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FPGA based RF pulse generator for NQR/NMR spectrometer

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Abstract

A FPGA based radio frequency source and pulse programmer for NQR is described. With the use of direct digital synthesis (DDS), the RF source has the ability to yield RF signal with short switching time and high resolution in frequency and phase. To facilitate the generation of RF pulses, pulse programmer implemented in FPGA, is also used as auxiliary controller of DDS. The pulse programmer controls the DDS to generate RF pulses according to predefined parameters.

Keywords: **FPGA; NQR; NMR; DDS**

1. Introduction

Nuclear Quadrupole Resonance (NQR) spectroscopy is an area of radio frequency spectroscopy which offers several possibilities for analytical detection of chemical substances in solid phases[1]. NQR provides unique signature of material of interest. NQR is related to Nuclear magnetic resonance (NMR) but does not require large magnetic field and thus this makes it useful for various applications from material characterization to mine detection [2].

The design of radio frequency source is critical to the development of NQR spectrometer. In addition to frequency range and spectral purity, it is generally desired that the RF source is capable of generating RF pulses with short switching time and high resolution in frequency and phase. For NQR signal detection from different

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samples RF pulses needs to be programmed. To adapt the RF pulses to various samples, the parameters of RF pulses such as pulse width, the gap between two pulses, and the frequency of the RF signal and the amplitude of the RF signal needs to be configurable and programmable. In order to realize programmability the signal pattern has to be initiated from low voltage/power level.

Conventionally, frequency synthesis is achieved through three methods: Analog mixing, phase locked loop, and direct digital synthesis. With the development of modern technologies, the DDS technique is becoming the most common choice for constructing RF source. Particularly for an NQR/NMR spectrometer this method has advantage of being able to control the frequency and phase of RF signal digitally, rapidly and precisely. Thus for low cost and compact NQR/NMR spectrometer DDS chips[3] are used as RF source. The main function of the excitation part of the NQR/NMR spectrometer is to create the pulse sequence patterns which is achieved with better precision than the the anolog circuits. This paper describes implementation details of DDS technique and pulse programmer in FPGA. Similar implementations in different platform like DSP[4] are available however implementation based on FPGA offers many advantages over others. FPGA due to its reconfigurable feature is most popular technology to implement prototype and test new algorithms[5].

2. Direct Digital Synthesizer (DDS)

DDS is the generation of signal waves by means of digital signal processing. The block diagram of DDS is shown in Figure 1.A. A time varying waveform is generated in digital domain and then using DAC it is converted to analog form. As the operations are digital it offers fast switching between output frequencies, better frequency resolution. The output level of DAC is updated in synchronous with master clock. As there are discrete changes in output voltage at clock rising edges, the output of DDS contains signal with fundamental frequency along with many higher harmonics. The higher harmonics are filtered away by passing it through a low pass filter.

The main components of DDS are phase accumulator, Look up table (LUT) also called as Phase to amplitude converter and DAC. The maximum output frequency depends on the clock frequency. The operating frequency depends on the clock frequency and the program tuning word which is stored in register called as frequency register. The binary number in the frequency register provides the main input to the phase accumulator. The phase accumulator is a variable modulus counter that increments the number stored in it each time it receives a clock pulse. It computes a phase address for the LUT (Phase to amplitude converter) which delivers the digital value of amplitude corresponding to sine of that phase angle to the DAC. The DAC converts the number to a corresponding value of analog voltage or current. The larger the added increment, the faster the accumulator overflows resulting in higher output frequency. If the increment is small, the phase accumulator will take many more steps, generating a slower waveform.

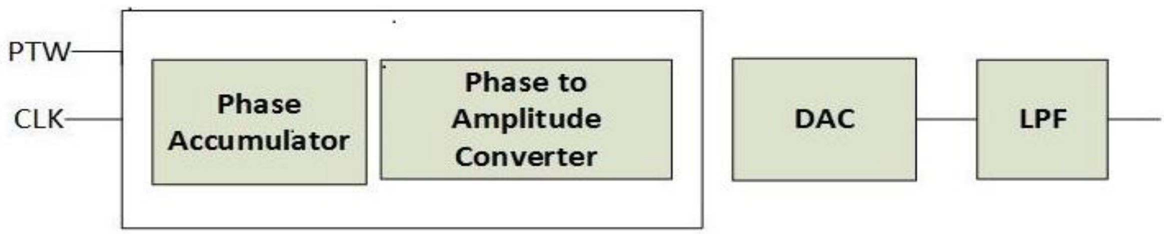

Figure 1 . Direct Digital Synthesizer