Intermediate Frequency Data Aquisition Device (*IF_DAD*) SD_DEC23-20

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Problem Statement

In the Aerospace industry, the failure of a safety critical system can lead to financial loss and even death. Nondestructive evaluation plays a crucial role in ensuring the safety of such systems. The Iowa State Center for Nondestructive Evaluation researches within various industries to optimize the lifespan of systems.

Our advisor, Dr. Al Qaseer, has requested that we design the Intermediate Frequency circuit of a Millimeter wave radar. Millimeter waves (30 - 300 GHz) are noted for their ability to penetrate non-conductive materials, namely, wood, concrete, and fiber composites. Our design will be used by researchers and future students to enhance the field of nondestructive evaluation and to promote safety in industry.

Design Requirements:

- Must interface with existing hardware/software that includes Up counters and Down counters, this will require a signal input and output.
- Our design will ideally output a 10 MHz signal, which will be "sped up" by the existing hardware.
- With the input signal that is returned from the output signal, we must convert that into its real and imaginary components.
- This converted data must be organized clearly into a file on the PC, so that Labview or Matlab may graph it.
- FPGA clock is 100 MHz.
- Communicating with PC to FPGA via a USB-C port.

Intended Users and Uses

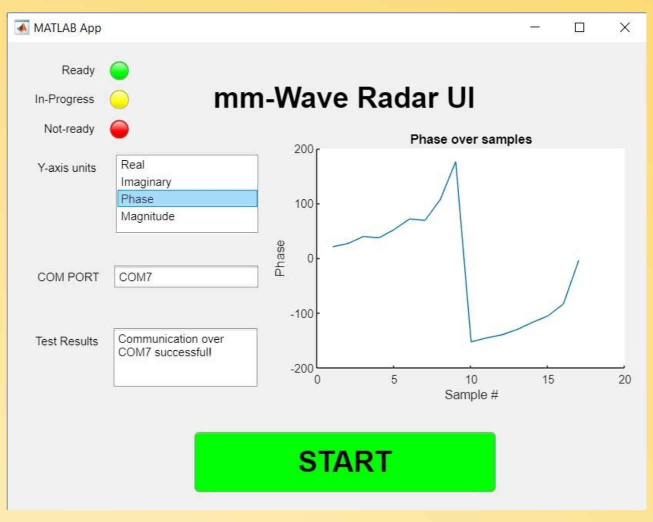
Users: Iowa State Researchers, and students.

Uses: Evaluating the integrity of a material without having to disassemble the product. This means detecting internal defects, cracks, and analyzing the material properties of insulating samples. While some imaging radars can be used to analyze metals, ours wouldn't likely have those capabilities due to the refractive instability of microwaves on conductive materials.

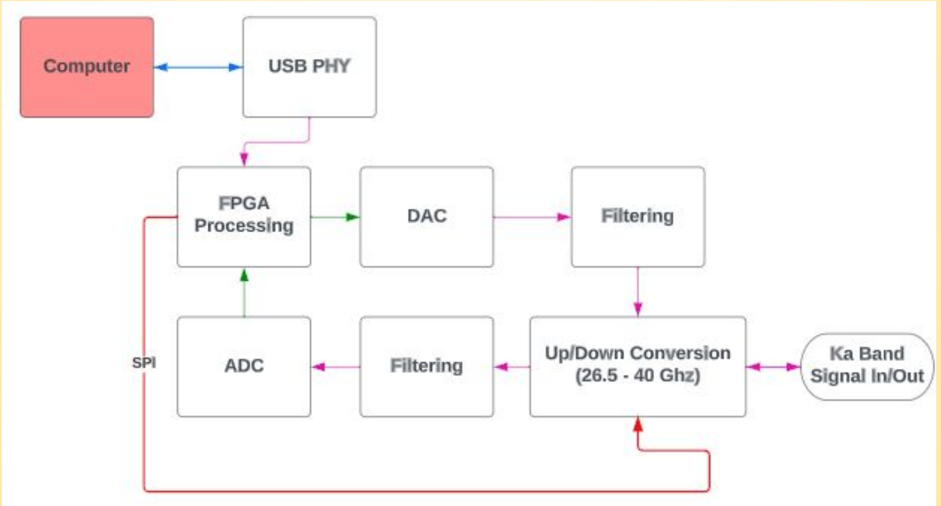
Design Approach

The delineation of work between members reflects the flow of our design.

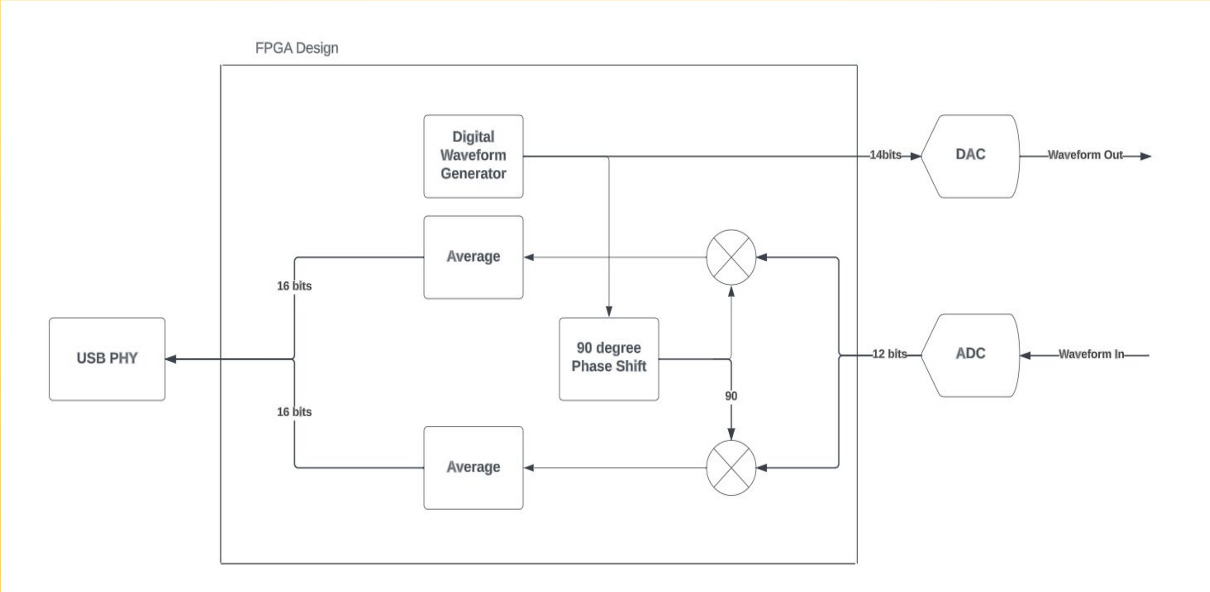
Computer Interface:
A Matlab program communicates with the FPGA and analyzes data received from the FPGA.



Hardware:
FPGA produces a 10 MHz sine wave. The DAC and up-converter to RF (26.5 - 40 GHz). Hardware then receives the signal, down converts it to the IF frequency, filters and sends it to the ADC where the FPGA processes and send data back to the UI

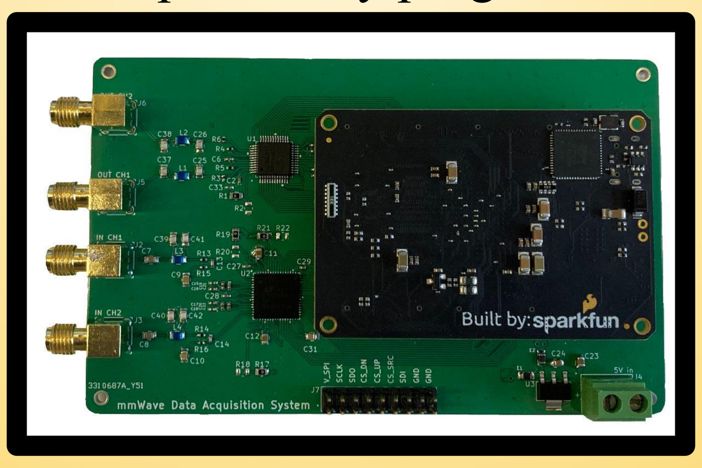


Digital Signal Processing (DSP):
The DSP system takes the raw data received by the ADC and splits it into real and imaginary parts based on the convolution of the original sine wave.



Technical Details:

- Four specific modules to implement, Hardware (ADC & DAC), SPI, DSP, and User Interface.
- HW, SPI, and DSP all require Vivado to program the FPGA (Xilinx Artix 7) in Verilog and C (via the Microblaze Processor)
- HW PCB interfaces with Alchitry AU FPGA development board, all HW, SPI, DSP code is loaded directly to the FPGA.
- UI requires MATLAB, specifically programmed in the MATLAB app designer

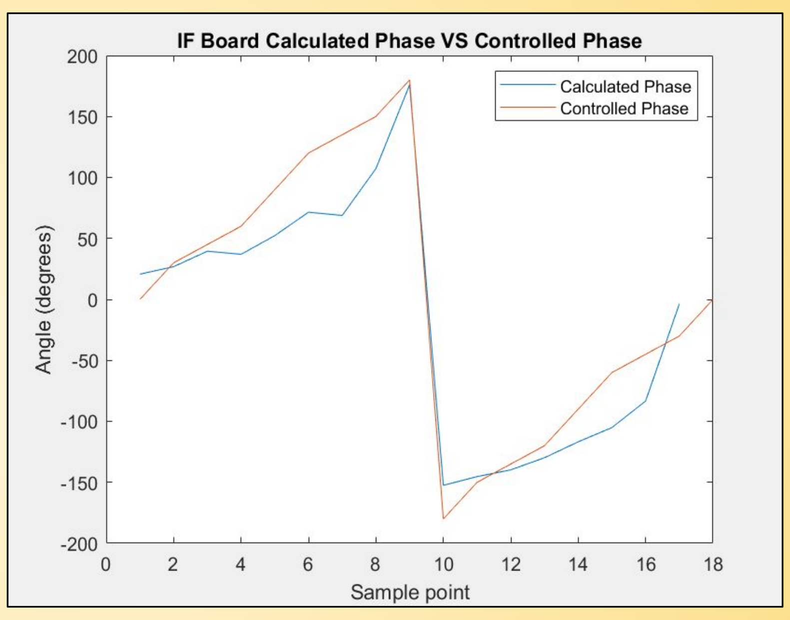


Testing

- Testing was done to emulate the phase and amplitude shifts the RF components introduce
- This testing consisted of inputting the sinusoidal IF waveform of 10 MHz into the reference of a function generator to artificially shift the phase of the IF output signal
- The output of the function generator was then fed back into the IF board for signal processing and data collection to the PC

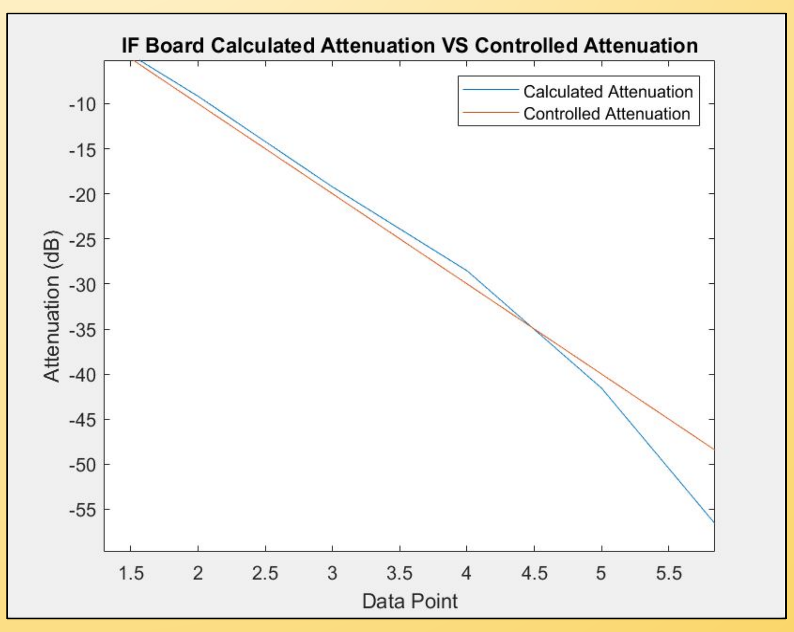
The plot to the right shows the data collected from the phase shifting

- As the phase of the IF output was swept from 0◦ to 360◦ the calculated phase from the IF board was able to predict the actual controlled phase difference



The plot to the right shows the data collected from attenuating the IF output

- As the IF output was attenuated from 0 dB to -50 dB the calculated attenuation from the IF board was accurately able to predict the actual controlled attenuation up to about - 40 dB



Standards:

- Regarding coaxial connectors at RF, and Millimeter-wave frequencies, we followed IEEE 287.1-2021, IEEE 287.2-2021, IEEE 287.3-2021.
- With presence of ADCs and DACs we had to be vigilant of terminology and test standards/protocol, so we paid close attention to IEEE 1658-2011, IEEE 1241-2010.

Resources:

- Please reference the QR code link to our website, for more information and design resources.