



Direct Digital Down-Conversion for LIGO Applications

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The Current

- A LIGO Interferometer uses about 20 unique RF circuit designs in its control servos.
- Though the functions of each design are similar,
- Each design is unique.
(carrier frequency, transfer function, gain, etc.)



The Question

Can we replace the multiple RF circuit designs with a single, re-configurable design?



The Answer

- With conventional analog electronics?

Nope.

- With Digital Signal Processing?

Yes! (That is, we think so.)



Why?

Hindrances

- Latency
- Introduce quantization noise
- Invest in new technology
- Learn new design techniques

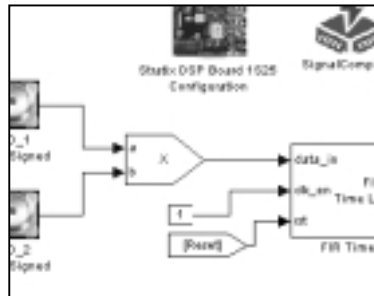
Benefits

- Single design replaces 20
- Software configurable
- Reduce thermal noise
- Eliminate component drift

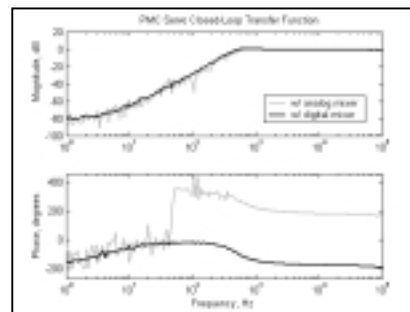
Overview



What is demodulation?



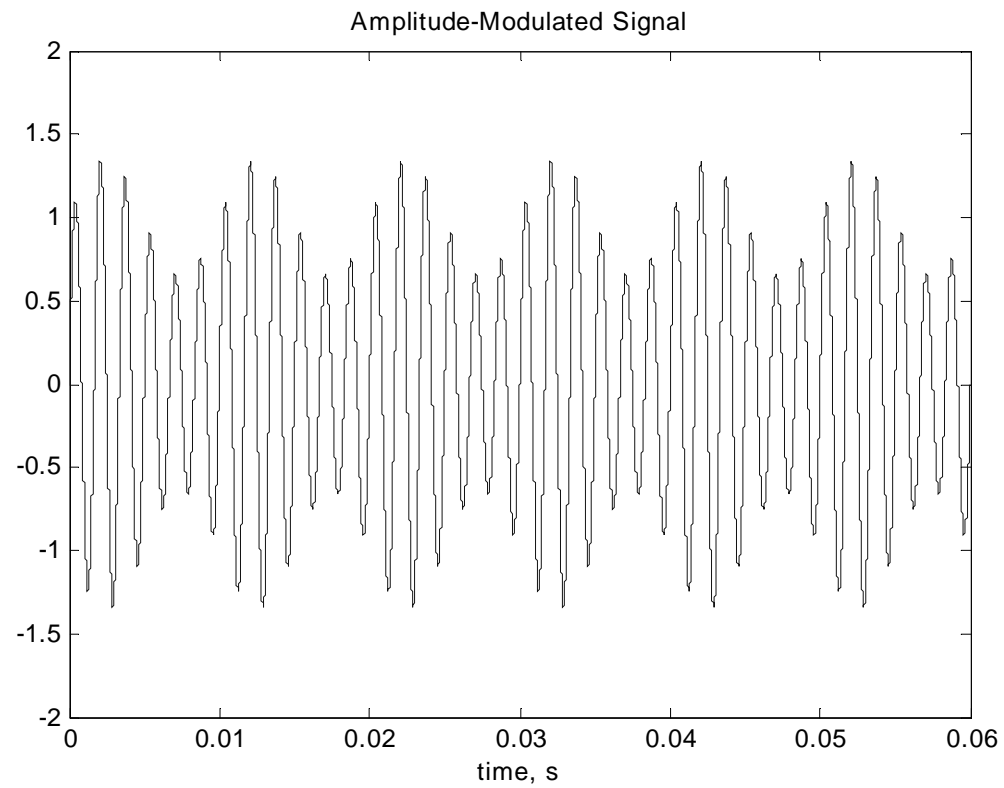
Digital Down-Converter Design



Testing in a LIGO servo

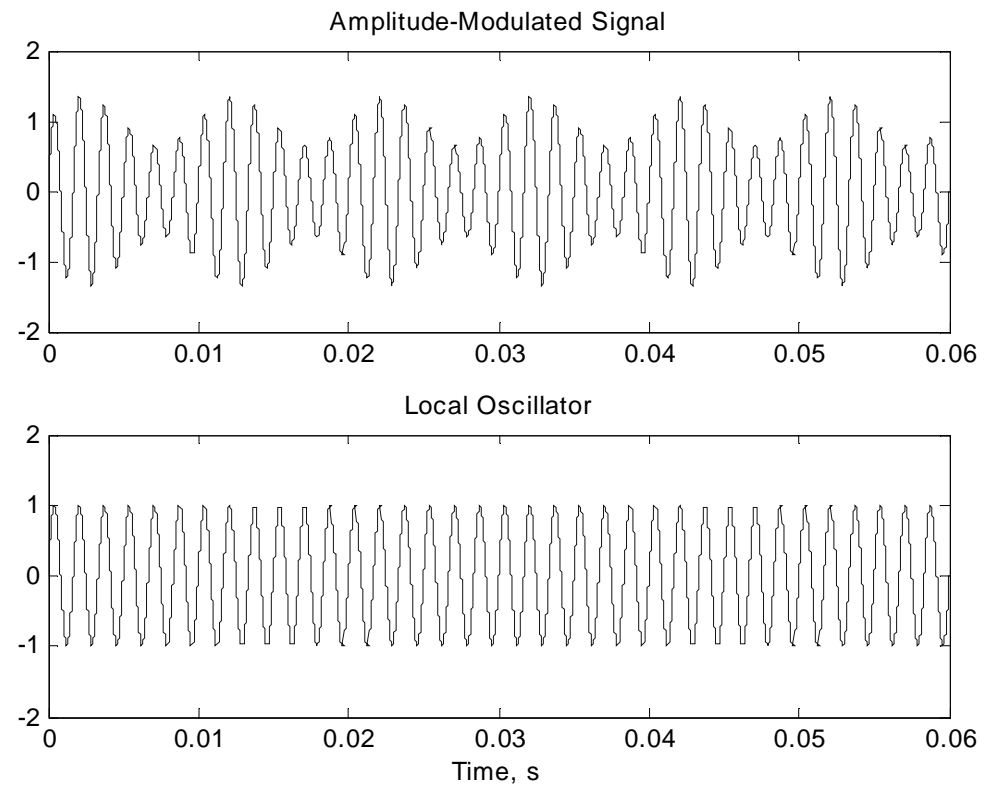


Demodulation



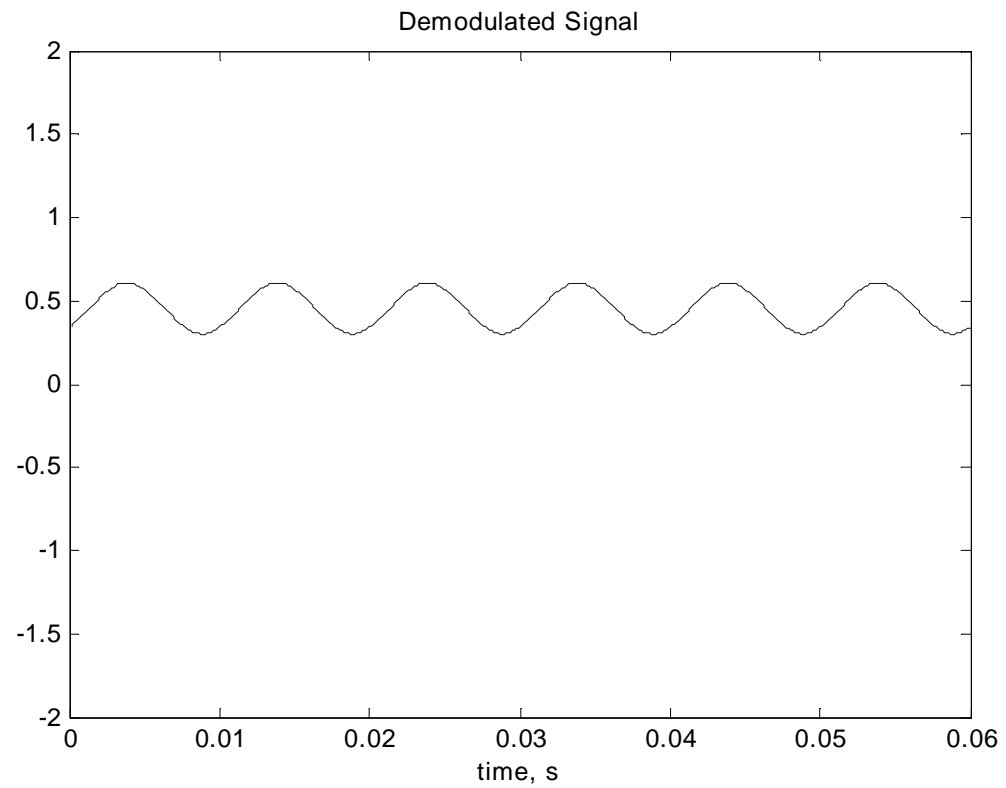


Demodulation





Demodulation





Demodulation

Uses, in general:

- AM, FM radio
- Mobile phones
- GPS

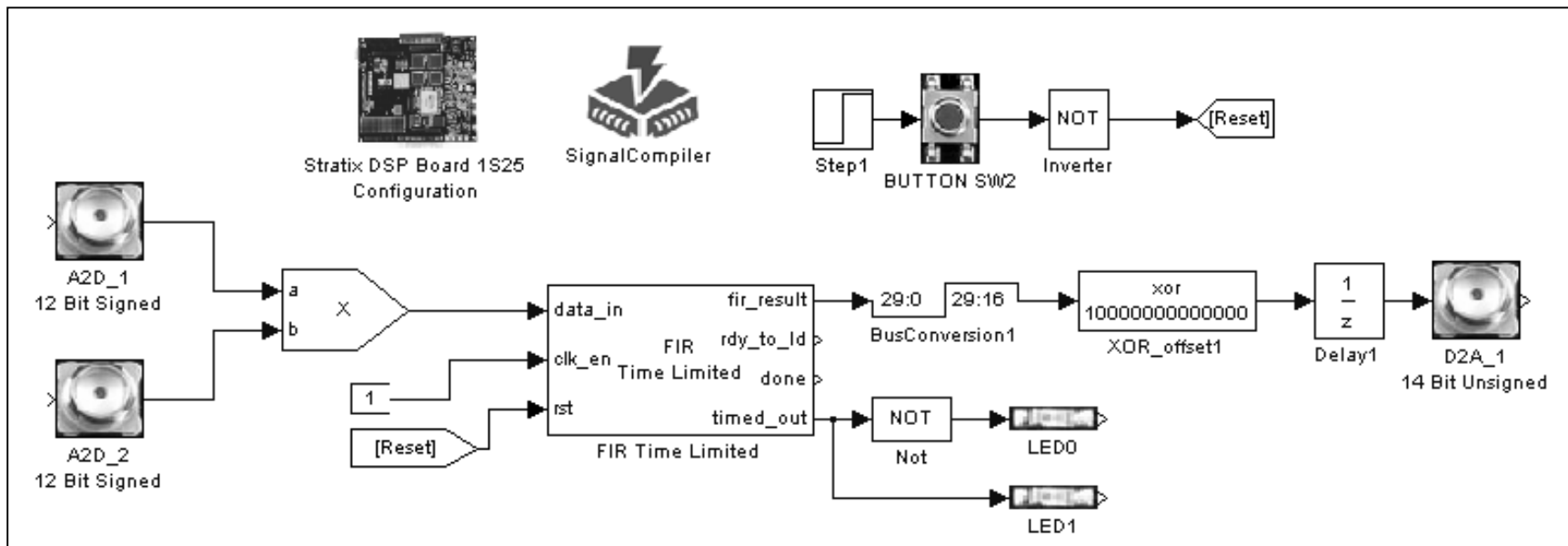
Use at LIGO:

- Pound-Drever-Hall Locking



Design using Stratix DSP Kit

- DSP Builder software compiles block-diagram designs.





Initial Results

- Initial design and testing yields

Latency: ~ 160 ns

Noise Floor: 100 nV / rtHz

- Acceptable performance for LIGO systems!



The Next Step

Test a DDC design in the Pre-Mode Cleaner servo at the LIGO 40-meter lab.

Why the Pre-Mode Cleaner?

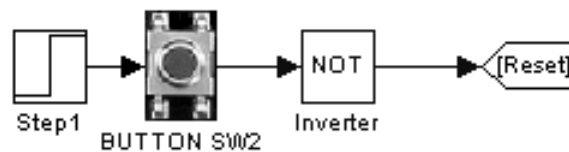
- Easy to bypass the analog demodulator
- Simple demodulation required



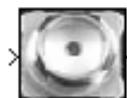
Stratix DSP Board 1S25
Configuration



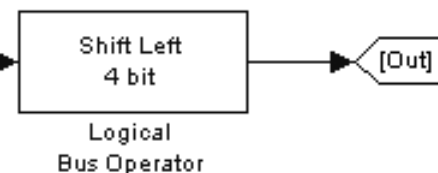
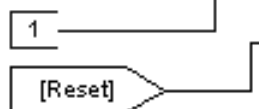
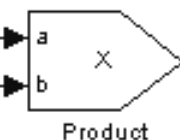
SignalCompiler



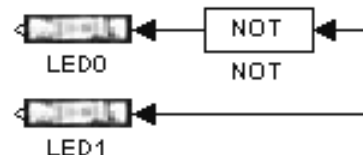
A2D_1
12 Bit Signed



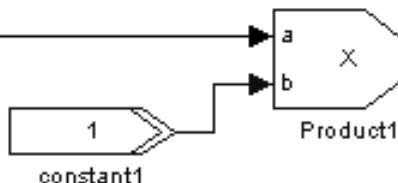
A2D_2
12 Bit Signed



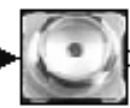
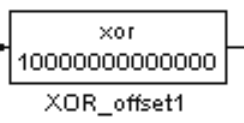
[Out]



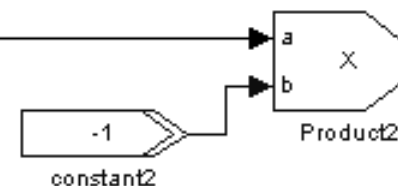
[Out]



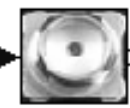
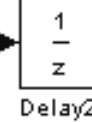
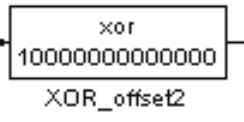
41:0 41:28
BusConversion1



D2A_1
14 Bit Unsigned



41:0 41:28
BusConversion2

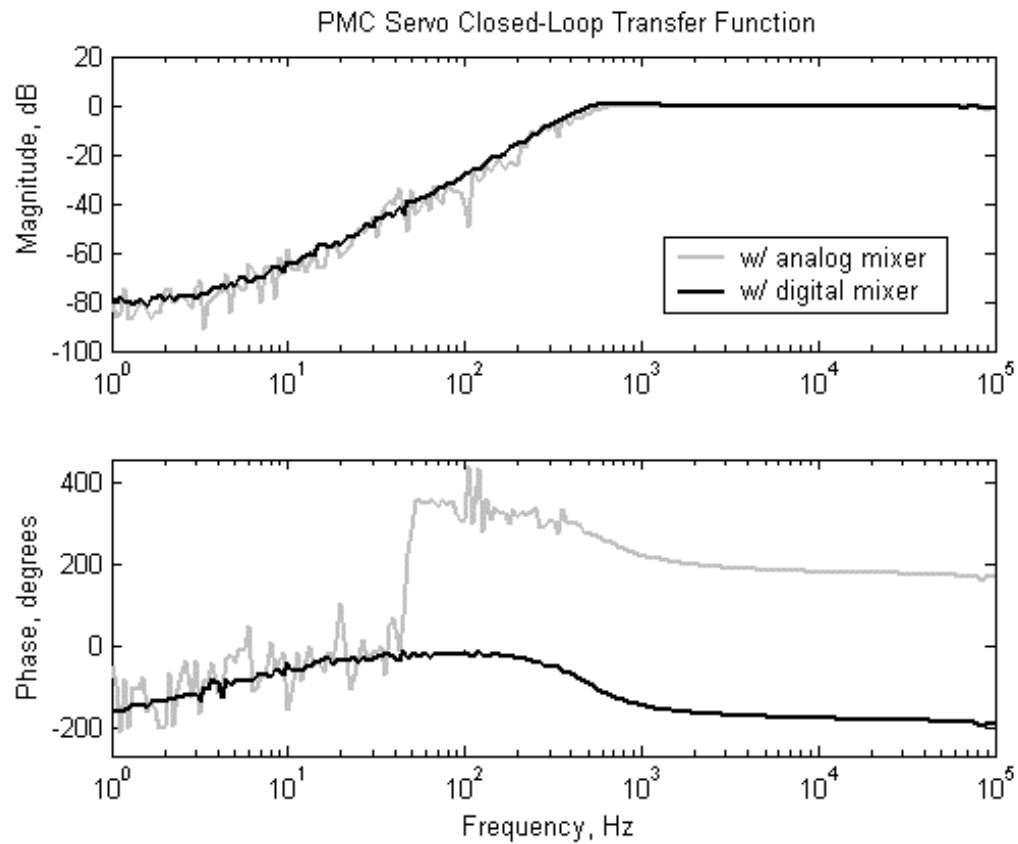


D2A_2
14 Bit Unsigned



Results

- Pre-Mode Cleaner successfully locked!





Significance

- First test of digital RF system at LIGO.
- Results were better than we expected!
- Shows promise for moving towards all-digital designs.
- Ian will continue to test digital systems on a more complex servo.



Recommendation

LIGO should strongly consider moving to digital RF systems for Advanced LIGO.



Acknowledgements

- Jay Heefner
- Curt Hovater
- Ian Krajbich
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