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Design and Implementation of a Low Power Consumption of ASK, FSK PSK, and QSK Modulators Based on FPAA Technology

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***Abstract*— Wireless communication techniques have become more popular due to their characteristics. These systems adopt the digital modification application, which provides more information for transmission and compatibility with digital data services as well as high information security and quality improvement. Digital wave signal-based communication techniques such as PSK, FSK, ASK, and QPSK considered among the most significant digital modulation techniques. These technologies are a crucial part of digital communication systems. Digital communication devices designed by FPAAs can provide multiple communication without arranging new devices and can support new within seconds. FPAA is extremely easy to reconfigure and program concerning FPGA or DSP-based applications. This article offers real-time implementation of ASK, FSK PSK, and QPSK modulator techniques with low power consumption based on the capability for dynamic reprogramming of the FPAA AN231E04 device Anadigm. FPAA techniques provide growing application and high pliability in the implementation of analog circuits. The measurements achieved from the proposed modulated circuits show that the form and properties of the theoretical outcomes agree perfectly with the practical outcomes. FPAA techniques provide growing application and high pliability in the implementation of analog circuits for minimizing the time of design and testing. Another feature is the minimum power exhaustion (165 mw) due to the switched capacitor method used by the FPAA Chip, which gives a high accuracy process.**

***Keywords*—FPAA; ASK; FSK; PSK; QPSK; digital modulation.**

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I. INTRODUCTION

These days, wireless communications see a huge qualitative change in high quality and request further security, credibility, efficiency. Reducing the cost, size, and waste of energy in modulation and demodulation circles is of great interest to industry researchers as well as a reduction in their size. The solutions proposed by industry and related research have encouraged analog works, which is usually a simple structure that raises energy proficiency per bit [1].

FPAA technology has joint hardware and software features, dependable and resilient, rapid reaction, easy to build model, low cost, and straightforward design for programmable architecture [2]. FPAA devices assist in obtaining some goals, which are used in the study of circuits implementation using the lowest number of components [3]. The FPAAs are the perfect solution for the fast implementation of analog prototype processing systems [4]. The system on the FPAA chip is an effective technique to address issues of proper analog techniques that is whole. FPAA does not modify the analog signal into a digital one; rather all the signal treatment units are implemented locally analog composed, thus preserving the high accuracy quality of the genuine signal [5]. The eminent systems for encoding information into the carrier are shift keying mechanism comprises amplitude, frequency, and phase-shift keying [6]. With the fast development of wireless communication, Field programmable gate array (FPGA) is used to test the digital hardware part, which features a small size, lower power, and lower cost of portable devices, while field-programmable analog array (FPAA) can be used to test the analog hardware [7]. FPAAs are qualified devices used for low-power applications. FPAAs systems have favorable safety features. FPAA systems can be the portion of the secure application. FPAA systems can be utilized to examine the protection of analog-signal abilities [8], implement amplification, filters, arbitrary wave signal, [9] intelligent sensor programs [10], analog neural application [11], and path map of the robotics application [12]. The architectonics of the FPAA AN231E04 device used are displayed in detail in Fig. 1 [13].

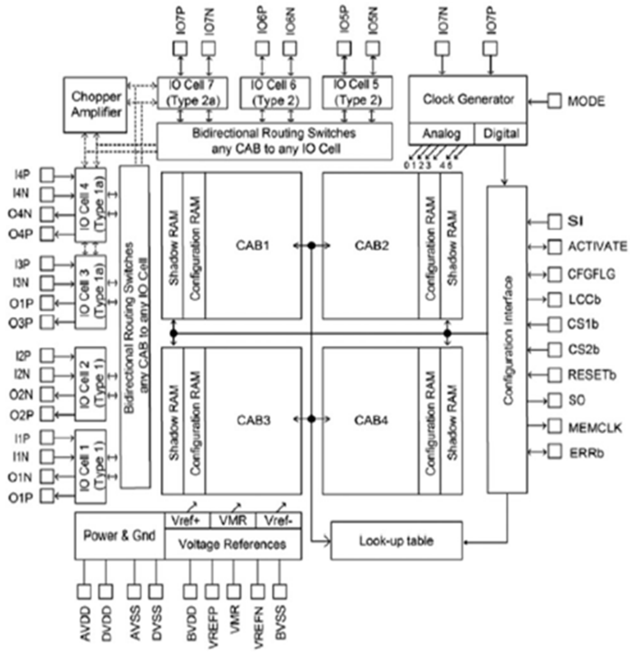

Fig. 1 Architectural overview of the AN231E04 device

FPAA is an analog system that facilitates one to build several analog Careers and integration, differentiation, sampling and holding, multiplying, filtering, oscillating, amplifying, and summing stage. The configuration of the sever CAB blocks can be programmed by Anadigm Designer 2, which includes the task of emulation that supplies a simple way to examine the circuit behavior [14].

This study displays a scientific approach to design and implement four modulation systems based on the FPAA device. In addition to estimating the power consummation of these modulators. The flowchart shown in Fig. 2 supplies the search execution phases to implement four types of modulated systems on an FPAA chip.

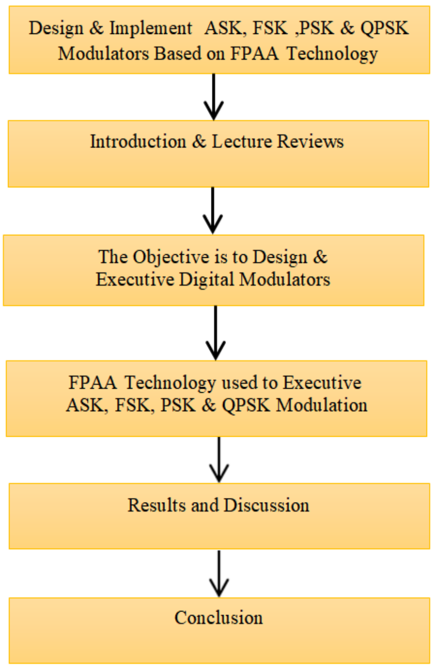

Fig. 2 The flowchart for the search execution phases.

II. Materials and Method

Amplitude-Shift Keying (ASK), frequency-shift keying (FSK), phase-shift keying PSK) is the common modulation and demodulation techniques used in digital communication systems [15]. PSK, FSK, and their derivatives may present high data rates and strong impedance to noise, but they encounter serious execution difficulty and energy dissipation [16]. ASK is often used due to its simple implementation and low energy dissipation of its detection circuit compared to other techniques. The three main types of digital modulation are discussed in this section: Amplitude-Shift Keying, Frequency-Shift Keying, and Phase-Shift Keying.

A. ASK Modulation

It is one of the major digital modulation methods, which is utilized in radiotelegraphy. The analog carrier amplitude is changed concerned with the digital input signal. The ASK modulation technique is used in military communication implementation, health observing systems, biomedical applications, etc. The feature of utilizing ASK being not to need extra bandwidth. This Linear modulation project carries on the message bits in the envelope of the signal transmitted, which has a sensitivity to noise and requirement a linear amplifiers, which are expensive and smaller power efficient [17].

In Binary Amplitude-Shift Keying (BASK) modulation, the capacity of the sinusoidal carrier signal is varied accord to the binary data (“0” or “1”) while keeping the frequency and phase constate. Fig. 3 represented the circuit diagram of the BASK modulator and its output signal, represented by Equation (1) [18].

$$\text{SBASK}(t) = x(t)\, B \sin(2\pi\, fc\, t + \varphi) \qquad (1)$$

Where $x(t) = 0$ *or* 1 and B, f_c *and* φ are the amplitude, frequency, and phase of the carrier signal, see Fig. 3.

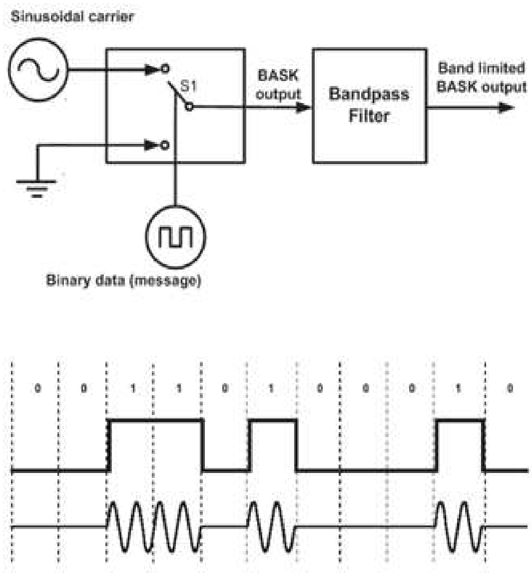

Fig. 3 ASK Modulator

B. FSK Modulation

FSK technique plays a significant role in high-frequency wireless communication purposes, wireless sensors, and biomedical usages, requiring a mightily minimum power [19].

It can be said that FSK is one of the most common modulation techniques used in digital telecommunications, which can be defined as the transmission of binary data "0" by frequency f_0 and binary data "1" by frequency f_1. It can be concluded that the FSK signal is due to the sum of two amplified amplitude (AM) signals of the different carrier frequency signals [15,20]:

$$f(t) = f_0(t)\sin(2\pi f_0 + \varphi) + f_1(t)\,sin(2\pi f_1 + \varphi) \quad (2)$$

FSK is closely used in modern communication devices. The principle of the FSK modulator is shown in Fig.4. Sequence binary information is first applied to an on / off level encoder, which can be chosen between two oscillators. When the down channel f_2 closes, producing the transmission of carrier frequency f_1. Close the oscillator in the upper channel f_1, producing the carrier frequency f_2 [21,22].

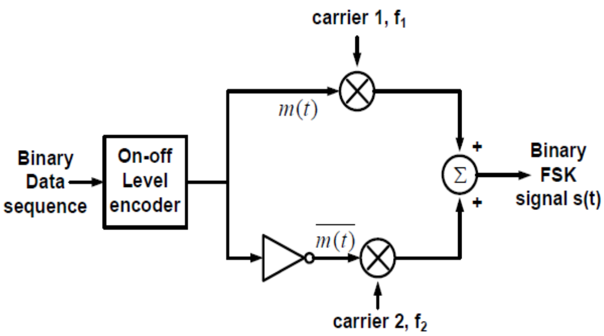

Fig. 4 FSK Modulator block diagram

C. PSK Modulation

Nowadays, the increasing demand for using phase-shift keying technologies because of the possibility of transferring the amount of data more than other technologies, like conventional on-off keying (OOK), offers higher receiver sensitivity [23].

The interest to use PSK signals grows due to the attractive properties of these signals represented by noise stabilities. Moreover, PSK signals are characterized by the simpleness of implementation so it is used as stationary units for wireless communication, navigating, and systems evolution [24]. BPSK is the simplest scheme of the PSK. It uses two carrier signals with a 180-degree phase-shift to generate its symbols. BPSK schematic is represented in Fig. 5. A BPSK signal can be represented by the following mathematical formula [25]-[28]:

$$S_n(t) = \sqrt{\frac{2E_S}{T_S}}\; Cos(2\pi f_c t + (1-n)\pi) \quad ,n = 0{,}1 \quad (3)$$

Where E_s is the energy per symbol, T_s is the symbol duration, and f_c is the carrier frequency. Based on the value of n, two signals can be generated:

$$\varphi_1(n) = \sqrt{\frac{2E_S}{T_S}}\; Cos(2\pi f_c t) \qquad when\; n = 1 \qquad (4)$$

$$\varphi_0(n) = -\sqrt{\frac{2E_S}{T_S}}\; Cos(2\pi f_c t) \qquad when\; n = 0 \qquad (5)$$

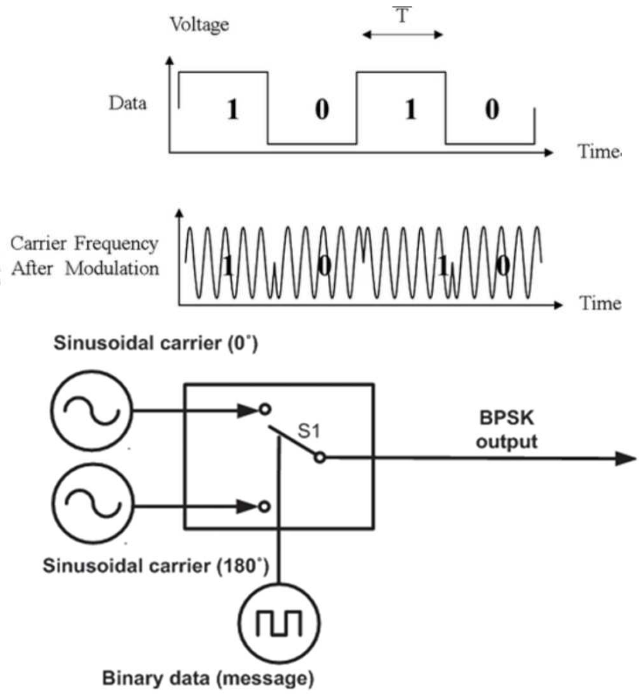

Fig. 5 BPSK Modulator block diagram [25], [26]

D. QPSK Modulation

Because of its intention spectral performance at a specific transmitted power, QPSK (Quadrature Shift Keying Phase) technique is vastly applied in transmitting satellite information. The researchers' focus in recent years on increasing data transmission rates dramatically due to the demand for data rates corroborative by the QPSK technique is growing [29], [30]. QPSK is 4-PSK see Fig.6-a.

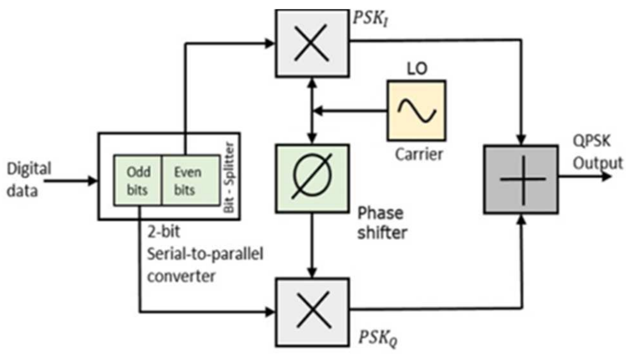

Fig. 6-a QPSK Modulator Block Diagram

In PSK all the information is converted into a coded form in the part of the transmitted signal [26[, [31]. A QPSK modulator works by separating the input binary sequence into even and odds streams. Generating a QPSK signal requires mixing the obtained encrypted information with the sine wave and the cosine wave high-frequency carriers having the same frequency to generate the I and Q phases. The two phases created are added to generate a modulated QPSK wave see Fig.6-b [32]. The mathematical form of the QPSK output signal can be obtained by the mathematical equation to generate the I and Q phases, [25], [26]:

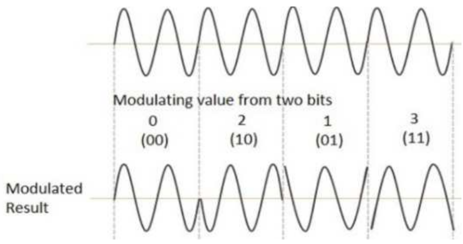

Fig. 6-b QPSK Modulator Block Diagram

$$Q(t) = \sqrt{\frac{2\,E_s}{T_s}}\cos\left(2\pi f_c t + \frac{(2i-1)}{4}\,\pi\right)\,, \qquad (6)$$

$$where\ i = 1,2,3,4$$

III. Results and Discussion

In this section, ASK, FSK, PSK and QPSK Modulators are designed and implemented using FPAA technology.

A. Implementation of Amplitude-Shift Keying

AN231E04 dpASP It is an analog signal processor with the ability to dynamically reprogramed itself. It is used very efficiently and works perfectly in signal preparation, filtering, gaining, rectifying, summating, subtracting, and multiplying. This Analogue Signal Processor also be suitable for sensor application and arbitrary waveform composition.

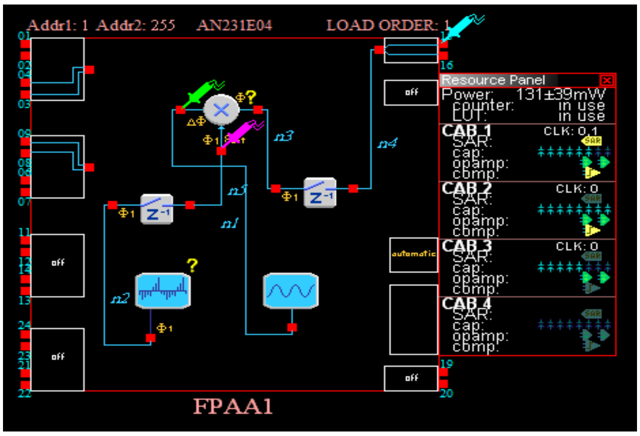

Fig. 7 ASK circuit diagram.

Fig. 7 presents a circuit diagram of a traditional ASK modulator using FPAA technology. It requires two input signals; the first input is the baseband signal S(t) generated using a periodic wave oscillator unit multiplied by periodic wave oscillator signal, which has more amplitude/voltage range than the input binary sequence signal. These signals are fed to the multiplier unit through the unit input cells (I_{n1}) and (I_{n2}).These signals are dealt with by the product of the multiplier and the multiplication factor of this unit as represented by the following mathematical equation:

$$V_{out} = V_1 * V_2 * M \qquad (7)$$

Where M is the multiplication factor was selected. It equals the Hold blocks are used to agree to the appearance of the signals at the outputs. The modulating voltage period is about 50 µs.

B. ASK Realization

ASK modulator circuit had been arranged on FPAA AN231E04. Binary inputs data with a frequency of 20 kHz and carrier waves $Cos\, w_c\, t$ with a frequency of 120 kHz were applied from the function generators; their amplitudes were adjusted to 1 v. Finally, the output wave obtained and observed on the oscilloscope see Fig. 8. The form and quality of theoretical results match perfectly with the practical. The transmitted signal is described by the carrier time Tc = (1/fc) = 8.333µsec and the data bit period Td = 25 µsec.

The bandwidth: $B = (1 + d)\, S$

where, S is the signal rate, and d is either 0 or 1.

$B = (1 + 1)120 = 240\ KHz,$ for *d=1*

$B = (1 + 0)120 = 120\ KHz\,,$ for *d=0*

The circuit consumes a power of 60 ± 18 mW.

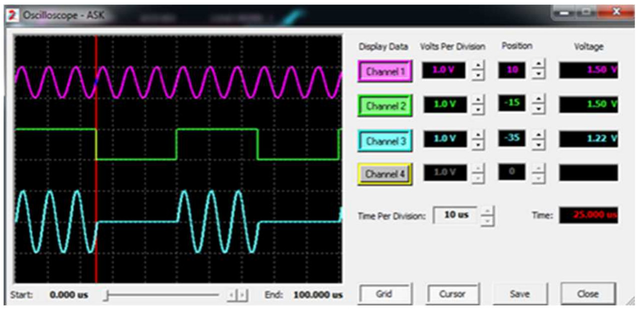

Fig. 8 ASK signal generator waveform

C. Proposed of Frequency-Shift Keying

Fig. 9 shows a frequency-shift keying circuit realization using the AN231E04 FPAA device in the professional design software Anadigm Designer AD2.8.0.10. FSK modulator comprises two Periodic Wave oscillators with a programmable amplitude and frequency output with low and high frequencies associated with a switch controlled by an internal clock. These two different frequencies are used to obtain the desired FSK signal. These oscillators have an uninterrupted output that is always perfect. Qualitative Periodic Waveform Generator used to create the binary input sequence is utilized with the Gain Stage with Switchable Inputs unit to select the frequencies to agree with the binary input, and two samples and hold units are employed to agree with the appearance of the signals at the outputs.

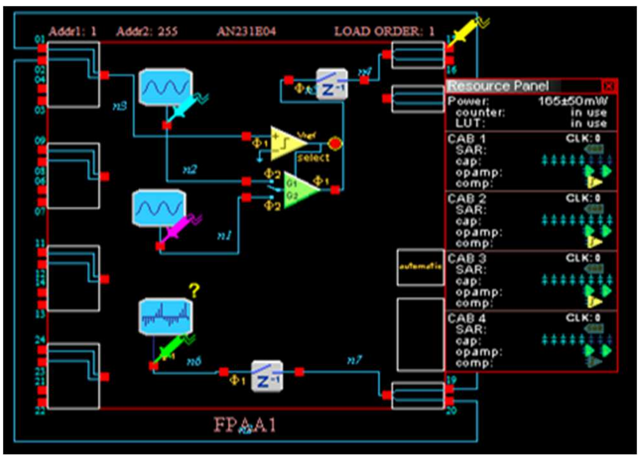

Fig. 9 FSK circuit diagram

D. FSK Realization

At frequency-shift keying, the data signal changes the carrier signal's frequency. For instance, if the data bit (25 μ sec) is logic "1" then output gives $f_1(70\ kHz)$ sinusoidal wave and for logic "0" gives f_2 (230 kHz) a sinusoidal wave. It is required 2 Δ f T >1

Where, $B = {}^{1}/_{2T}$, $2\,\Delta f = f_2 - f_1$

In this system $2\,\Delta f\ T = 260 * 25 * 10^{-3} = 6.5$

FSK is very immune to noise. It is known that the amplitude of the signal is affected by the presence of the noise, while it does not affect the frequency value of the transmitted signal. This modulation output signal is displayed in Fig. 10. The circuit consumes a power of 165 ± 50 mW.

E. Implementation of Phase-Shift Keying

In BPSK, display in Fig.11, the circuit consists of a few information sequences that will modulate the carrier signal. The information signal is a binary digit created using a qualitative signal generator. Two different carrier signals generated using a sine wave oscillator and the gain half module. Phases Gain stage were inverted to signal between zero and 180 before applying to the gain-control amplifier with switchable inputs unit as an "on" and "off" switch based on the voltage value applied to switch.

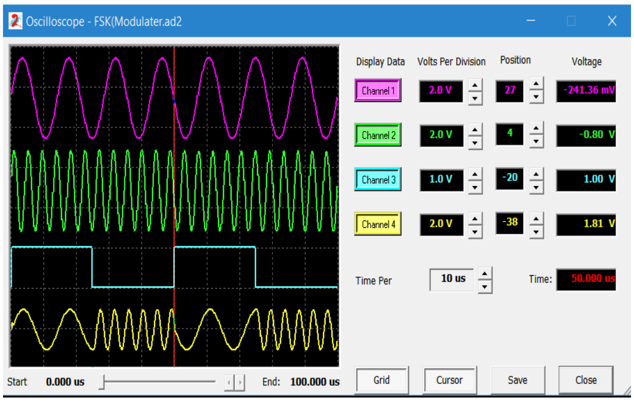

Fig. 10 FSK input signal, the modulated signal

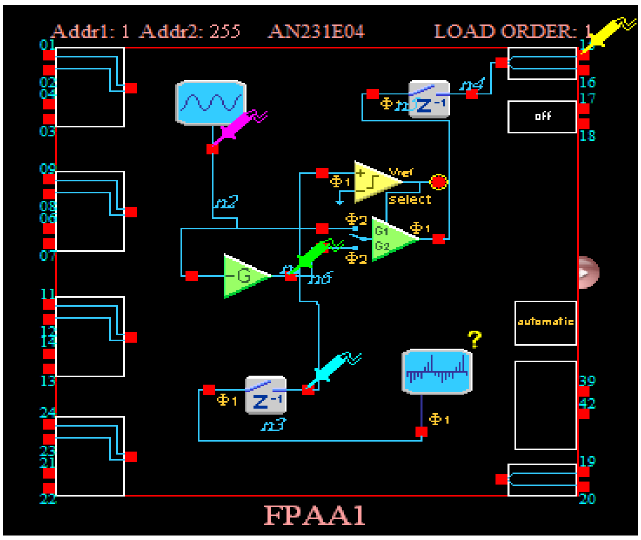

Fig. 11 FSK input signal, the modulated signal

F. PSK Realization

Fig. 12 presents a BPSK signal. Nowadays, PSK is widespread compared to ASK or FSK. Binary PSK is a simple technique like an ASK technique with a significant characteristic: high immunity to noise. The binary information signal used in PSK modulation is 25μ sec. Based on the information signal's logic level, the carrier waveform characteristics are varied with a frequency equal to 120 kHz. It has a bandwidth equal to that of the ASK technique, but less bandwidth compared to that of the BFSK technique. The separating of two carrier signals does not consume bandwidth.

$$B = (1 + 1)120 = 240\ KHz$$

Bandwidth efficiency, $\rho = \frac{R_b}{B}$ bits/s/Hz

where R_b is the data rate and B is the used channel bandwidth.

$$\rho = \frac{40}{240} = 0.166$$

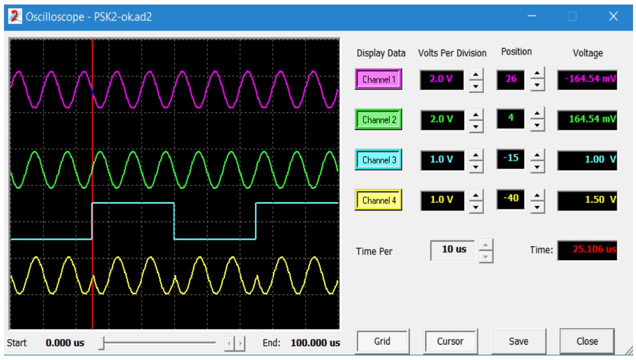

Fig. 12 PSK implementation results

G. Circuit diagram of Proposed QPSK System

Fig. 13 represents the QPSK modulator circuit using the FPAA AN231E04 chip.

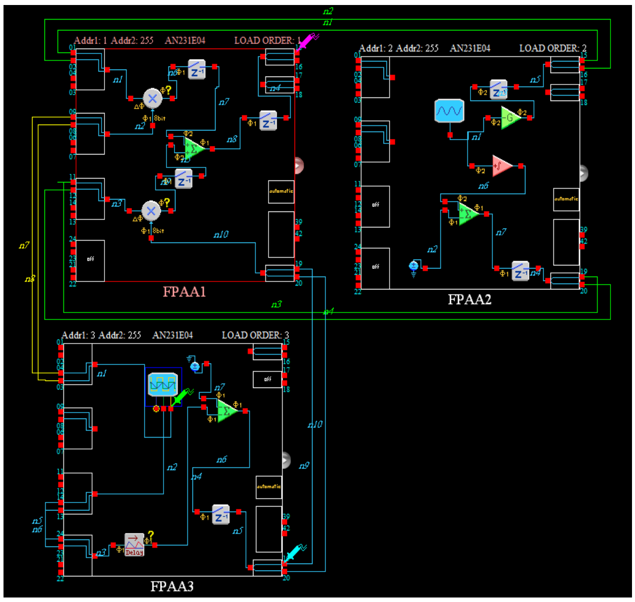

Fig. 13 QPSK Modulator circuit diagram

A PeriodicWave oscillator with square wave outputs is used to generate a 20KHz input data signal. It has a programmable frequency, duty cycle, and peak levels. This oscillator has continuous output. Bit splitters are needed to split the two data bits to generate QPSK.

Analog delay line, summing stage, DC voltage source, and sample and hold CAM are required to split binary data stream into the in-phase and quadrature-phase components which are employed to generate the I-data and Q-data. These separated bits are then passed through two balanced modulators. The carrier frequency used is the same for both the modulators, which are 80 kHz generated using sinewave oscillator CAM. A phase difference of 90 degrees obtained using an integrator, DC voltage, and summing CAM see Fig. 14. Two multipliers' CAMs used to build a balanced modulator to multiply the input bits to the carrier signal to form a BPSK signal is used to generate the QPSK output signal Fig. 15. Finally, summing CAM used for adding these two binaries phase shift keyed signals generate a QPSK signal.

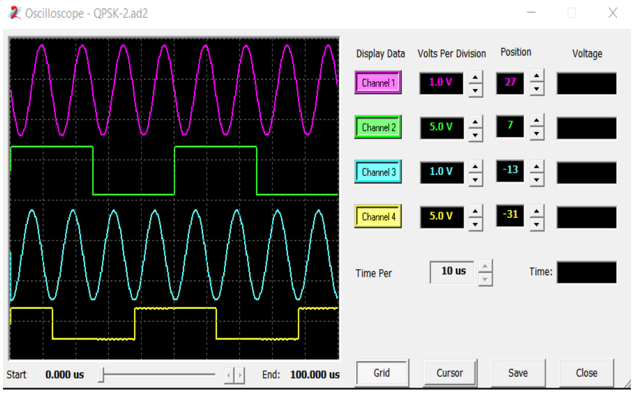

Fig. 14 Bit-streams of I-data and Q-data , Sin wave & Cos wave

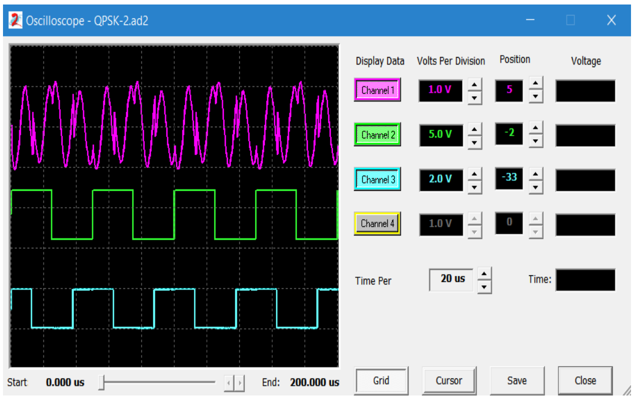

Fig.15 Signal description of the proposed QPAK

IV. Conclusion

Digital communication plays a vital in today's electronic world. Digital communications are rugged in a sense; it is more immunity to channel noise and deformation. Various modulation systems like BASK, BFSK, BPSK, and QPSK were used to acquire high speed and flexibility. Circuits are achieved on the AN231E04 FPAA board, which spends no more than only 388 mW of energy. Because of the dynamic change in the reconfiguration structure, you can say that the system can obtain the same signal strength. All these modulation techniques were implemented based on FPAA technology, and the waveform has been displayed in the system band output. As a result, it can be concluded that FPAA may find wider applications in the future, given that it has many performances, such as compactness, versatility, and flexibility, so no active external elements or filters are required.

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