Digital Transmit Waveform Generator for Incoherent Scatter Radar

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Abstract

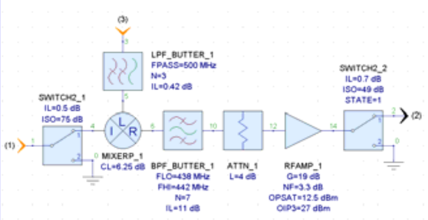
The Millstone Hill Incoherent Scatter Radar facility currently uses an analog waveform generator to transmit a 440 MHz pulsed sine wave. It is totally functional, however there are many benefits to the use of a digital waveform generator. This paper discusses the creation of a digital transmit waveform generator for the Millstone Hill Incoherent Scatter Radar. It includes the process of testing the prototype direct digital synthesizer and analog components; choosing the proper elements to create the final product; and the design and construction of the circuit boards.

Initial Testing

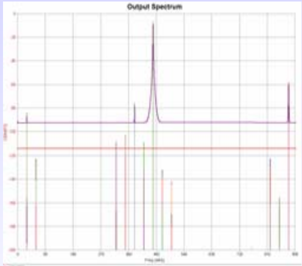
Once the analog parts were chosen, I used a program called GENESYS to test the output of the analog section. I entered in the parts I was using and specified information about them, such as insertion loss, gain and IP3 value. The program provided a graph of the spectrum from the output of the analog section. It took into account problems that merely adding component information would not provide for, such as coupling between components.

The graph showed a peak at the desired frequency of 440 MHz. It also showed a smaller peak located at 410 MHz. This extra peak was due to the mixer. Because a mixer works by taking two signals and both adding and subtracting them, it outputs two signals. We are using the sum of the two signals, but the difference creeps in past the filter. Fortunately, the unwanted spike is so small compared to the spike at 440 MHz, that it can be neglected.

We were able to experiment using GENESYS and found that the unwanted spike was smallest when the intermediate frequency was around 30 MHz.



Analog schematic as entered into GENESYS



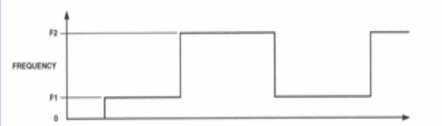
Signal vs. Frequency graph from GENESYS

Direct Digital Synthesizer

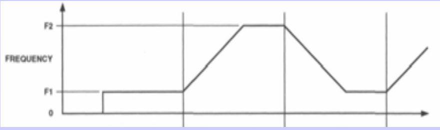
The key component in the creation of the digital waveform generator was the Analog Devices AD9852 direct digital synthesizer (DDS). In addition to the accuracy with which a frequency can be selected, the AD9852 DDS also allows for precise signal modulation.

The DDS chip can modulate the signal in five ways which are shown graphically:

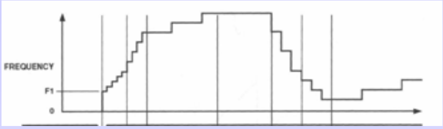
Single Tone Mode



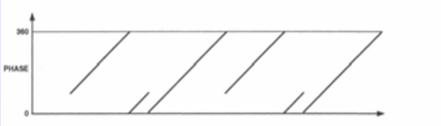
Unramped Frequency Shift Keying Mode



Ramped Frequency Shift Keying Mode

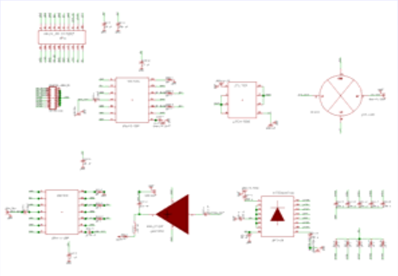


Non-linear Chirp Mode

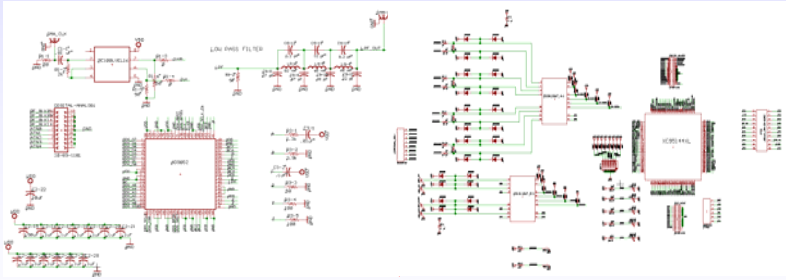


Binary Phase Shift Keying Mode

The digital board contains the DDS to digitally modulate the signal providing more accuracy and flexibility, and a programmable logic chip to control operation of both digital and analog sections. The analog section is used for blanking, upconversion, and amplitude control of the signal.



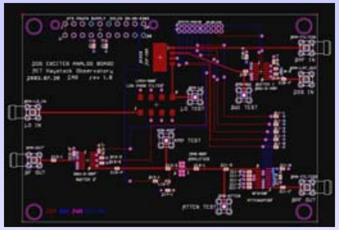
Analog section Schematic



Digital Section Schematic

Board Design

The boards were designed using the computer program Eagle 4.09. I was able to use some of the more basic parts from the program's library, but the more specialized parts had to be specifically designed. Once the parts were created, they were placed onto a schematic diagrams. All parts, plus all extra capacitors and resistors were added to make sure the signal was as clean as possible, and then everything on the schematics was connected with nets. Then the program transferred the parts to a board layout. At this point, I was able to specify a power plane and ground plane and move the parts to where they would be on the actual board. The placement of parts was decided in order that the traces connecting the parts would be as short as possible, yet the parts would not be too close as to avoid coupling. Once the board seemed to be right, CAM files were made to be sent to the board manufacturer's design rule check program. This checked to make sure that nothing was too small to be made and that nothing on the board was too close together. Finally, the files were sent out for good so that the company could manufacture the boards. Once we received the boards, all parts were soldered on using solder paste and a hot air gun so that the boards could be tested for functionality.



Analog and Digital Board Layout Designs

Conclusion

There was not enough time in this program to run a test of the final product. We did not encounter any problems in the initial testing or the board production, which implies that the boards will be successful. However, further testing needs to be completed before a conclusion can be reached.

Acknowledgements

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