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Simulation and Implementation of Amplitude-Shift Keying Modulation in Digital Communication Systems: A Practical Approach

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Abstract

Advancements in wireless communication systems have positioned digital communication as a fundamental technology. Among the array of digital modulation methods, Amplitude Shift Keying (ASK) holds a significant position. This study centrally involves the simulation of the ASK modulation scheme using MATLAB software, accentuating practicality in design and execution. Notably, the correlation between simulated results and practical implications stands as a noteworthy achievement. The investigation demonstrates the conversion of a Unipolar return-to-zero square pulse message signal into a sinusoidal form, facilitating seamless transmission to the endpoint.

Three key elements structure this study: the generation of the message signal, the creation of the carrier signal, and their amalgamation to generate the ASK signal. Diverse integrated circuits are employed, encompassing the utilization of a 555 timer to generate the message signal, an LM324 quad operational amplifier chip for carrier signal generation, and a CD4016 multiplexer chip for ASK signal generation. The simulated ASK system closely aligned with the practically designed setup, validating the accuracy of the theoretical model. This convergence can be attributed to meticulous considerations in circuit design and the careful selection of standard values, resulting in a compelling correlation between simulation predictions and real-world implementation.

The graphical representation of the ASK signal, plotted via MATLAB, exhibited a remarkable match between theoretical and practical outputs. Furthermore, the outcomes suggest promising avenues for future exploration. One such direction involves enhancing the system's capacity by implementing an M-ray ASK system, a potential means to augment data transmission rates beyond the binary framework. Additionally, introducing randomness to the binary signal through the integration of a binary number generator emerges as a prospective area for future enhancements.

Keywords: Modulation, Amplitude Shift Keying (ASK), Signal.

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Introduction

In electronics and telecommunications, modulation involves adjusting one or more qualities of a repetitive waveform, which is called the carrier signal. This adjustment is done by using a modulating signal that usually carries information intended for transmission. Broadly speaking, in telecommunications, modulation involves embedding a message signal, such as a digital bit stream or an analog audio signal, within another signal capable of physical transmission. The modulation of a sine waveform results in the conversion of a baseband message signal, occupying a narrow frequency range, into a passband signal covering a moderate to high frequency range enabling it to traverse a filter.

A basic type of ASK modulation involves the modulation of amplitude in a carrier wave by directly assigning source data bits to waveform symbols [1]. Within digital modulation, an analog carrier signal is modified by a discrete signal. These methods can be likened to converting digital-to-analog during modulation and the reverse, analog-to-digital, during demodulation or detection [2]. Changes in the

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carrier signal are chosen from a limited set of M distinct symbols [3].

The fundamental types of digital modulation method are PSK, and FSK, and AKS [4].The modulation process is facilitated by a device known as a modulator, and its counterpart, demodulation, is essentially the reverse of the modulation process and is performed by a device referred to as a demodulator [5]. Amplitude modulation occurs when there is a variation in the amplitude of the carrier signal, frequency modulation when there is a change in frequency, and phase modulation when there is a shift in phase [6]. Each of these alterations serves specific purposes. The benefits of the modulation process in wireless communication systems include a reduction in antenna size, minimizing interference, and allowing multiplexing techniques for different signals [7].

In the present era, characterized by a vast global population of mobile users, there is an increasing demand for a more dependable communication system featuring higher data transmission rates and increased channel capacity for long-distance data transfer [8]. Overcoming the challenges of ensuring superior quality in communication services, once a significant hurdle, is now easily achievable through the application of various digital modulation techniques [9]. These techniques offer heightened carrying capacity, a lower probability of errors, improved quality, enhanced security, and broader bandwidth services [10].

When transmitting digital signals via carrier modulation in a channel, carrier expression involves three variables [11]. This leads to the division of digital signal modulation technology into three methods:[12] Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), and Phase Shift Keying (PSK). Among these, Quadrature Phase Shift Keying (QPSK) stands out as one of the most commonly employed digital signal modulation techniques [13].

Amplitude-shift keying (ASK) operates as a form of amplitude modulation that transmits digital data by modifying the amplitude of a carrier wave. In an ASK system, the binary symbol 1 is communicated by sending a carrier wave of fixed amplitude at a fixed frequency for a duration of T seconds. If the signal value is 1, the carrier signal is transmitted; otherwise, for a signal value of 0, no carrier is transmitted. In any digital modulation method, a finite number of distinct signals is used to represent digital data. ASK employs a limited set of amplitudes, each linked to a unique binary digit pattern [14]. Typically, each amplitude encodes an equal number of bits, and each bit pattern represents the symbol associated with that specific amplitude. The demodulator, designed for the symbol set used by the modulator, detects the received signal's amplitude and associates it with the corresponding symbol, thereby retrieving the original data. Throughout this process, the carrier's frequency and phase remain constant [15].

The ASK signal can be created by connecting the incoming data (in unipolar form) and the sinusoidal carrier to the inputs of a product modulator or balanced modulator [16].In ASK, the carrier's amplitude is adjusted based on information, while other parameters remain constant. Transmitting a bit 1 involves using a carrier with a specific amplitude. When transmitting a bit 0, the amplitude changes while maintaining a constant frequency [17]. On-Off Keying (OOK) is a specialized type of ASK where one of the amplitudes is zero, as illustrated below [18].

The objective of this project is to develop and put into operation an Amplitude-Shift Keying (ASK) transmitter system. The project aims to assess and contrast the real-world outcomes with the simulated results, utilizing MATLAB communication system tools. It is required to design the ASK system such that the message signal generator and the carrier signal must be built practically, then multiplied together to get the ASK output signal. The message signal must be square pulses, while the carrier signal must be sinusoidal. After implementing the system, all the results from practical part must be compared with those obtained from the simulation using MATLAB language.

1. Methods

Amplitude-shift keying (ASK) is a form of modulation [19] that represents digital data as variations in the amplitude of a carrier wave [20]. The simulation was divided into three parts, to simplify the programming operation which is shown in the flow chart in Fig .1 , where the initialization of the system parameters is conducted before the first part, such that the system operates properly, as follows:

First carrier generation $x(t) = A_C \sin(2\pi f_c t)$.The carrier signal must be higher frequency than the message signal, second message generation. It must be unipolar signal and third , modulation process this step represents the generation of ASK signal, by multiplying the carrier and the message signals together

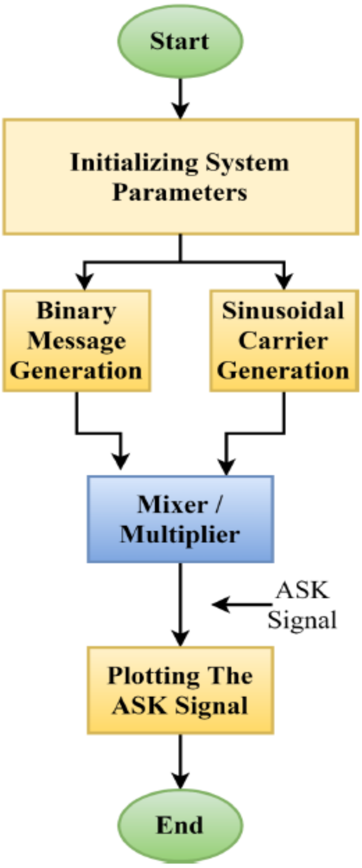


Fig. 1 Flow-Chart for the MATLAB ASK simulation programming.

The sampling frequency is to be able to simulate the continuous time signal in the discrete time environment of the computer. The sampling frequency was chosen far away of the carrier signal and message frequencies. The carrier frequency is fixed to 2000Hz (2KHz), while the message frequency was 50Hz. It is shown that the carrier frequency will be set to 2KHz and its amplitude will be 5 Volts. The code above will also plot the carrier signal. After successfully generating the carrier signal, the message signal is generated as follows: The message signal should be binary square wave unipolar return to zero (URZ), signal. First, we generate the polar return to zero (PRZ), signal, then we convert it to unipolar return to zero signal. The MATLAB program code shown above was initialized according to the practical design circuits, which will be shown in the next section.

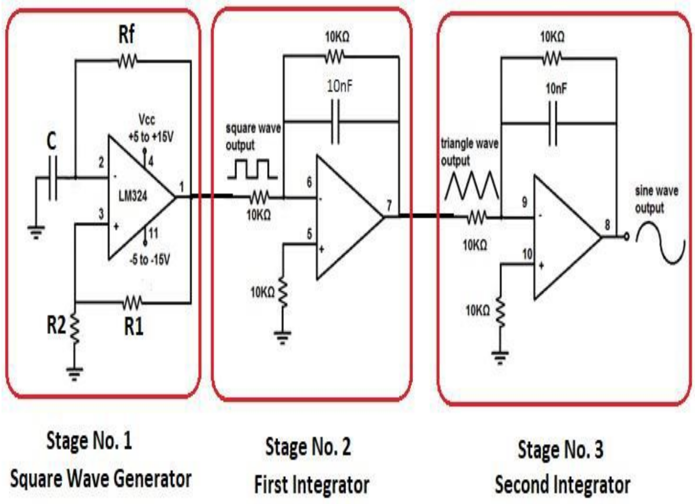
1.1 Practical Circuits Design of ASK System

The practical implementation differs that the simulation, in which, each block of the flow-chart shown in Fig. (3.1) will get its own circuit diagram. That is, there will be three parts of the implementation design, as achieved for the MATLAB programming procedures. These circuits are; carrier signal generator, message signal generator, and the multiplexer circuits.

1.2 Carrier Signal Circuit Design

The carrier signal should be sinusoidal one as given in Equation 2.2. That is, there must be a sinusoidal oscillator. Different sinusoidal oscillators are present in the practical field. However, each oscillator has its advantages and disadvantages, such as the phase shift oscillator, which is difficult to initiate the oscillation operation, and the Wein-bridge oscillator, which is unstable in the oscillation operation, there is also Colpitts and Hartley oscillators, which are used for very high frequencies.

The best method we found practically is to generate a square wave signal and then convert it to sinusoidal signal by two consecutive integrators, as shown in Fig .2. In this circuit diagram, the first stage consists of a single Operational Amplifier (OP-AMP), which produces the square wave of frequency 2KHz. The second stage is the first integrator, which is employs another OP-AMP. In this stage, the output is a triangular signal of frequency 2KHz. The last stage is the second integrator, which is also uses an OP-AMP, where the output will be pure sinusoidal signal of frequency 2KHz, as will be seen later in Chapter Four.



Stage No. 1
Square Wave Generator

Stage No. 2
First Integrator

Stage No. 3
Second Integrator

Fig .2 Configuration Circuit diagram for the carrier signal generator

The duration of the output waveform is determined by the RC time constant of two-timing components and the feedback ratio set by the R1, R2 voltage divider network, which establishes the reference voltage level. When the positive and negative values of the amplifier's saturation voltage are of equal magnitude, resulting in t1 = t2 (where t1 represents the duration of the positive voltage and t2 represents the duration of the negative voltage), the expression for the oscillation period becomes, where the design parameter β is given as

$$\beta = \frac{R_2}{R_1 + R_2} \tag{1}$$

Table 1: List of used components value

#	Component	Designed value
1	**Rf**	**10 $k\Omega$**

2	C	**10 $k\Omega$**
3	R1	**10 $k\Omega$**
4	R2	**82KΩ**

For 2KHz frequency, assume that R1 = 10KΩ and R2 = 82KΩ, then 82 × 10^3 β = 10 × 10_3 + 82 × 10_3 = 0.89

Setting C = 10nF, then the feedback resistor R_f can be calculated using Equation below

$$Rf = \frac{1}{1+0.89} \approx k\Omega \qquad (2)$$

2 × 10 × 10−9 × 2000 × ln (1 − 0.89)

Because of there is no standard resistor valued 9KΩ, then it is roughly approximated to the standard value which is 10KΩ. The other two stages are simple first order integrator and the resistor-capacitor values fixed to 10KΩ, and 10nF, respectively. The OP-AMP chip circuit was LM324, which contains quad individual OP-AMPs as shown in the pin-out diagram in Fig .3

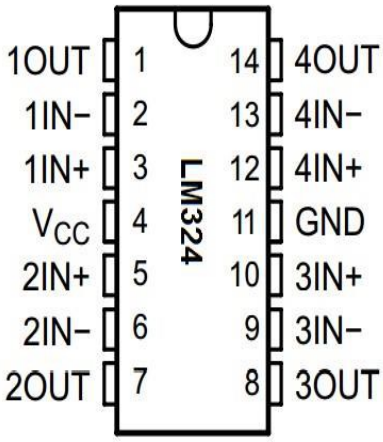


Fig. 3: Pinout diagram of LM324 quad OP-AMP chip circuit.

1.1 Message Signal Circuit Design

Up to this level, the carrier signal is ready. It is time to generate the message signal. The message signal is a simple binary stream, which is a train of pulses as stated in the Chapter Two. In this context, the Integrated Circuit (IC) 555 timer is used. The fundamental 555 oscillator circuit is highly adaptable, allowing for the creation of various interesting variations. The most straightforward 555 free-running stable oscillator circuit involves connecting pin 3 (output) directly to the timing capacitor through a single resistor, as illustrated in Fig. 4.

During the HIGH state at pin 3, the capacitor undergoes charging via the resistor. Once the voltage across the capacitor attains 2/3Vcc, the transition is initiated by pin 6, leading to a change in state, causing the output at pin 3 to go LOW. Following this, the capacitor discharges via the same resistor until pin 2 hits the voltage level of 1/3Vcc, triggering another state change. Consequently, the capacitor engages in a continuous oscillation, alternating between charging and discharging phases, swinging back and forth between voltage levels of 2/3Vcc and 1/3Vcc through the same resistor. This process generates alternating HIGH and LOW states at the output, specifically at pin 3

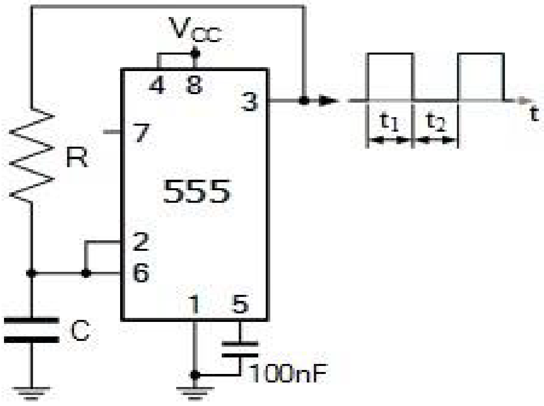


Fig. 4 Message signal generated employed the 555 timer IC.

While the capacitor undergoes both charging and discharging via the same resistor, the duty cycle in this fundamental configuration remains very close to 50%, or 1:1. The cycle time (T) of the resulting series of square wave output pulses is determined as follows,

$$T = 2\ln(2)RC \qquad (3)$$

For 50Hz, message frequency, the designed values for R and C can be determined as follows, suppose that the capacitor C = 1μF, then, the resistor R can be calculated from equation as follows,

$$R = \frac{1}{2 \times 50 \times In(2) \times 1 \times 10^{-6}} \approx 228\Omega \quad (4)$$

That is, the nearest standard resistor value to the 288Ω is 3KΩ. It is good practice to select a variable capacitor to make a variable message frequency.

2.4 Multiplexing Circuit Design

Nevertheless, the message signal is becoming ready. Now it is time to design the multiplexing circuit. In fact, the multiplexing is a switching operation, which passes the carrier signal when the message at HIGH state and prevent passing the carrier signal when the message signal at its LOW state. The digital IC CD4016 is best practice because it is compatible with both OP-AMP and the 555-time ICs. The pinout configuration diagram of the CD4016 IC is shown in Fig. 5.

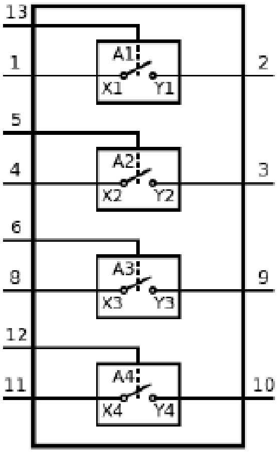


Fig. 5 Pinout configuration diagram for the IC CD4016

The CD4016 consists of four analog bilateral switches, each equipped with an active-high enable input (A) and two input/output terminals (X and Y). Enabling the switch (setting it to HIGH) establishes a low-impedance connection between the X and Y terminals, indicating an ON state. Conversely, setting the enable to LOW creates a high-impedance path between X and Y, turning the switch OFF. As a result, the project's circuit diagram can be depicted as shown in Fig. 6.

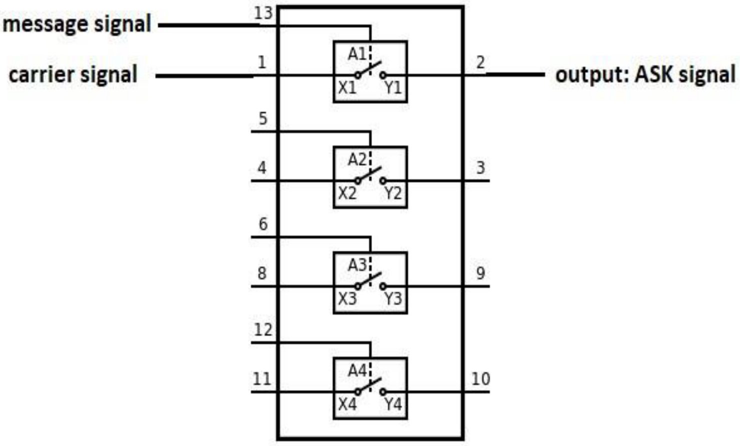


Fig. 6 ASK signal generation using CD4016.

The complete circuit diagram of the ASK system can be fig. d out in Fig .7, where the carrier signal generator, the message signal generator, and the multiplexer are connected altogether.

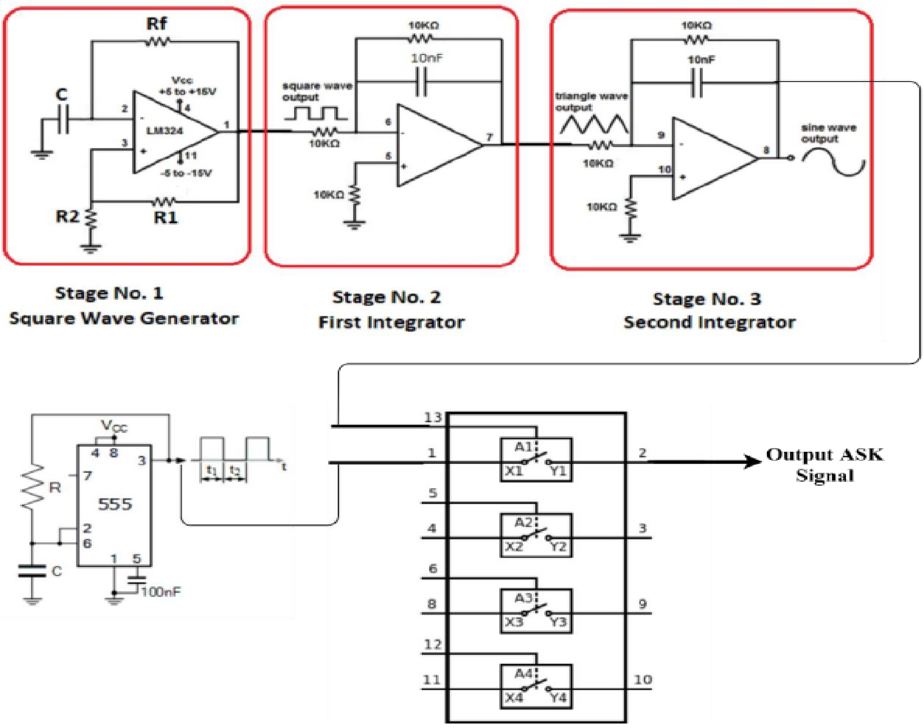


Fig . 7 Complete circuit diagrams of the ASK signal generation using LM324, 555timer, and CD4016 ICs

3.Results and Discussion

The simulation program listed in Chapter Three, will be evaluated here as a first part of the results in this part of the project. Fig 8 shows the generation of the sinusoidal carrier signal of 2KHz. It is shown that the carrier frequency is as set at the beginning of the program, in the system parameters initiation part.

However, only $20ms$ was plotted, since the plot of all the one second which contains all the 2000 cycles is giving no understandable meaning. The horizontal axis represents the time-domain, while the vertical axis stands for the amplitude of the carrier signal.

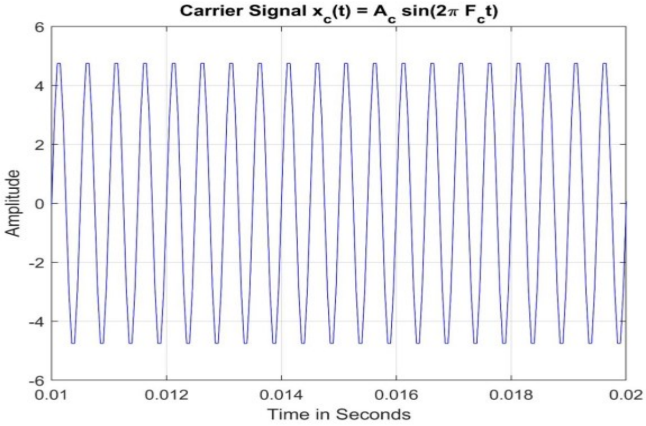


Fig . 8 Sinusoidal carrier signal generated from the MATLAB ASK simulation programming

On the other hand, the message signal was generated through two steps, since the programming becomes simpler, Initially, we generated the polar return-to-zero signal, depicted in the upper section of Fig. (4.2). Subsequently, this signal was converted into the unipolar non-return-to-zero format, illustrated in the lower section of Fig. 9.

Hence, the message signal becomes ready to be multiplexed with the carrier signal, as will be seen later in this section

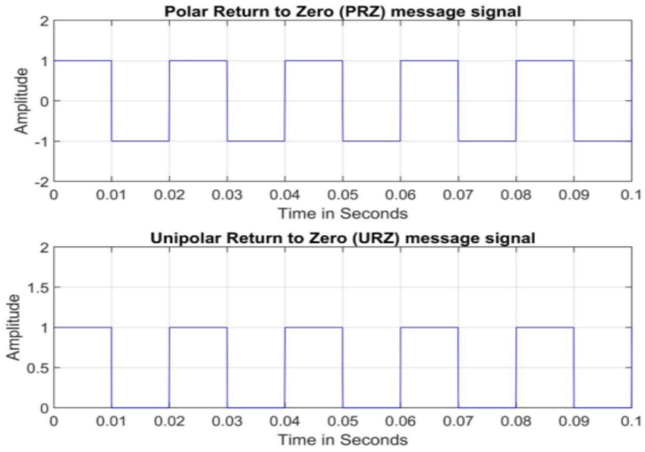


Fig .9: The message signal generation steps using the MATLAB ASK simulation programming. The upper part represents the Polar return to zero and the lower part stands for the unipolar return to zero binary stream signal.

For more convenience, Fig 10 displays the previous generated signals, the carrier and the message signals. The upper part of Fig 11 shows the 2KHz sinusoidal carrier signal, the middle part shows the polar return to zero signal before it converted to the binary signal. Lower part of Fig 10 depicts the binary stream message signal. Consequently, using this figure, one can imagen what the output will be by projecting the upper part on the lower part of Fig 10.

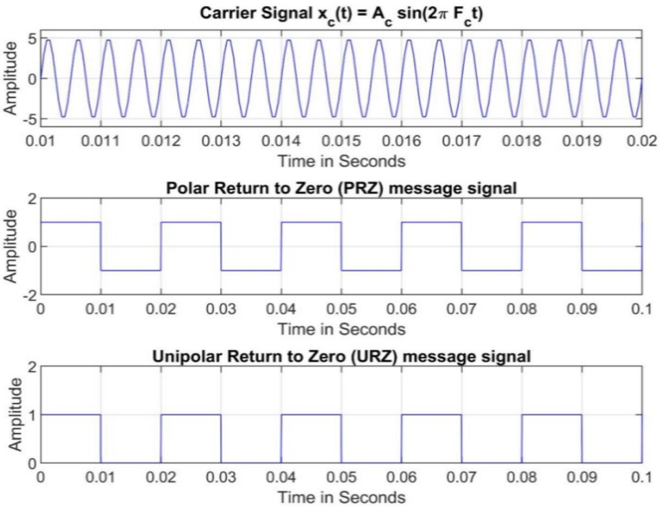


Fig. 10 The message signal generation steps using the MATLAB ASK simulation programming and the carrier signal The upper part represents carrier signal, the middle part refers to the Polar return to zero and the lower part stands for the unipolar return to zero binary stream signal.

Finally, Fig 11 shows the designated result of this project. It is shown in Fig 11, the upper part, that the message signal is pure pulses of logic HIGH and logic LOW. The middle part is the sinusoidal carrier signal. These two signals are multiplexed together to obtain the ASK signal, which is shown in the lower part of Fig 11. That is, the ASK signal shows that when the message signal is at logic HIGH, the carrier signal appears in the output, while when the message signal is in its logic LOW, the carrier signal is suppressed. This is the ASK Signal which we need to reach it in the practical implementation, as will be seen in the next section in this chapter. The results of both parts, in other words, the simulation results and the practical implementation results should be matched to each other.

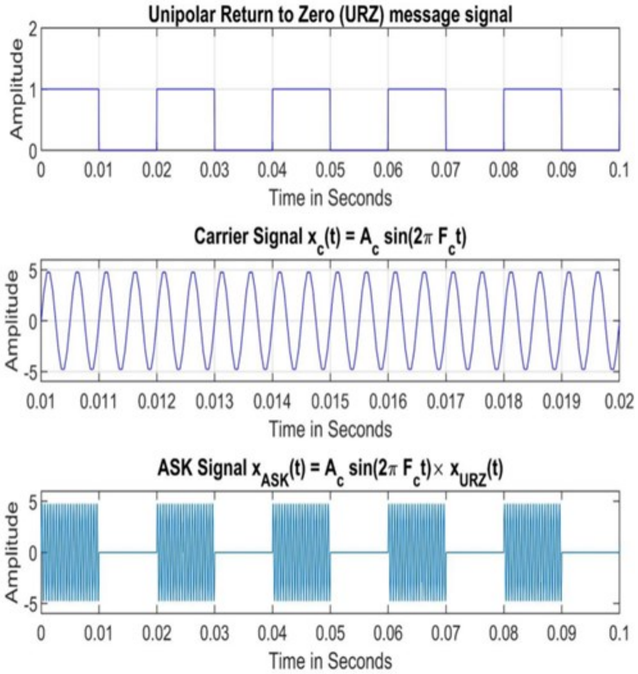


Fig. 11 The output ASK signal obtained from the MATLAB simulation program

The Upper part is the message signal generation. The middle part represents carrier signal, the lower part is the required ASK signal, which is the result of multiplexing the upper part with the middle part.

Practical Implementation Results

In this section, the implementation of the circuit diagram shown in Fig. (3.7) will be conducted. However, before we discuss the results, it is worth noting that the results have been obtained using the ***Digital PC based Oscilloscope*** type ***Hantek series 6022BE*** which has a bandwidth of 20MHz and sampling rate of 48MS/s. However, Fig 12 presents the generated signal. The message signal is clearly having two states; HIGH and LOW. The frequency of the binary stream is 50Hz, moreover, the amplitude is 5V, where each division is 2V/division, that is, the amplitude is 5V since the maximum is 2.5 divisions.

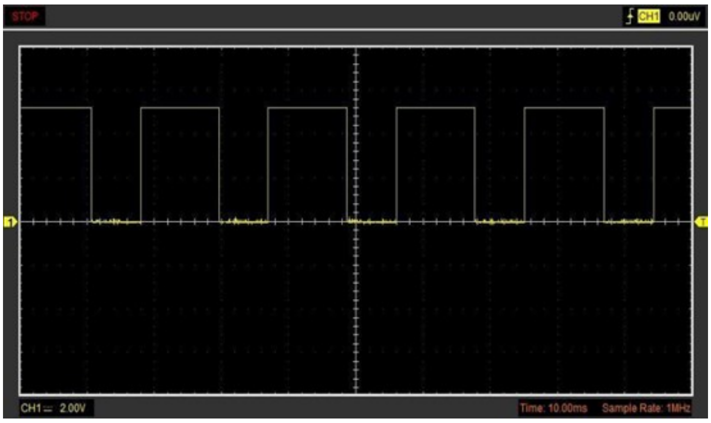


Fig. 12 The message signal which is generated due to the IC 555-timer at its output pin 3

Fig 13 shows the first step of the carrier generation. At beginning, the carrier is a square pulse of 2KHz. That is, the square wave was generated with amplitude equals to 10.2V, furthermore, it is shown that the square pulse having two peaks, ± Vcc, where the supply voltage (Vcc) was ± 5.1V. Moreover, the period of the square wave is shown in Fig 13 and Fig 15 to be 500*us,* where the frequency will be $1/(500 \times 10-6) = 2$ Thus, Fig 14 explains more details about the measuring values, since it is a screen shoot to bring out all the digital oscilloscope settings. Hence, the peak to peak voltages, the duration, the frequency, the time settings, and the vertical axis settings are all clear to the reader for more convenience.

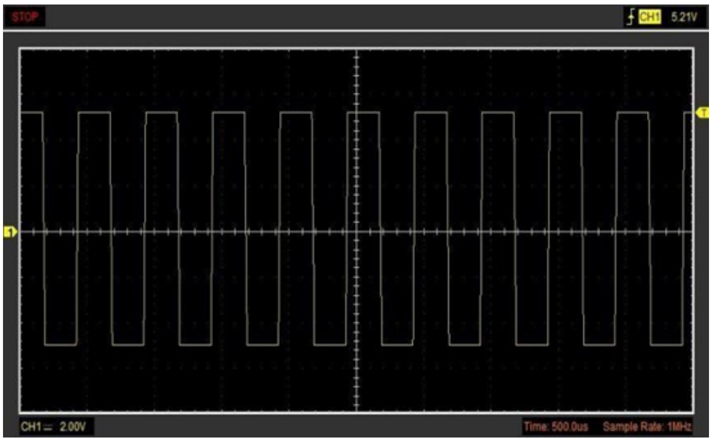


Fig. 13 Square pulse generation as a first step to generate the sinusoidal carrier signal using LM324 IC, this output is from pin 1

Finally, the ASK signal can be generated after multiplexing the carrier signal with the message signal. The output can be seen in Fig 14 and its screen shoot in Fig 15 When the message signal at its HIGH state, the carrier appears in the output pin 2 of the multiplexer, and when the message goes to LOW, the carrier signal is suppressed, as shown in Fig 14 and Fig 15 .

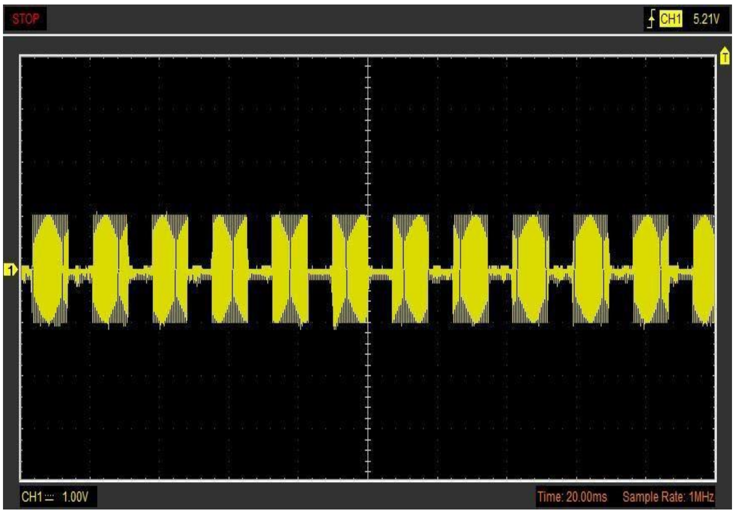
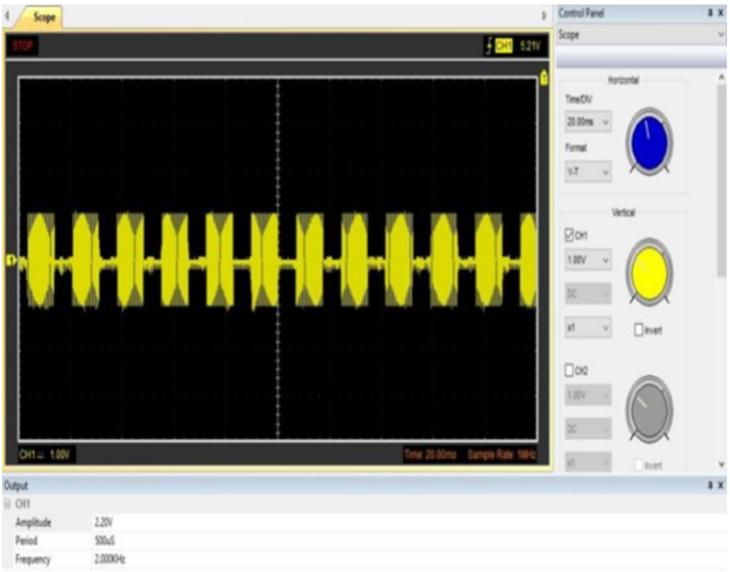


Fig. 14 ASK signal at the output of pin 2 of the multiplexer



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Output
CH1
Amplitude    2.20V
Period       500uS
Frequency    2.000KHz
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Fig. 15 Screen shoot for the output of ASK signal**.**

2. Compare the Results:

The research achieved a critical alignment between simulated and practical signals, pivotal for implementing Amplitude Shift Keying (ASK) modulation. Signal generation involved intricate steps: converting the message signal from polar-to-binary format, ensuring clarity in logic states for modulation. The visualization exemplified how the carrier signal's behavior precisely matched the logic states within the message signal, a cornerstone for successful ASK modulation. This synchronization confirmed the accuracy of simulation outcomes and emphasized the vital stages necessary for a robust ASK modulation process, laying a strong foundation for practical application in communication systems.

This work substantiates the accuracy of Amplitude Shift Keying (ASK) modulation through aligned simulations and practical implementation. Its emphasis on meticulous circuit design and standard values validates theoretical models in real-world applications. Recommendations for an advanced ASK system and randomness integration offer pathways for increased data rates. By comparing favorably against existing studies, it sets a benchmark for precision in ASK modulation. This research's significance lies in advancing ASK's reliability in digital communication, offering practical insights and paving the way for future enhancements in communication technologies.

When we compare our work with other works we find that we implemented meticulous circuit design, ensuring precise simulation-to-practical alignment whereas other studies had a primarily simulation-based approach without emphasis on practical implementation, and we introduced novel techniques in circuit design, proposes advanced ASK system implementations whereas the others introduced adheres to conventional methods without exploring innovative approaches, in addition of that our study gives a superiority evident in simulation-practical synchronization and advanced recommendations but other studies gave lacks emphasis on aligning simulation results with real-world implementations.

5. Conclusion

The Amplitude Shift Keying system was simulated using MATLAB and designed practically using different components. However, the ASK signal was determined mathematically and plotted using MATLAB. The practical part was completely matching the simulation. This is due to the appropriate selection for the standard values of the designed circuit diagram. For future work, its recommended to Implement the M-ary ASK system to make it capable to transmit more data rate and make the binary signal random by implementing a binary number generator.

4. Future Works

Implement M-ary ASK: Upgrade to M-ary ASK for higher data rates by encoding multiple levels per symbol.

Introduce Signal Randomization: Use a binary number generator to add randomness to the binary signal for enhanced security.

Validate Practical Performance: Continue testing to ensure real-world performance matches simulations.

Optimize Circuit Design: Further refine circuit values for better efficiency and reliability.

Enhance Error Handling: Explore error correction methods to improve data integrity.

Consider Real-world Deployment: Assess practical challenges for effective

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