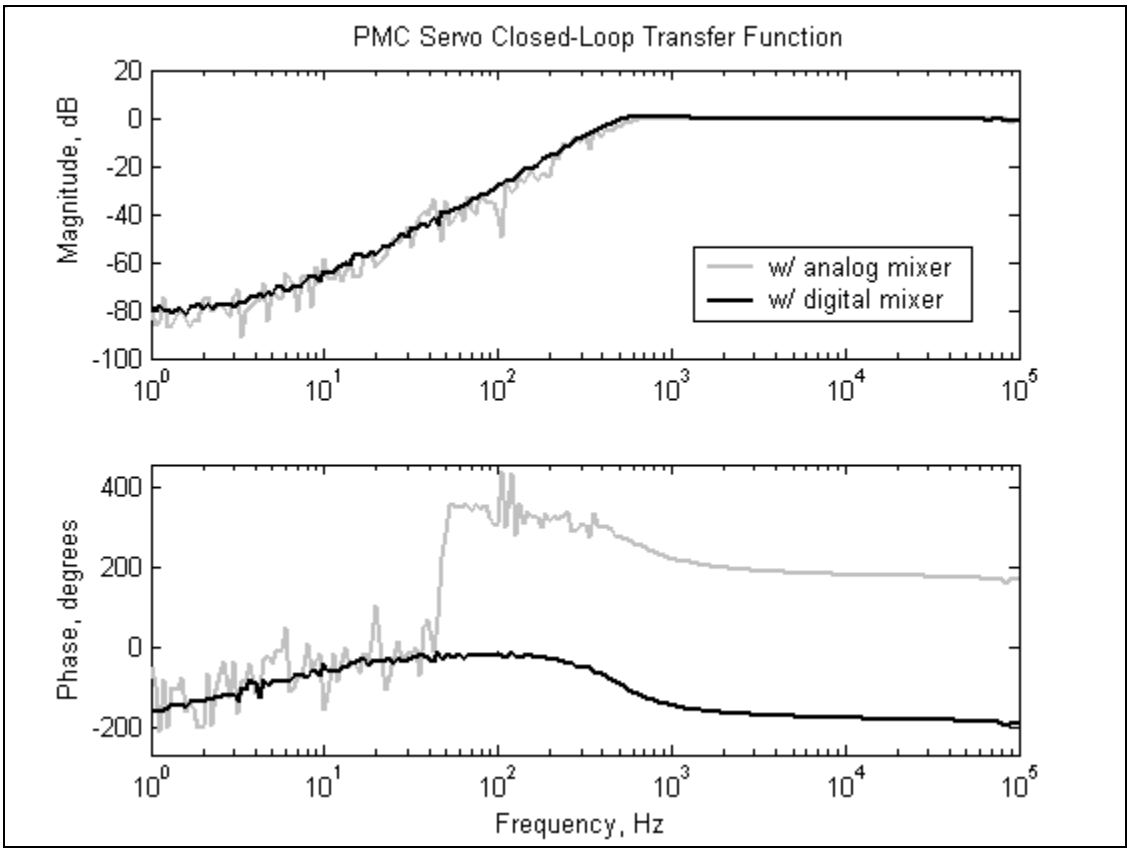

Figure 1. Closed-loop transfer function comparison

As we can see from Figure 1, the PMC servo performed similarly with both mixers. The most noticeable difference is noise rejection. When using the digital mixer, we see a smoother, or quieter, response. This indicates that we should be able to achieve acceptable noise rejection, especially if we employed better analog-to-digital converters (ADCs) in a final design. While the Stratix Kit uses 12-bit ADCs, we would like to use 14- or 16-bit ADCs, which would yield increased performance.

With the results of this test, we see that DDC can be a reality for LIGO systems. The positive outcome of this test has spawned interest in further testing DDC designs in similar servos. One possible test, the frequency servo, would require us to program transfer functions, in addition to the digital mixer, in the Stratix Kit.

4. CHALLENGES

The largest challenge for us has been understanding and using the Altera DSP Builder software. DSP Builder allows us to simply create a block diagram and compile to our hardware without writing any actual software code. While this makes for very quick progress from the start, it also limits our control over exactly what we want to design. Using Altera's FIR and IIR filter wizards are also challenging. Though they provide documentation for each tool, we spent much time learning and overcoming their quirks. Furthermore, each tool uses a completely unique interface, which means that each tool has its own set of quirks to be learned.

5. GOALS

So far, we have tested a basic DDC design in a LIGO system and shown that its performance is acceptable. With only two more weeks for me to work on the project, I would like to program a working I/Q demodulator, as well as test the Stratix Kit in another LIGO system.