Experiment 6

Frequency Demodulation using Pulse Average Discriminator (6-3)

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Course Title & Number:

RF Communications (EET-2325C)

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Objective:

The objective of this experiment is to demonstrate the operation of a pulse-averaging discriminator in the demodulation of frequency-modulated (FM) signals. This involves constructing a pulse-averaging discriminator circuit and analyzing its effectiveness in recovering the original intelligence signal from the FM signal by averaging fixed-width pulses using a low-pass filter. By varying the modulating signal frequency and observing the corresponding output, the experiment aims to highlight the functionality and behavior of the pulse-averaging discriminator in practical applications.

Materials:

- 2206 FM generator (used in Project 5-1)
- Oscilloscope
- Frequency counter
- 74123 or 74LS123 dual TTL one-shot (The 74121 and 74122 TTL ICs also work in this application)
- 0.01-μF capacitor
- 0.02-μF capacitors (2 pieces)
- 1-kΩ resistor
- 4.7-kΩ resistor
- 15-kΩ resistors (2 pieces)
- Power supplies of +12 V and +5 V

Background:

Frequency Modulation (FM) is a method for transmitting information by varying the frequency of a carrier wave. FM demodulators, such as the pulse-averaging discriminator, extract the original signal from the modulated carrier wave.

A pulse-averaging discriminator converts frequency variations into fixed-width pulses using a monostable multivibrator (one-shot multivibrator). These pulses are averaged using a low-pass filter to recover the original signal. The 74123 dual TTL one-shot multivibrator is used in this experiment to generate the fixed-width pulses.

The frequency variations in the FM signal change the rate of pulse generation. Higher frequencies produce more pulses per unit time, and lower frequencies produce fewer pulses. The low-pass filter averages these pulses to reconstruct the original modulating signal.

In this experiment, an XR-2206 function generator creates the FM signal. By adjusting the modulating signal frequency and observing the demodulated output, the experiment demonstrates the operation of a pulse-averaging discriminator.

Procedure:

1. **Construct the Circuit**:

   - Build the experimental circuit as shown in Fig. 6-5. The output from the XR-2206 function generator is taken from pin 11, providing a 5-V square wave compatible with the TTL logic circuitry in the 74123 one-shot. The signal is frequency-modulated and follows the sine-wave output that appears at pin 2 on the 2206.

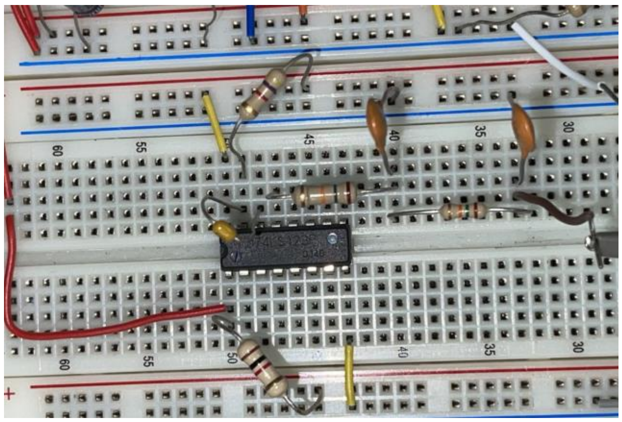

Figure 1 - Constructed pulse-averaging discriminator circuit based on the schematic.

2. **Setup Frequency Counter**:

   - Connect the frequency counter to the 2206 output at pin 11, then adjust the 100-kΩ potentiometer for a center frequency of 20 kHz. Ensure the modulating signal input from the external function generator is reduced to zero during this adjustment.

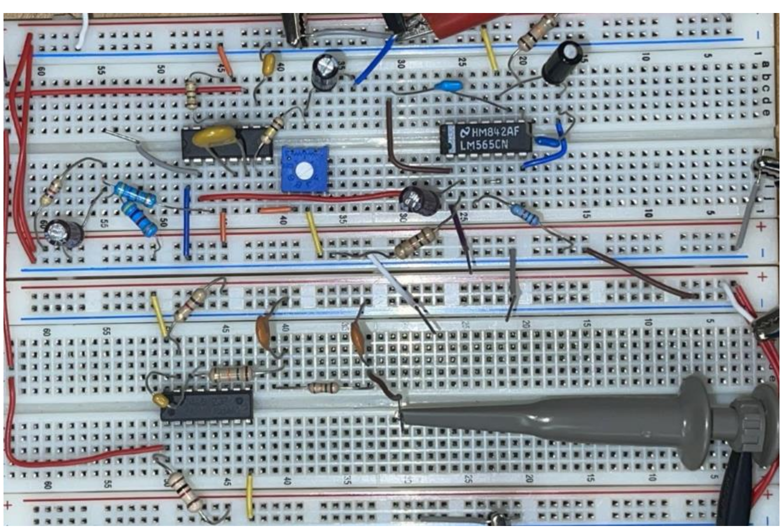

Figure 2 - Breadboard setup of the complete pulse-averaging discriminator circuit with all connections.

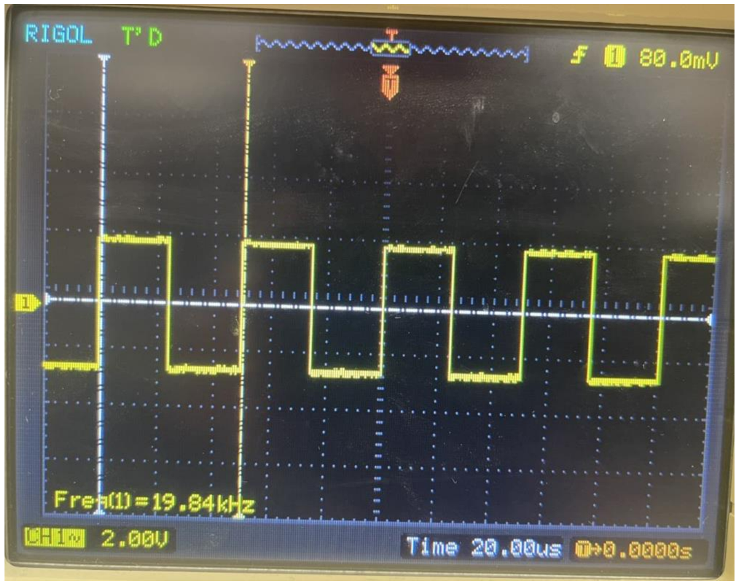

Figure 3 - Oscilloscope display showing the frequency-modulated square wave output at pin 11 of the XR-2206 function generator with a frequency of approximately 19.84 kHz.

3. **Observe Pulses with Oscilloscope**:

    - Connect the oscilloscope output to pin 13 of the 74123 one-shot. Observe a chain of pulses with a pulse width of approximately 15 μs. Adjust the 100 $k\Omega$ potentiometer on the 2206 to vary the frequency over a narrow range around 20 kHz. Note that the frequency of the pulses changes, but the pulse width remains constant.

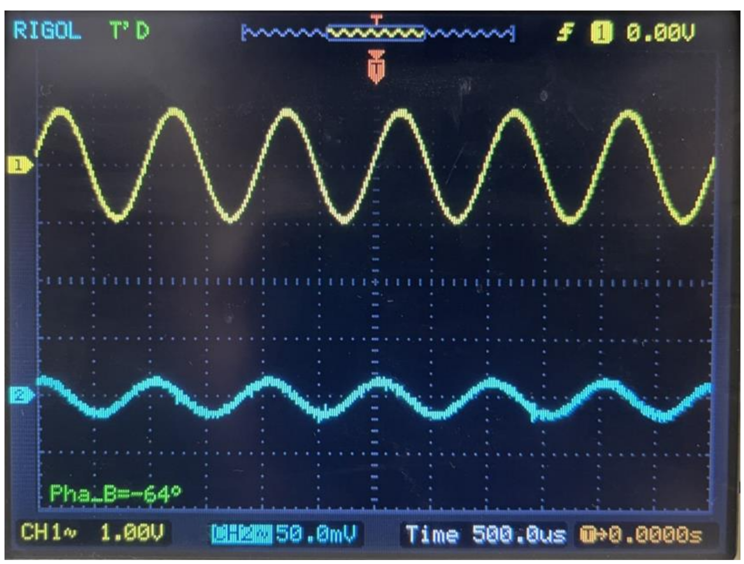

Figure 4 - Oscilloscope display showing the chain of pulses from pin 13 of the 74123 one-shot multivibrator. The yellow waveform represents the input signal, and the blue waveform represents the output pulses.

4. **Vary Frequency and Amplitude of Modulating Signal**:

- Vary the amplitude of the modulating signal from the external function generator and observe its effect on the output waveform using the oscilloscope. Note how the amplitude changes impact the recovered signal.

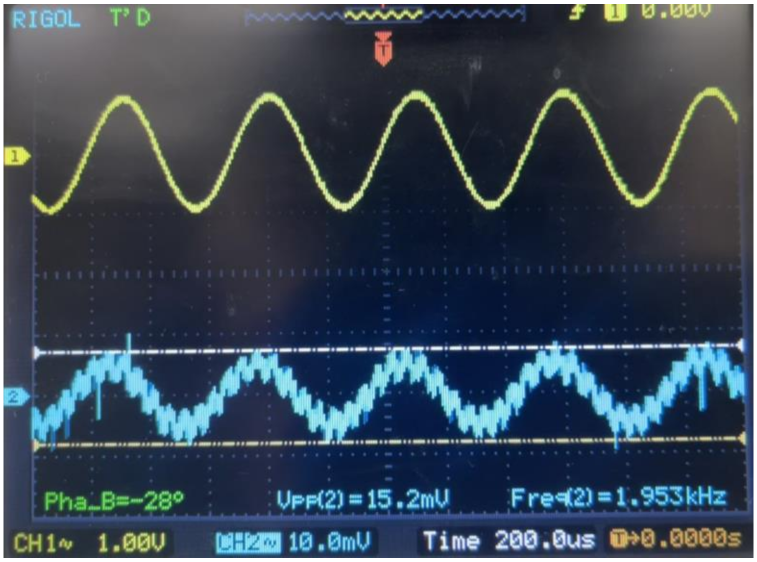

Figure 5 - Oscilloscope display showing the recovered signal (blue) with the input signal (yellow) when the amplitude of the input signal is at a baseline level.

Figure 6 - Oscilloscope display showing the recovered signal (blue) with the input signal (yellow) as the amplitude of the input signal is increased. Note the slight increase in the recovered signal amplitude.

Data & Observations:

During the experiment, several key observations were made regarding the behavior of the pulse-averaging discriminator circuit. When the oscilloscope was connected to pin 13 of the 74123 one-shot, a chain of pulses with a pulse width of approximately 15 μs was observed. Varying the frequency of the input signal with the 100-kΩ potentiometer on the XR-2206 did not affect the pulse width, demonstrating the stability of the pulse width generated by the one-shot multivibrator, irrespective of the input signal frequency.

As the modulating signal frequency from the external function generator was varied from 200 Hz to 2 kHz, changes in the frequency of the pulses generated by the one-shot multivibrator were observed on the oscilloscope. Despite these changes, the recovered signal at the output of the low-pass filter remained consistent with the modulating signal frequency, verifying the circuit's ability to demodulate the frequency-modulated signal accurately.

Additionally, when the amplitude of the modulating signal from the external function generator was varied, the recovered signal's amplitude also increased slightly with the input signal's amplitude. However, the recovered signal's amplitude remained significantly smaller than the input signal's amplitude. This indicates that while the circuit can demodulate the FM signal, the amplitude of the recovered signal is not directly proportional to the input signal amplitude. Furthermore, phase shifts in the recovered signal corresponding to changes in the input signal amplitude were observed, which can be attributed to the phase response characteristics of the low-pass filter used in the circuit.

Various oscilloscope screenshots (Figures 5 and 6) visually confirmed the behavior of the recovered signal (blue waveform) in relation to the input signal (yellow waveform). These observations aligned with theoretical expectations, demonstrating the circuit's effectiveness in demodulating FM signals, though with some limitations in the recovered signal's amplitude.

Discussion of Experimental Results, Sources of Error, and Accuracy of Measurements

The experiment demonstrated the operation of a pulse-averaging discriminator in demodulating FM signals. The stability of the pulse width and accurate demodulation of frequency variations were key indicators of the circuit's effectiveness. Potential sources of error could include inaccuracies in the component values (resistors and capacitors) used in the timing circuit of the one-shot multivibrator, which could slightly affect the pulse width. Additionally, any noise in the signal or improper connections on the breadboard could introduce errors in the observed waveforms.

The accuracy of the measurements was ensured by using calibrated equipment and verifying connections multiple times during the experiment. Minor discrepancies in the recovered signal's amplitude indicate that further tuning of the circuit might be necessary for optimal performance. The experiment provided valuable insights into the functionality and behavior of pulse-averaging discriminators in practical applications.

Answers to Lab Questions:

1. **The circuit that generates fixed-width fixed-amplitude pulses is known as a(n) ________.**
    - a. Astable multivibrator
    - b. Pulse generator
    - c. Oscillator
    - **d. One-shot multivibrator**

A one-shot multivibrator (monostable multivibrator) generates pulses of a fixed width and amplitude when triggered. This is consistent with the behavior observed in the experiment.

2. **The circuit that smooths the pulses into the original intelligence signal is the ________.**
    - **a. Low-pass filter**
    - b. High-pass filter

A low-pass filter averages the incoming pulse train, smoothing it into a continuous waveform that represents the original intelligence signal. This process is crucial for demodulating the FM signal.

3. **Another FM demodulator that uses the principle of averaging pulses in a filter is the ________.**
    - a. Phase-locked loop
    - b. Foster-Seeley discriminator
    - **c. Quadrature detector**
    - d. Ratio detector

The quadrature detector is another type of FM demodulator that averages pulses in a filter to recover the modulating signal. It is similar in principle to the pulse-averaging discriminator used in this experiment.

4. **The amplitude of the recovered intelligence signal is directly proportional to ________.**
    - a. Carrier frequency
    - b. Carrier deviation
    - **c. Pulse amplitude**
    - d. Pulse width

The amplitude of the recovered signal depends on the amplitude of the pulses generated by the one-shot multivibrator. As the pulse amplitude increases, the recovered signal amplitude increases correspondingly.

5. **As the frequency of the modulating signal increases, the recovered signal output amplitude ________.**
    - a. Decreases
    - b. Increases
    - **c. Remains the same**
    - d. Drops to zero

In this experiment, it was observed that increasing the frequency of the modulating signal did not significantly affect the amplitude of the recovered signal. The amplitude remained relatively constant, demonstrating that the recovered signal's amplitude is not dependent on the frequency of the modulating signal.

Conclusion:

The objective of this experiment was to demonstrate the operation of a pulse-averaging discriminator in demodulating FM signals. The circuit successfully generated fixed-width, fixed-amplitude pulses using a one-shot multivibrator and recovered the original intelligence signal with a low-pass filter. The results confirmed the stability of the pulse width and accurate demodulation of frequency variations.

It was observed that varying the frequency of the modulating signal did not significantly affect the recovered signal's amplitude, which remained relatively constant. However, increasing the amplitude of the input signal resulted in a slight increase in the recovered signal's amplitude, although it was still smaller than the input signal amplitude. These observations align with the theoretical principles of pulse-averaging discriminators.

The experiment highlighted the importance of component accuracy and stable connections for reliable circuit performance. Minor discrepancies in the recovered signal's amplitude suggest further tuning and optimization of the circuit components may be necessary.

For future work, exploring different filter configurations and improving the amplitude fidelity of the recovered signal are recommended. Additionally, examining the effects of noise and implementing noise reduction techniques could enhance the circuit's performance.

Overall, the experiment demonstrated the principles and practical application of a pulse-averaging discriminator in FM signal demodulation, providing a solid foundation for further refinement of FM demodulation techniques.