

Implementation of Digital and Analog Modulation Systems using FPGA

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Abstract— FPGA (Field Programmable Gate Array) based implementations of digital and analog modulation techniques play a vital rule in the design of signal processing system. The performance and flexibility provided by reconfigurable computing speeds up the development process in signal processing implementations using FPGA. Different methods for digital and analog modulation are designed in this paper by using Sg System Generator tools & Vivado. Then all designed systems are implemented successfully in an FPGA hardware via the NEXYS 4 DDR with ARTIX 7 XC7A100T. A comparison between five types of digital modulation techniques is discussed in terms of resources utilization in FPGA hardware. And also, the implementation of analog modulations in FPGA is contributed in this work. The hardware implementation shows that the number of slice LUTs in ASK modulation is 0.07% while in FSK modulation is 0.13% of the total number of slice LUTs. And also, the number of bounded IO that used for PSK modulation is 4.8% while in PM modulation is 61.4% of the total number bounded IO.

Keywords: FPGA (Field Programmable Gate Array), digital signal processor (DSP)

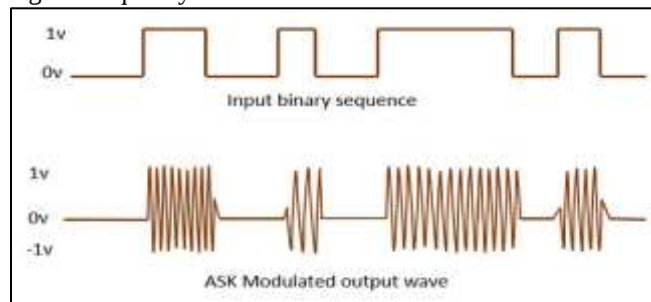
I. INTRODUCTION

Understanding and processing information has become increasingly needed due to the increasing use of computers. And because of these, the usage of signal processing has increased. A digital signal processor (DSP) is a particular form of microprocessor, while an FPGA is an excellent alternative design platform in the implementation of digital systems due to their ability to quickly process parallel hardware designs with minimal cost. In DSP system's implementations, FPGAs became a basic part particularly in fields such as digital communications. Communication is the process of transfer information. It means that the transmitter sends the encoded symbols through the communication channel, and the receiver decoded the information to recover the original data. The modulation method is used in the communication process that increases multiplexing, the range of communication, and improves the quality of reception. It is defined as the method of covering the information contents of a baseband signal on a carrier signal. Quarter Phase Shift Keying (QPSK) modulator is designed using ISE system generator with Hardware Co-simulation tools. Then the designed system is converted to VHDL (Very High-Speed Integrated Circuit Hardware Descriptive Language). ISE Simulation software is used to synthesize the converted VHDL code and implement it in an FPGA. In this work the proposed QPSK modulator is implemented in an FPGA at low power. Digital Modulation Technique is implemented in FPGA for High Range Resolution (HRR). In this work, designing Binary Phase Shift Keying (BPSK) modulation is considered with different methods. BASK, BFSK, DPSK and

BPSK are designed using ISE system generator and implemented in FPGA using Nexys 2 with Spartan 3E board.

II. DIGITAL MODULATION

Digital modulation indicates the method of transmitting a digital signal with low-frequency over a carrier signal with higher-frequency.



A. Digital Modulation Techniques

Digital modulation indicates the method of transmitting a digital signal with low-frequency over a carrier signal with higher-frequency. In radio communications system, modulation is supported by varying the characteristic of carrier sinusoidal signal (amplitude, phase, frequency, or any combination of them). At the transmitter side, the modulator imposes the physical change to the carrier. And at the receiver side, a demodulator recovers the information. The most used digital modulation methods are:

1) Binary Amplitude Shift Keying (BASK)

In a BASK modulation, the carrier signal's amplitude is altered in consistent with the message bit's values without changing the frequency and phase. The BASK modulated signal is represented by the carrier signal when the message data is 1, otherwise, it is represented by 0. In modulation process, the modulated signal is created by multiplying the bits data with a carrier signal. $(t) = \{Ac \sin(2\pi f_c t); \text{ if message data} = 1 \text{ } 0; \text{ if message data} = 0 \text{ } (1)$

2) Binary Frequency Shift Keying (BFSK)

In a BFSK modulation, the carrier signal's frequency is altered in consistent with the message bit's values without changing the amplitude and phase. In BFSK, two carrier signals are used in modulation. The modulated signal is represented by the first carrier signal when the message data is 1, while it is represented by the second carrier signal when the message data is 0 [17]. $(t) = \{Ac \sin(2\pi f_1 t); \text{ if message data} = 1 \text{ } Ac \sin(2\pi f_2 t); \text{ if message data} = 0 \text{ } (2)$ Where $f_s \ll f_1 \text{ \& } f_2$.

3) Binary Phase Shift Keying (BPSK)

In a BPSK modulation, the sinusoidal carrier signal's phase is altered in consistent with the message bit's values without changing frequency and amplitude. In BPSK, the modulated signal is represented by the positive value of the carrier signal when the message data is 1, while it is represented by the negative value of the carrier signal when the message data is

0 [19, 20]. $(t) = \{Ac \sin(2\pi f_c t); \text{if message data} = 1 - Ac \sin(2\pi f_c t); \text{if message data} = 0\}$ (3)

4) Quarter Phase Shift Keying (QPSK)

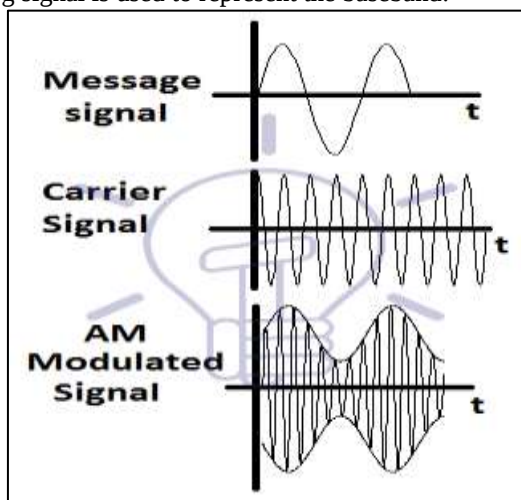
QPSK modulation is based on phase modulation. Two bits are used to represent each symbol, I and Q channels are used to modulate these bits. Sine and cosine waves are used as carrier signals for I and Q channels respectively. There are four cases in QPSK modulation: (00, 01, 10 and 11). In each case, different phases are used to create QPSK and these phases are 0° , 90° , 270° and 360° . The symbol period is Indonesian J Elec Eng & pComp Sci ISSN: 2502-4752 Implementation of digital and analog modulation systems using FPGA (Raya. K Mohammed) 487 double the bit period $T_s = 2T$. As compared with traditional digital modulation methods (BFSK BPSK BASK), QPSK is considered as fast modulation method.

5) Differential Phase Shift Keying (DPSK)

DPSK is a mutual method of phase modulation which transfers binary data by varying the phase of the carrier signal. As well as in BPSK and QPSK, there is no insurance which signal is passed according to its phase if the constellation is rotated by some influence in the communications channel. This issue can be solved by using the data to alteration instead of set the phase. In DPSK, the modulated signal's phase is shifted corresponding to the earlier signal element. DPSK doesn't required a synchronous carrier at the receiver. The modulated signal is represented by the negative value of the carrier signal when the message data is 0, while it represented by the shifted phase of the preceding carrier signal when the message data is 1. For that reason, in the receiver, the preceding received bits are used to distinguish the current bit. $(t) = \{Ac \cos(2\pi f_c t + \theta(t) + \theta); \theta \text{ is } \pi \text{ if message data} = 1 Ac \cos(2\pi f_c t + \theta); \theta \text{ is } 0 \text{ if message data} = 0\}$ (4) where $\theta(t)$ is phase information and θ is the phase shift presented by the channel.

III. ANALOG MODULATION

Analog modulation indicates the method of transmitting an analog baseband signal with low-frequency over a carrier signal with higher-frequency. In this type of modulation, an analog signal is used to represent the baseband.



A. Analog Modulation Techniques

1) Amplitude Modulation Technique (AM)

In AM, the carrier signal's amplitude is changed in consistent with the message signal's amplitude. Suppose that the message signal is $m(t)$ and the carrier signal is $c(t) = A \cos(\omega_c t)$, then the AM signal $Y(t)$ is represent by [24, 25]: $Y(t) = [A + m(t)]\cos(\omega_c t)$ (5)

2) Frequency Modulation Technique (FM)

In FM, the carrier signal's frequency is changed in consistent with the message signal's amplitude. Suppose that the message signal is $m(t)$ and the carrier signal is $c(t) = A \cos(\omega_c t)$, then the FM signal $Y(t)$ is represent by: $Y(t) = A \cos(\omega_c t + k_f \int m(\alpha) d\alpha)$ (6)

3) Phase Modulation Technique (PM)

In PM, the carrier signal's phase is changed in consistent with the message signal's amplitude. Suppose that the message signal is $m(t)$ and the carrier signal is $c(t) = A \cos(\omega_c t)$ then PM signal $Y(t)$ is represent by: $Y(t) = A \cos(\omega_c t + k_{pm}(t))$ (7)

IV. RESULT AND ANALYSIS

All the designed digital and analog modulation systems had been successfully converted to VHDL codes using HDL Netlist tools in system generator token with the appropriate settings of FPGA board and clock requirements. Then, VHDL codes are synthesized, implemented, and successfully converted to bitstreams that are downloadable to NEXYS4 DDR Board with ARTIX 7 XC7A100T-1CSG324C FPGA device. In system generator's environments, the input signals are demonstrated as external inputs in system generator, these inputs are successfully connected to FPGA board's input switches. The inputs and outputs to the gateway in and gateway out blocks are assigned successfully to the available input switches and output leds in the target board during the process of implementing the constrain file in Vivado.

The process of programing the FPGA board with FSK bitstream is shown in Figure 1(b) Figure 1(a) show the schematic results of FSK modulation. Figure 2 shows FSK waveform simulation results. Table 1 shows the utilization summery of digital and analog modulation techniques such as: number of slice LUTs, Slice Register, Slice, LUT as Logic, LUT as memory, LUT flip flop pairs, and number of IO blocks.

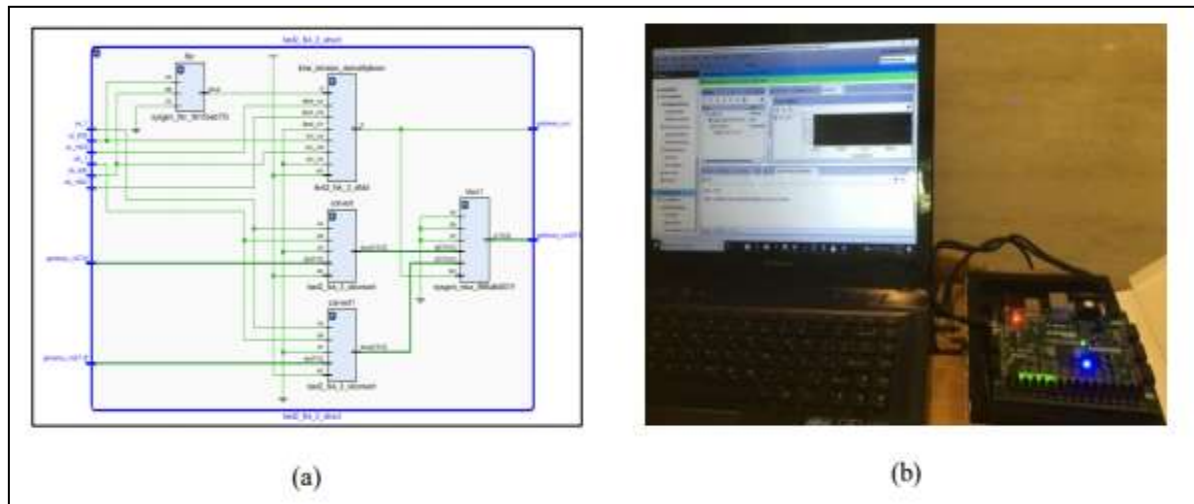


Fig. 1: FSK hardware implementation. (a) Schematic results, (b) Programming FPGA board

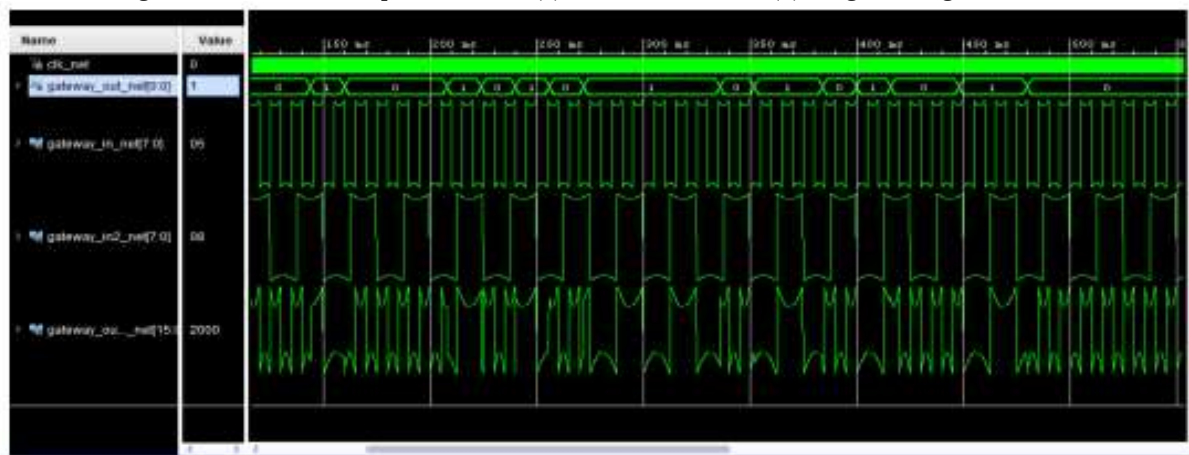


Fig. 2: FSK simulation results

V. LITERATURE REVIEW

A. Quadri, F., Tete, A.D.

It presented the review of the different digital modulation techniques and the various methods and tools that are used to implement it on FPGA along with the design summary and logic utilization of the resources.

It includes an approach for the implementation of three modulators mainly Amplitude Shift Keying modulator, Phase Shift Keying modulators and Frequency Shift Keying modulator in VHDL by means of Xilinx 13.1 and simulation in Modelsim.

B. R.Gandhiraj, Ranjini Ram, K.P.Soman

It presented a small tutorial for the new users in the field of software defined radio. Applications are build up using graphical user interface called the GNU radio companion (GRC).

The idea behind developing such a tool kit is to give practical exposure in the communication concepts like basic signal generations, signal operations, multi-rate concepts, analog and digital modulation schemes and finally multiplexing schemes with the help of GNU radio.

VI. CONCLUSION

In this work, the design and implementation of analog and digital modulation techniques are obtained in system generator with Vivado 2017.4. The main contribution of this paper is the implementation of analog modulation in FPGA hardware. The FPGA implementation of digital modulation such as BASK, BFSK, BPSK, DPSK, and QPSK and analog modulation such as AM, FM and PM modulation techniques have been tested using NEXYS 4 ARTIX 7 DDR FPGA board. With the FPGA-based digital and analog modulation system, the results from this work proved that the numbers of FPGA resources required for digital modulation schemas are less than the ones required for analog modulation schemas.

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