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Design of FIR digital filter based on MATLAB and FPGA

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Abstract: Aiming at the characteristics of FIR digital filter, this paper designs an amplifier and AD,DA module as the connection of input and output, which can adjust the magnification in real time to meet the input requirements, and burn the FIR engineering hardware circuit program into the quartus after configuring the PIN, and enter the real signal for testing. Finally download to FPGA chip.
Keywords: Digital filter, MATLAB, FPGA, top-down, modular design.

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1. INTRODUCTION

In the 21st century, the contribution of electronic engineering technology to society is increasing, especially in the field of communication, and the various signal processing technologies involved in it are getting more and more attention. In the 60 's, the field of digital signal processing science gained rapid development, its theoretical system and research framework slowly matured, its processing principle is: signal transmission in, the use of hardware system with mathematical skills calculation, conversion signal, in order to obtain a clearer and processing signal, mathematically expressed in sequence. and digital filter plays an extremely important role in this discipline. Digital filter is a discrete time system, when digital filter is used to process analog signal, the input analog signal must be sampled and ad converted first[1-3]. It covers a wide range of areas, including communication systems, automatic control, biotechnology, mechanical manufacturing, remote sensing measurement, radar scanning, aerospace detection, power remote control, automation instruments and so on.

2. CONTENTS AND REQUIREMENTS OF THE PROJECT

This design is mainly using Figure 1 implementation scheme, in MATLAB signal processing box Fdatool tools to design the FIR filter parameters to meet the requirements of performance indicators, and then the use of Fdatool to derive the ideal filter coefficient, and then in the Dspbuilder tool to establish a filter model and simulation, After compilation, the VHD file is imported into the Quartus ⅱ project, and the required FIR filter can be obtained by connecting to the AD and Da modules[4]. By using the actual signal for filtering analysis, the ideal filtered signal and the actual hardware filtered signal are obtained by MATLAB and Quartusⅱ, and their comparison and analysis are carried out, and the implementation scheme is shown in Fig. 1.

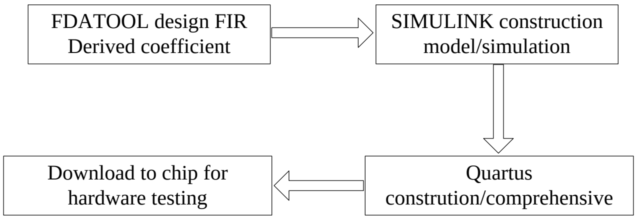

Fig. 1 Implementation Scenarios

3. MATLAB DESIGN FIR DIGITAL FILTER

3.1 MATLAB IntroductiOn

MATLAB is a very powerful and practical scientific computing software[5], it can solve a lot of complex and difficult mathematical calculations, but also to help establish model simulation, as well as the design of various engineering solutions, and so on, greatly helped people in the field of scientific research and engineering breakthroughs, shorten the research and design cycle, improve the efficiency of mental work, It's a civilized booster in the true sense of the meaning. It has powerful features, simple use, strong expansion and development capabilities, easy programming, high efficiency, rich computing resources and so on.

3.2 Directprogramming design FIR

Before using the tool to design fir, three different filters[6] were designed by MATLAB programming to realize the window function method. such as using Window function method to design low-pass filter, using Hanning window function method to design a high-pass filter, using Blackman window function method to design a band-pass filter.

3.3 FDATOOL tool design FIR

FDATOOL is a special tool for designing filters brought with MATLAB. Through visual operations, the parameters of the filters can be arbitrarily adjusted, making the design process simple and fast. The designed filter can also export different types of HDL files as needed, so that users can directly use the derived program to design or integrate the next step. This section will use the window function method to design an FIR low-pass filter, and all subsequent design processes will also revolve around this. MATLAB already integrates FDATOOL in the toolbox, which can be opened in the toolbox, or can be opened by typing FDATOOL in the command line window. FDATOOL is a special tool for designing filters brought with MATLAB. Through visual operations, the parameters of the filters can be arbitrarily adjusted, making the design process simple and fast. The designed filter can also export different types of HDL files as needed, so that users can directly use the derived program to design or integrate the next step. This section will use the window function method to design an FIR low-pass filter, and all subsequent design processes will also revolve around this. MATLAB already integrates FDATOOL in the toolbox, which can be opened in the toolbox, or can be opened by typing FDATOOL in the command line window.

3.4 Design filters

The FDATOOL interface is arranged with a set of tool buttons on the lower left side. Select the Design Filter button, enter the design filter interface, and make the following choices, as shown in Fig. 2.

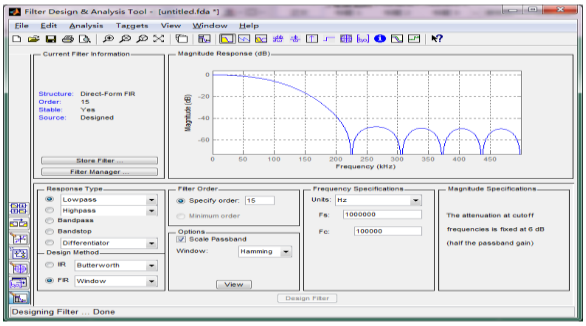

Fig. 2 FDATOOL design interface.

3.5 Filter coefficient

After FDATOOL has designed the FIR filter, the coefficient can be observed by selecting the menu "Filter Coeffients". As shown in Fig. 3, the coefficient(15-order direct I) of the FIR filter designed by FDATOOL is shown.

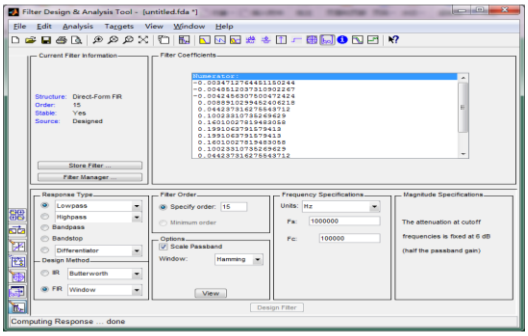

Fig. 3 Filter coefficient

After obtaining the filter coefficient, select the "Export" command under the FDATOOL "File" menu and begin to derive the filter coefficient into the workspace. The calculated coefficients can determine what kind of filter the subsequent FIR model is, how the performance requirements are, etc.. It can be said that the coefficients here determine everything. Therefore, the coefficients first imported into workspace are floating-point types and can not be directly applied to FPGA applications. Therefore, we need to perform quantitative coefficients. The design of FIR filters in FDATOOL is mainly to analyze performance, quantify coefficients, and prepare for the establishment of models later.

3.6 SIMULINK establishes FIR model

The SIMULINK component contains a variety of libraries that are suitable for simulation modeling and can support a variety of dynamic simulation systems with different sampling rates. Including signal processing, automatic control, discrete models, and various mathematical operations. SIMULINK is also a graphical window. Drag the component to build the model, intuitive and simple. The general steps are: select the required functional modules in the module library and drag them into the design window. According to the design connection model, set the simulation parameters, run and begin to observe the simulation results, compare and analyze the model and improve the model until the simulation has a good running state. The following section describes the low-pass FIR filter designed by using SIMULINK to model simulation FDATOOL.

Type SIMULINK in the MATLAB command window, create a new model file on the file menu, and search the libraries for Digital Filter Design, Wine Wave, Scape, and Ad. The connection is shown in Fig. 4 below.

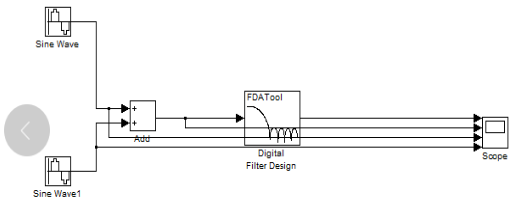

Fig. 4 SIMULINK model

Click the Digital Filter Design component to pop up a design interface similar to FDATOOL. Here we fill in the relevant parameters according to the settings in FDATOOL. After realizing the model, we close the interface and set the sine wave module, as shown in Fig. 5.

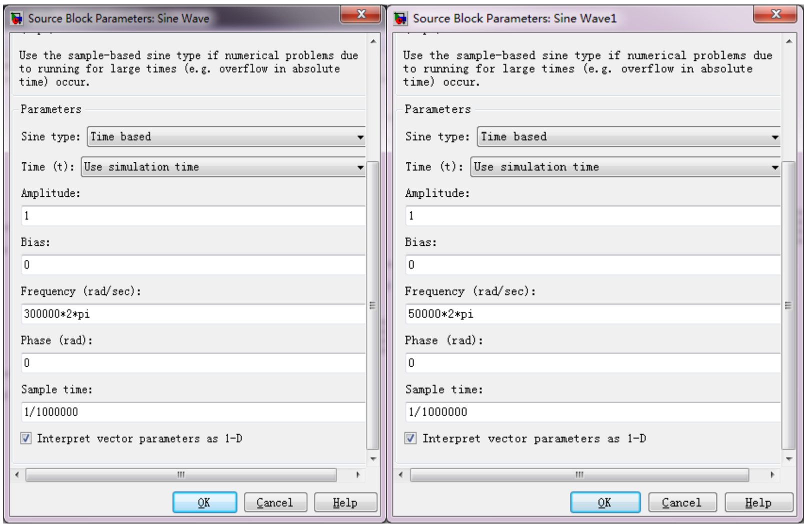

Fig. 5 String wave settings

3.7 DSP _ builder modeling

Install the DSP build and then, in the Simulink library, it will look like Fig. 6.

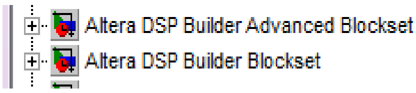

Fig. 6 DSP _ builder Advanced Library

These two high-level libraries appear. It is the key to our modeling and compilation. It is also an important bridge to the QUARTUS software behind us, allowing us to visually design an FIR digital filter. Create a new model file as usual and create a simple model, as shown in Fig. 7.

This is a 4-order filter. We can turn it into a submodel to facilitate calling and saving space in larger systems. As shown in Fig. 8, turn the system into a subsystem Subsystem, which facilitates the establishment of higher order FIR filters.

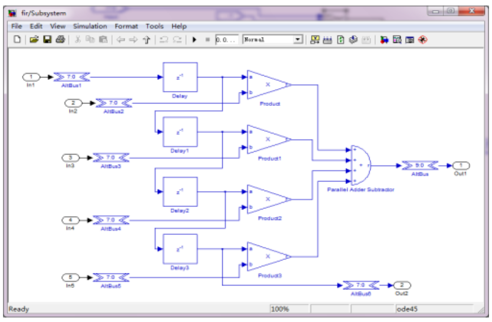

Fig. 7 Submodule of DSP _ builder model

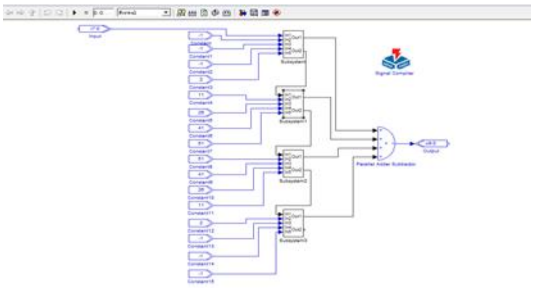

Fig. 8 DSP_builder general model

Write the quantitative coefficients calculated in FDATOOL in the CONSTANT component to form the above system and establish a 16-order filter model. After the model is established, signal generators and oscilloscopes are added and parameters are set for simulation as shown in Figure 3.23. The sampling frequency of the FIR filter designed here is 1MHz, and the cutoff frequency is 0.1 MHz, so we enter the signals of 0.05 MHz and 0.2 MHz. According to theory, the signal of 0.2 MHz should be filtered, and the 0.05 MHz signal can pass. The model simulation is shown in Fig. 9.

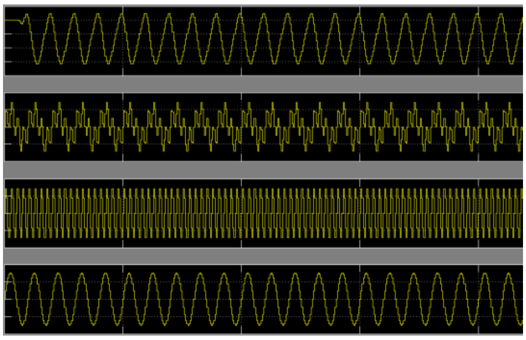

Fig. 9 Simulation waveform

It can be seen from the figure that the third 0.2 MHz signal is perfectly filtered, while the fourth 0.05 MHz signal can pass. After the synthesized second signal input filter, only the first FIR output signal(0.05 MHz) is left. From this, it can be obtained that the filter is true and correct at the algorithm level. The FIR model is correct.

4. DESIGN OF FIR’S PERIPHERAL CIRCUIT

4.1 LM358 Amplifier Module

The LM358 is a dual op amp consisting of two independent, high-gain, internal frequency compensated dual op amplifiers. There are two modes of operation: single power supply and double power supply. Under normal conditions, the input current is not related to the voltage. It is generally used in signal amplifiers, DC gain modules, and all other applications that can be powered by a single power source. Fig.10 is the design of the LM358 amplifier, which constitutes a magnification by the ratio of the sliding resistance R2 control to the R1 resistance.

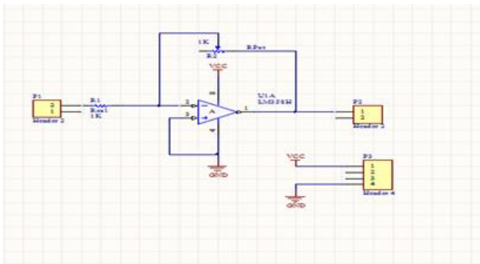

Fig. 10 Principle diagram of LM358 circuit

4.2 Diagram of TLC 5615

It can be seen from the timing diagram that when the CS is low and the CLK clock is an upward edge, one bit of DIN data is moved into the 16 displacement register. When CS is high, the 10-bit valid data of the register is locked in the DAC register for circuit conversion. The serial input data at this time can not be received. Note that the CS jump must occur during the low level of CLK. Fig.11 is a schematic diagram of the TLC 5615 circuit.

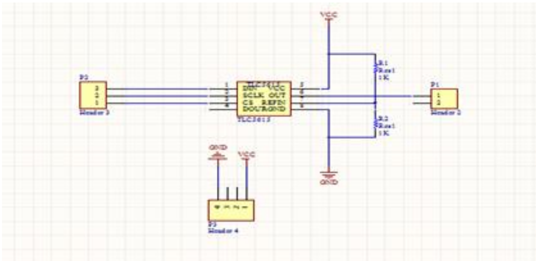

Fig. 11 TLC 5615 circuit schematic

5. CONCLUSION

This topic is to design an FIR digital filter. We need to understand the principle and structure of the filter. We need to understand the entire design process in order to grasp the progress, better guide the design ideas, and encounter problems before we have countermeasures. FIR digital filter has the advantages of stability and linearity, but there are also problems such as large structure and resource consumption. This is also the reason why the FIR designed in this paper has only 16 orders, because the higher the order, the larger the size of the filter. We need to consider the actual needs to design the optimal results.

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