Project Plan V2 EE491
MAY1623

Low-Cost High-Accuracy Spectral Test System

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1. Requirement Specification

1.1 Project Statement

Accurate spectral test is widely used in science and engineering. In particular, accurate spectral test is critical to high performance data converters used base stations, medical instruments, seismic signal detection, military applications, and so on. IEEE standards and prevalent industry solutions impose several stringent requirements on the linearity of input signals, on exact coherency in sampling, and on tolerable jitter in the clock signal. All of these requirements make accurate spectral testing expensive and time consuming, and make the test setup difficult to maintain and calibrate.

The goal of this project is to develop a prototype test system for Extremely Cost-Effective Spectral Test. Recently published spectral test algorithms will be implemented for dramatically relaxing the stringent requirements. The concrete objective is to demonstrate a PCB test system for very low-cost, high-accuracy full spectrum test for high performance ADCs from Texas Instruments. The PCB will include a low cost sine wave generator, a clock generator, a low-order RC filter block, an ADC input driver, a socket for an ADC under test, and ADC output collection. The collected data will be transferred to a computer for analysis and display. Spectral test results will be compared with results obtained from Audio Precision instruments.

1.2 Concept Sketch/Mockup

Design requirement:

The DUT(device under test) we are going to use is ADS8881 from Texas Instrument. The standard method to test the ADC is using the audio precision instruments to generate the pure sine wave and feed this sine wave into the ADC. But the cost of generating a pure sine wave is very high, because the audio precision is very expensive. So the alternative approach to test the ADC is using the DAC to generate the relative low purity sine wave, and use the algorithm to correct the distortions that comes from the DAC's sine wave.

Assessment of Proposed solution:

Our proposed solutions is using the DAC to generate the sine wave and test the ADC. By doing this, the advantage is that it is low cost, relaxes the testing requirements, and in the end is high accuracy. Cost is a main issue in terms of project budget, an audio precision instrument usually worth 2000 dollars, but a DAC only cost 2 to 3 dollars. Even though the audio precision instrument will generate a much purer sine wave than DAC, the inaccuracies caused by DAC will be fixed by algorithm. In terms of testing requirement, the inaccuracies are introduced by DAC, but we will still get the accurate testing results, so the testing requirements are related. Based on our design references (Dr. Chen's master student Ben Magstadt's Thesis) the test results made by DAC will be very close to the results made by audio precision instruments.

Validation and Acceptance Test:

Most of the functional blocks will be tested individually in the software simulation, and after all of them pass the design requirements, the PCB will be made, and the further testing will be done on the PCB. For the software testing, the testing benches and results will be included in the reports/ plans later.

1.3 System Block Diagram

The system level block diagram can be seen below in Figure 1. For this test board, we will be using a DAC to generate an impure sine wave. This sine wave will be passed through a buffer for isolation and will be exposed to one of two filters. One of the filters will be an RC Filter while the other will be an RR Filter or voltage divider. Only one filter will be selected at a time, and our board's logic will switch between the two filters as needed. This output will be buffered and sent to the ADC under test. In real time, the digital output data of the ADC will be sent back to our FPGA in real time. From here, we will use spectral test algorithms on the PC to interpret the results of the ADC under test.

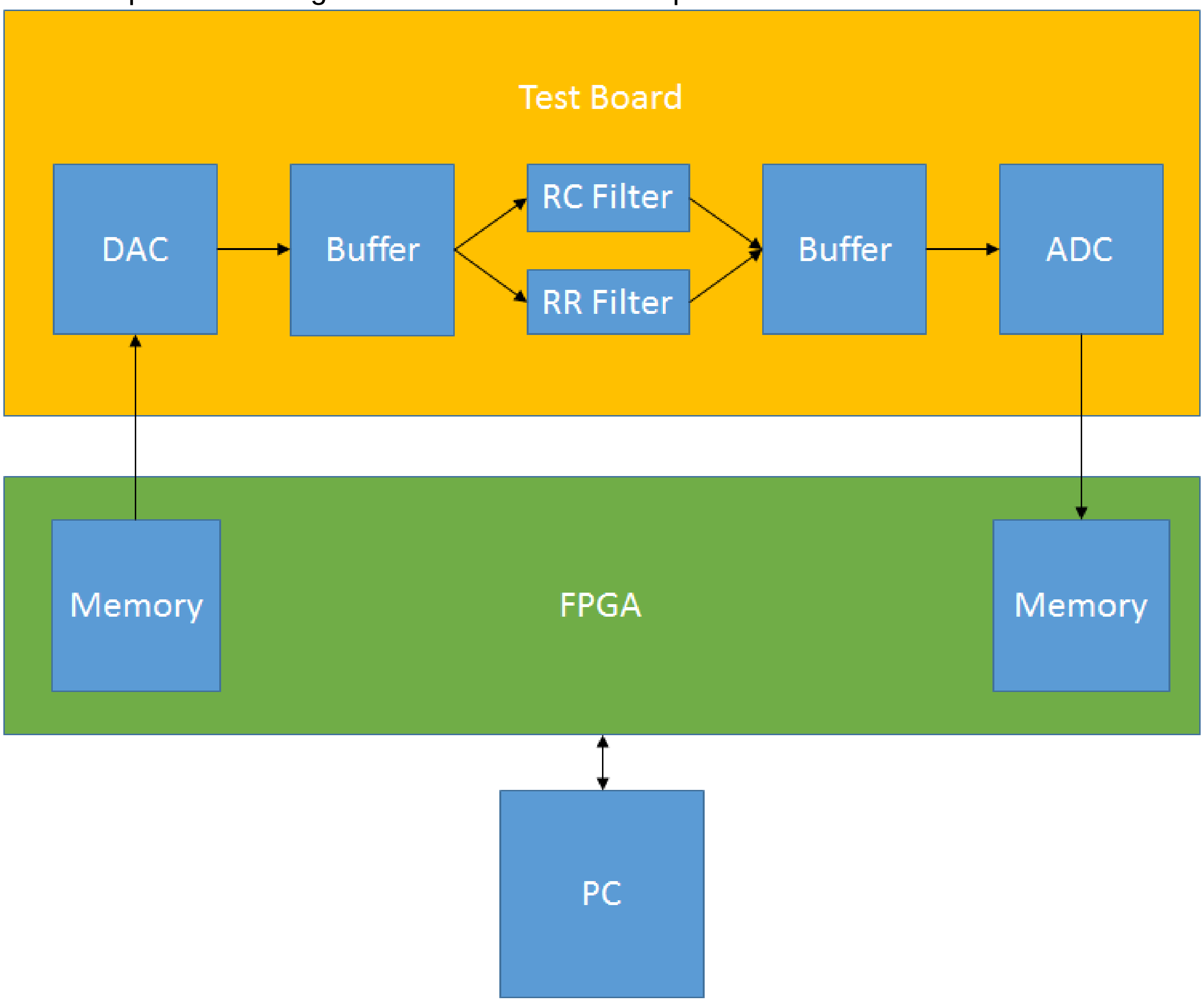

Figure 1: Block Diagram of the Low-Cost High Accuracy Spectral Test System

1.4 System Description

1.4.1 Content:

In this project, we are asking to design a circuit board to test the accurate spectral. The typical accurate spectral testing is very choosy. It requires a very pure sine wave which can be very difficult to generate when the under-test ADC is accurate. Our project is to use the non-standard way to test the ADC. This means we can feed the nonlinear (impure) sine wave to the ADC. This method will significantly reduce the cost of ADC testing.

The ADC we choose in this project is the ADS8881 from Texas Instruments, it's a 18-bit differential input ADC, with maximum sample rate at 1MSPS. Our goal is to design a circuit board which can support ADS8881, and allow the user to plug different ADS8881 chips and test the quality of them.

1.4.2 Technical approach:

In order to be able to test the ADC with nonlinear input, we need to feed the sine wave to two different filters separately. This will allowed us to distinguish the noise from input signal and the noise from the ADC.

1.4.3 Process details:

We need to design a circuit to support our ADS8881, with the power to drive the ADC. We will do this using a set of batteries, which as a result will help us reduce the background noise. For the input of the ADC, we will use the DAC to generate the sine wave. The sine wave THD (total harmonic distortion) from this method is typically around -50dB to -80dB, depends on which DAC we use. Nevertheless, it is larger than the pure sine wave THD required in standard test. The digital input to DAC is from the memory located on the FPGA. We also want to share the clock signal, generated from the FPGA) between the DAC and ADC to sure our signal is coherent.

For this semester we need to get our circuit board fabricated and get the output signal from the ADC. In the later semester, we will add the computer program with the algorithm so we can interpret the data from ADC and get the accurate spectral test result.

1.4.4 Test plan:

For this semester, we need to test our hardware part. We will test to ensure that the board is in fact being powered up. We will also test to see if the waveforms which we are receiving from the ADC and DAC are what we expect, as well as analyze the signal integrity of them. In addition, we will check the signal integrity of the digital communication between our board and the FPGA.

The software tests will be for the second semester and will likely consist of ensuring that the code can be uploaded to the FPGA, as well as the code gives logical results in comparison to the Audio Precision Equipment.

1.5 Operating Environment

The overall system is broken into three different environments, the PCB which we are going to fabricate, the FPGA which we will utilize to communicate with the system, and the PC GUI which will contain the software spectral test algorithms. The PCB will contain the everything between the ADC and the DAC, which can be seen in gold in Figure 1. The FPGA will contain the memory to which we program the SPI communication, which can be seen in green in Figure 1. We will be using Verilog with the FPGA's interface software to do this. From here, the test results will be extracted from the FPGA and be sent to our PC, which will pipe into MATLAB to implement the algorithms. After this happens the project goal is met for the test board.

MAIN

1.6 Functional Requirements

The main functional requirement of this test board is to deliver accurate spectral test using the algorithms devised in Ben's Thesis. These spectral test results must be comparable to spectral test results from Audio Precision equipment for this alternate method to be considered valid.

An alternate functional requirement is the speed of the test. The test should take be high speed and completely controllable by the user through the PC. No physical switching should be needed on the board. All switching between filters must be done digitally.

1.7 Non-Functional Requirements

The project is titled Low Cost High Accuracy Spectral Test System, with emphasis on the low cost, therefore this is one of the non-functional requirements. Below is our cost analysis:

Budget: $200

Anticipated Costs:

- TI ADC under test (free from Dr. Chen)
- Any TI semiconductor chips (free from Dr. Chen)
- Other Surface Mount Components ~$20
- PCB Fabrication and Technology ~$50
- Battery for power supply ~$10

The BOM for the project has not been constructed yet. Once it is, it will be placed here.

1.8 Market/Literature Survey

As stated earlier, the Iowa State Graduate Student Benjamin Magstadt based his graduate thesis around this idea of relaxing the specifications needed for spectral testing. We are using his research and implementing it into a test board for one specific kind of ADC. The alternative, which we will be comparing this to, is the traditional spectral testing which involves Audio Precision equipment. The technology for spectral testing exists, we are just trying to implement an alternative, and compare our results to the traditional standard.

1.9 Deliverables

The deliverables we are going to give:

Semester 1: simulation results, design schematics, functional PCB
Semester 2: verilog codes, proof of FPGA interfacing with PCB, output data from ADC, data analysis results from MATLAB

2. Work Breakdown Structure

2.1 Project Schedule

Start Date	Description	Deadline
9/1/15	Research	9/22/15
9/22/15	Schematic Version 1	10/6/15
10/6/15	Schematic Final Version	10/20/15
10/20/15	PCB Version 1 (Component Placement & Board Outline)	10/27/15
10/27/15	PCB Version 2 (First Draft with routes)	11/3/15
11/3/15	PCB Final Version	11/17/15
11/17/15	PCB Fabrication	12/3/15
12/3/15	Testing/Presentation	12/9/15
1/1/16	Software Implementation	5/15/16

2.2 Risks/Feasibility Assessment

In order to replace the traditional Spectral Test System, we are utilizing the research of Benjamin Magstadt who proposed that three algorithms with the right system would provide comparable results to the very expensive Audio Precision Instruments. In his thesis, he achieved a proof of concept, so if we follow his algorithms the project should be feasible. We will be using his design and approach as a strong reference as we incorporate our low cost high-accuracy spectral test system.

2.3 Conclusion

The goal of the project is to develop, test, and document a prototype for the Low Cost High Accuracy Spectral Test System for the TI ADS8881. Here, we will created hardware in the form of a PCB for the system, and will create and incorporate functional Matlab programs of Ben's algorithms to perform the Spectral test. Our data will be visible on a PC which is directly controlling the PCB board. The device under test will simply be inserted into a socket, for easy insertion and removal for a large number of ADS8881s.

3. Design Updates 11/10/15:

Based on our present progress, the plan should be adjusted as the following:

3.1 Hardware

We are in the process of drawing PCB, this is going to take us a week at least, due to the fact we need to look for different footprints when we design the PCB. And some design details need to be considered like how to assign digital and analog grounds in the same schematics and how to connect these grounds with grounds in other schematics, if we don't do the ground assigning appropriately the digital and analog signal will interfere with each other.

3.2 Software

After the PCB is fabricated, we are going to use SPI communication protocol to interface with PCB, a SPI need at least a slave and a master. In our system, DAC and ADC are two slaves and the FPGA is master. So in order to use FPGA as a master, we need to write the verilog codes and examine the timing in the ModelSim first, and after that, we will upload the master codes into FPGA and assign input and output pins from FPGA to master. So then the FPGA can actually control the slaves on the PCB.

Reference

1. Ben's Master Thesis:

Magstadt, Benjamin Thomas, "Relaxing the requirements for accurate spectral testing of data converters" (2014). Graduate Theses and Dissertations. Paper 13918.