Demonstration of Frequency Shift Keying

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***Abstract*—Frequency Shift Keying (FSK) is a modulation technique used in digital communication systems to transmit binary data over a carrier wave. In FSK, binary data (0s and 1s) is represented by shifting the frequency of the carrier signal between two distinct frequencies. The carrier signal is typically a sinusoidal wave. In digital communication, data is represented in binary form, where 0 represents one state (e.g., low voltage) and 1 represents another state (e.g., high voltage).**

The link to codes is https://github.com/ritikadhaker/EE307-Project-2023-G8

I. Introduction

FSK [1] involves shifting the carrier signal's frequency between two predetermined frequencies to represent binary 0s and 1s. The choice of frequencies depends on the specific FSK scheme. When transmitting binary data, the FSK modulator changes the carrier signal frequency accordingly. For example, if transmitting 0, the carrier frequency remains constant, and if transmitting 1, the carrier frequency shifts.

At the receiving end, a demodulator [2] detects carrier frequency changes, interpreting them as binary data. The demodulator distinguishes between the two frequencies to recover the original digital data.

FSK has two main types - Binary FSK (BFSK) and Multi-level FSK (MFSK). BFSK has two distinct carrier frequencies, one for 0 and the other for 1. MFSK uses more than two carrier frequencies to represent multiple binary bits simultaneously, improving data transmission efficiency. Each unique frequency combination represents a different binary value.

FSK offers advantages, including resistance to amplitude variations and noise, making it suitable for various communication applications like wireless communication [3], satellite communication [4], and some forms of digital modulation in radio broadcasting [2] . However, FSK is less bandwidth-efficient compared to modulation techniques like Quadrature Amplitude Modulation (QAM) [5] and Phase Shift Keying (PSK) [1], which can transmit more data in the same bandwidth.

II. Project Overview

In the project, FSK was demonstrated and explored using various tools and methods. A combination of software simulation, Python programming, Simulink, and practical hardware implementation in Multisim was employed. The project comprised three main components

A. Python Code

A Python program was developed to simulate FSK modulation and demodulation. FSK signals were generated by shifting frequencies to represent binary data, and methods for demodulating the received signals were included. This software component served as a fundamental building block for the project.

B. MATLAB Simulink Implementation

In Simulink, a simulation of an FSK communication system was created. The Simulink model included blocks for generating FSK-modulated signals, transmitting them through a simulated communication channel, and then demodulating and recovering the original binary data. This simulation allowed the performance and characteristics of FSK to be analyzed in a controlled environment.

C. Multisim Circuit

To bring the project into the physical realm, a circuit was built using Multisim. The circuit involved the use of two transistors and other electronic components to implement FSK modulation and demodulation. This practical aspect of the project allowed real-world challenges in FSK signal processing, including issues related to electronic components and noise, to be observed. Following are the key objectives and outcomes of our study:

- The principles of FSK modulation and demodulation were demonstrated.
- The functionality of the Python code in generating and decoding FSK signals was validated.
- The performance of FSK modulation and demodulation was evaluated through Simulink simulations.
- Practical implementation challenges and electronic component interactions in the Multisim circuit were explored.
- A deeper understanding of FSK as a digital modulation technique and its applications in communication systems was gained.

The project demonstrates a well-rounded approach to understanding and applying FSK in both software and hardware contexts. Theoretical knowledge is combined with practical skills, making it a valuable learning experience in the field of digital communication and signal processing.

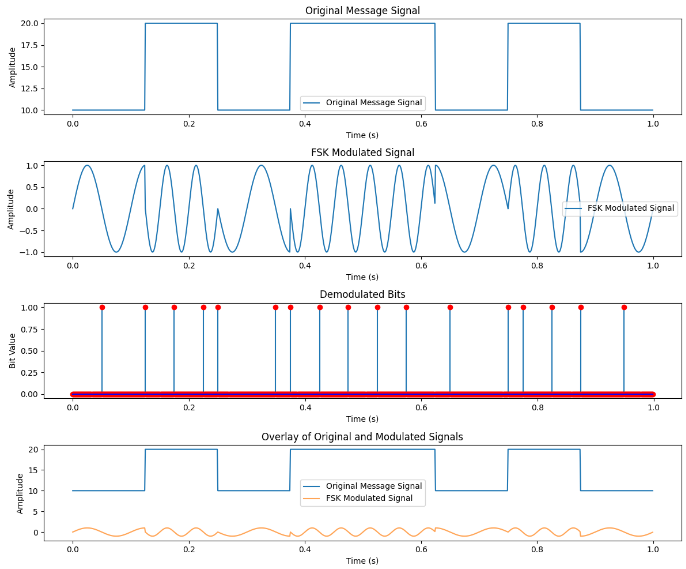

Fig. 1. Python plots for FSK modulation and demodulation

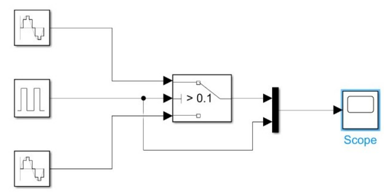

Fig. 2. MATLAB Simulink simulation for modulation in FSK

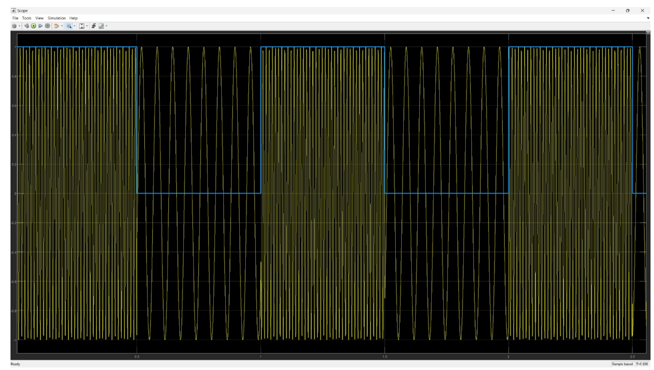

Fig. 3. MATLAB Simulink Circuit for modulation in FSK

III. Methodology

A. Python Demonstration

The code begins by importing the necessary libraries, NumPy for numerical operations and array handling, and Matplotlib for plotting. The function, *generate_fsk_signal*, is used to generate an FSK-modulated signal. It takes a binary message (message), sampling frequency (fs), frequencies for '0' (f0) and '1' (f1), and the duration of the signal (duration). It uses NumPy to return the time array (t), the repeated FSK signal *fsk_signal_repeated*, and the modulated signal *modulated_signal*, the signal is modulated using sine function. The function, *fsk_demodulation*, performs FSK demodulation. It takes the modulated signal (signal), sampling frequency (fs), and frequencies for '0' (f0) and '1' (f1). It then calculates the instantaneous phase and frequency of the signal and demodulates the bits based on a threshold frequency. A threshold frequency determines whether a bit is '0' or '1'. We have set the parameters for the FSK signal, including the sampling frequency (fs), frequencies for '0' (f0) and '1' (f1), and the signal duration (duration). A binary message is defined, and the *generate_fsk_signal* function is called to generate the FSK-modulated signal. Then the FSK demodulation function is called to demodulate the FSK-modulated signal. Then we finally plot the original message signal, the FSK modulated signal, and the demodulated bits by using Matplotlib. Four subplots are created to visualize the different stages of the FSK communication system. Fig. 1 shows the respective results.

B. MATLAB Simulink Demonstration

FSK, a modulation method, alters a carrier signal's frequency to convey data. We conducted an experiment using Simulink to simulate FSK modulation and demodulation. Our aim was to grasp FSK's fundamentals and examine how modulation and demodulation impact signal transmission.

Modulation

The modulation circuit (Fig. 2) is designed to implement FSK modulation. Generates a sine wave with a particular frequency. We used two of these with frequencies set to 12 Hz for high-frequency input and 4 Hz for low-frequency input. The pulse wave generator generates a regular pulse. An ideal switch that passes high-frequency sine wave when pulse received from pulse wave generator is 1 and passes low-frequency sine wave when pulse is 0. Fig. 3 shows the circuit simulation of modulation in FSK.

Demodulation

The demodulation circuit element present in (Fig. 4) is designed to implement FSK demodulation. Charge Pump PLL automatically adjusts the phase of a locally generated signal to match the phase of an input signal. It acts as a Low Pass Filter. Relation Operator compares the output of the Charge Pump PLL to the constant value 0. Fig. 5 shows the circuit simulation of demodulation in FSK.

C. Multisim Demonstration

Figure 1 is the circuit that represents the process of FSK. The circuit under investigation involves AM modulation and demodulation processes. This report aims to dissect the circuit components, elucidate their functionalities, and analyze the purpose behind AM modulation and demodulation in signal transmission. As shown in the circuit, we require the components: Voltage Pulse Generator (for binary input), Voltage Controlled Oscillator (VCO), and Exclusive OR (XOR) Gate.

Modulation

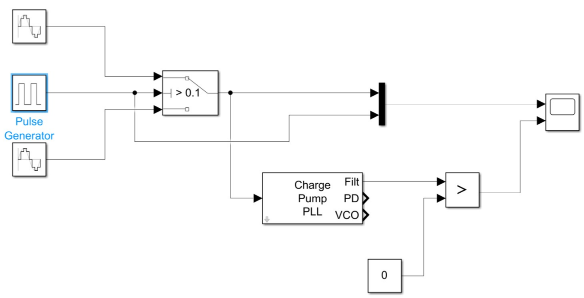

Fig. 4. MATLAB Simulink Circuit for modulation and demodulation in FSK

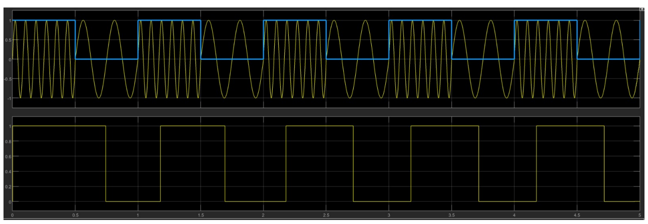

Fig. 5. MATLAB Simulink Circuit for demodulation in FSK

Comparator, amplifier, and voltage divider collaborate to modulate input signal amplitude in response to information signal variations.

Demodulation

Rectifier and demodulator recover the original information from the modulated signal, ensuring accurate signal extraction.

Circuit Overview

In Fig. 6, the comparator is likely used for signal comparison. It may play a role in detecting changes or thresholds in the signal. The amplifier boosts the strength of the signal, ensuring that the modulated information is carried out effectively. The rectifier converts the alternating current (AC) signal into direct current (DC), possibly for better handling and processing. The voltage divider could be shaping the signal or providing a specific voltage reference for subsequent stages in the circuit. The demodulator is a crucial component responsible for extracting the original information from the modulated signal. It could be implemented as an envelope detector or another demodulation technique.

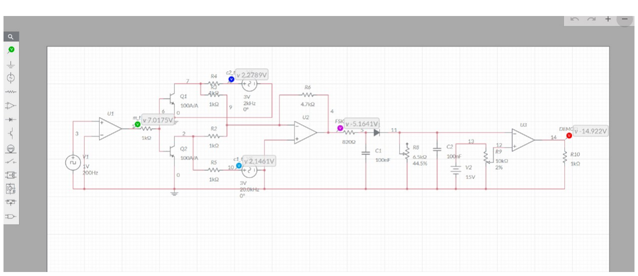

Fig. 6. Multisim Circuit for simulation of FSK Modulation

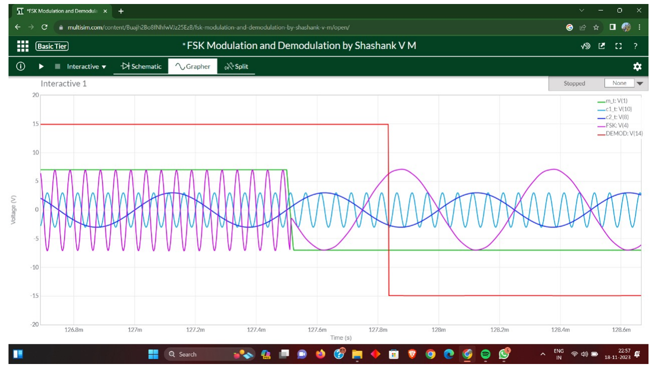

Fig. 7. FSK simulation plot demonstrating modulation followed by demodulation.

The comparator, amplifier, and voltage divider collaborate to modulate the input signal, altering its amplitude in response to the information signal. The rectifier and demodulator work together to recover the original information from the modulated signal, ensuring accurate signal extraction. The circuit's purpose is to modulate an input signal using amplitude modulation, transmit it efficiently, and then demodulate it to retrieve the original information. In a simulation environment like Multisim, the performance of each component can be tested to observe how they collectively achieve modulation and demodulation. The simulated signals can be seen in Fig. 7.

IV. Experiments

In this section, the arduino implementation of the project is discussed. We use the digital signal processing (DSP) concept to create a sine wave Fig.10. We take samples of the sine wave at a particular sampling rate. Then we will convert the sampled data into the range of 0-255 corresponding to the voltage level of that sample. Using this process we will create a lookup table of the PWM values corresponding to a sine wave.

Since we are sampling only the value of the sine signal at different time instances. The frequency of the reconstructed signal will be defined as how much time interval we have taken to plot the samples. We will output each sample with a different time interval to get different frequency signals (Fig. 9). Using a button as an input, we set the frequency to 10Hz when it is pressed and 2Hz otherwise. A capacitor is added to the output to act as a low-pass filter. It filters out the high PWM frequencies of Arduino and the modulated sine wave remains at the output. The Arduino implementation is shown in Fig. 9.

V. Applications

FSK has found widespread applications across diverse fields due to its versatile ability to modulate carrier signal frequencies.

- In the realm of telecommunications, FSK serves as a prevalent technology for voice and data transmission over

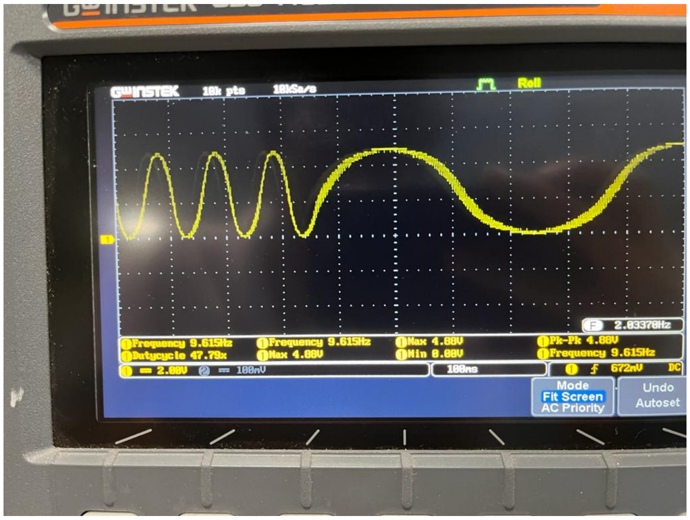

Fig. 8. Waveform produced in arduino.

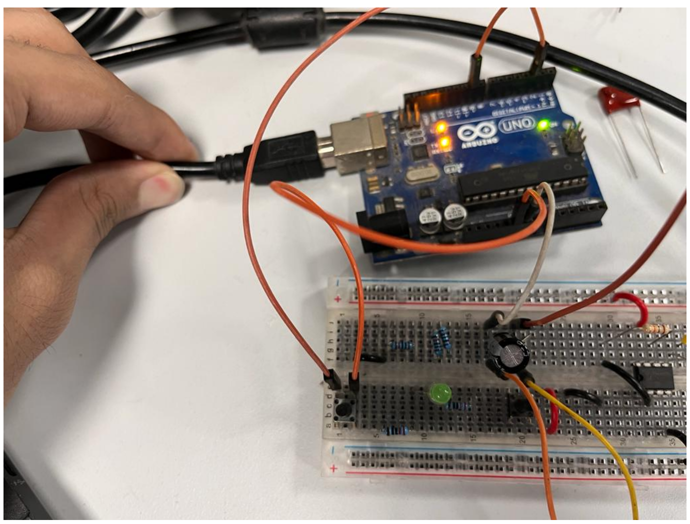

Fig. 9. Arduino implementation of FSK

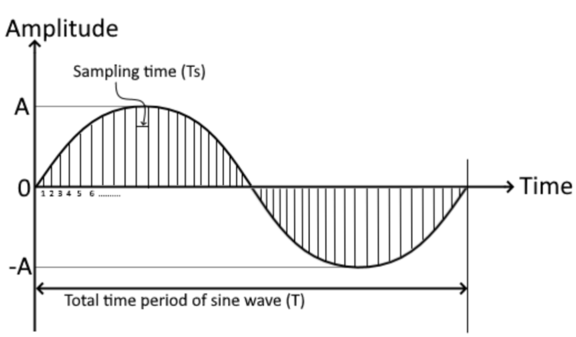

Fig. 10. Sine wave using DSP

extended distances. Its efficiency ensures clear communication in various scenarios, such as cordless telephones and walkie-talkies, where FSK's frequency modulation facilitates wireless human speech transmission.

- FSK is integral to data transmission, notably in radio frequency identification (RFID) systems for encoding and transmitting data between RFID tags and readers. This proves invaluable in industries like logistics and supply chain management for object identification and tracking. Satellite communication systems also leverage FSK for global communication and broadcasting.
- FSK is a cornerstone in data transmission systems, playing a crucial role in modulating digital information. In computer networks, FSK is employed in modems to convert digital data into analog signals for reliable transmission over telephone lines. Wireless communication technologies, including Bluetooth and Wi-Fi, utilize FSK for encoding and transmitting data, facilitating seamless connectivity and data exchange.
- Digital broadcasting systems like digital television (DTV) and digital radio benefit from FSK modulation, ensuring the transmission of high-quality audio and video signals for an enhanced entertainment experience.
- In industrial settings, FSK is utilized for industrial automation and control systems. It enables the transmission of control signals and sensor data, facilitating remote monitoring and control of various processes in sectors such as manufacturing and energy.

Relevance in Present-Time

In contrast to more advanced modulation schemes, FSK may not offer the same data rates or spectral efficiency. However, its relevance persists in specific use cases where its characteristics align with the communication requirements. FSK is robust, especially in the presence of noise, but other techniques like QAM and OFDM can offer improved robustness. Advanced techniques like QAM (Quadrature Amplitude Modulation) and OFDM (Orthogonal Frequency Division Multiplexing) generally support higher data rates compared to traditional FSK. QPSK (Quadrature Phase Shift Keying), QAM and OFDM are more bandwidth-efficient than FSK, allowing for higher data transmission within the available spectrum.

The choice of modulation technique depends on the specific requirements of the communication system, including data rate, bandwidth efficiency, and resistance to noise. While FSK remains relevant, especially in specific applications, more advanced modulation schemes are often preferred for high-performance communication systems.

VI. Contribution Details

- Ranu Lal (210002061): Implemented circuit using Multisim, provided content for the report and presentation related to Multisim implementation

- Rishabh Patil (210002062): Implemented circuit using Multisim, provided content for the report and presentation related to Multisim implementation
- Ritika Dhaker (210002064): Demonstrated FSK using Python code, provided content for Introduction, Project Overview, Applications and Present Day Relevance, designed and formatted presentation template, created GitHub repo, and added codes.
- Rupal Shah (210002065): Demonstrated FSK using Python code, provided content for report related to Python implementation, designed and created a report on LaTeX, created the github page.
- Saattvik Thourwal (210002066): Simulated FSK using MATLAB Simulink, implemented FSK using Arduino, provided report content on Simulink and Arduino
- Sarthak Nandre (210002067): Simulated FSK using MATLAB Simulink, provided content for report and presentation related to Simulink
- Shaikh Baba (210002068): Provided content for report and presentation on Multisim circuit implementation of FSK
- Shashank Sharma (210002069): Provided content for report and presentation on Python code for implementation of FSK

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