Experiment 5

Frequency Demodulation with PLL (6-2)

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Course Title & Number:

RF Communications (EET-2325C)

Submitted to:

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Objective:

The objective of this experiment is to demonstrate the operation of a phase-locked loop (PLL) as a demodulator for frequency-modulated (FM) signals. Using the 565 PLL circuit in conjunction with the 2206 FM modulator, the experiment aims to show how the PLL can accurately recover the original modulating signal from an FM input. This process highlights the excellent fidelity, wide range response, and noise suppression capabilities of PLLs, making them an ideal choice for FM demodulation in various critical applications. The successful completion of this experiment will provide a deeper understanding of the practical applications and advantages of using PLLs for FM signal demodulation.

Materials:

- 2206 function generator circuit (used in Project 5-1)
- 565 PLL circuit (used in Project 6-1)
- Oscilloscope
- Frequency counter
- Function generator
- Power supply (+12V)
- 0.001-μF capacitor
- 10-kΩ potentiometer
- 10-μF capacitor
- 4.7-kΩ resistors (2 pieces)
- 47-kΩ resistor
- 150-Ω resistor
- 0.002-μF capacitor
- 1-μF capacitor
- Connecting wires and breadboard

Background:

Frequency modulation (FM) is a method of encoding information in a carrier wave by varying the instantaneous frequency of the wave according to the amplitude of the input signal. In FM, the frequency deviation from the carrier is directly proportional to the amplitude of the modulating signal. A common method for demodulating FM signals is the phase-locked loop (PLL).

A PLL is a control system that generates an output signal whose phase is related to the phase of an input signal. It consists of a phase detector, a low-pass filter (LPF), and a voltage-controlled oscillator (VCO). The phase detector compares the phase of the input FM signal with the phase of the VCO output and generates an error signal proportional to the phase difference. This error signal is then filtered by the LPF to remove high-frequency components, producing a control voltage that adjusts the VCO frequency. The VCO output frequency tracks the input frequency, effectively demodulating the FM signal.

The 565 PLL IC is widely used for FM demodulation due to its excellent fidelity, wide range response, and noise suppression capabilities. The output of the loop filter in the PLL is a faithful reproduction of the original modulating signal, making it an ideal choice for critical applications.

In this experiment, the 2206 function generator will be used to generate the FM signal, and the 565 PLL will be used to demodulate this signal. The goal is to observe how the PLL can recover the original modulating signal from the FM input, demonstrating the practical application and effectiveness of PLLs in FM demodulation.

Procedure:

1. **Construct the Circuit:**
    - Assemble the circuit as shown in Fig. 6-4. It combines the 2206 IC frequency modulator from the previous experiment and the 565 PLL circuit.

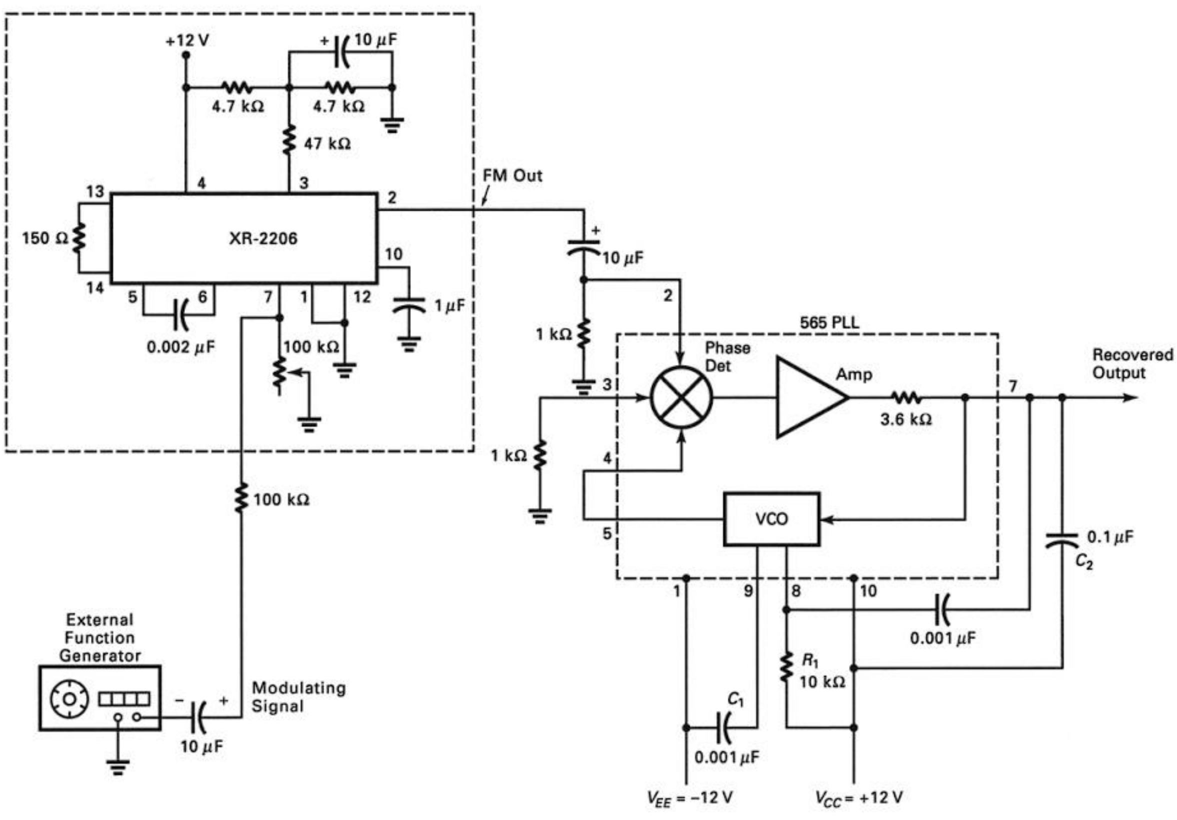

Figure 1 - Fig. 6-4 in the Lab Manual.

- Replace the $0.01-\mu F$ capacitor in the PLL circuit with a $0.001-\mu F$ capacitor.
- Replace the 2.7-kΩ resistor R_1 with a 10-kΩ potentiometer.

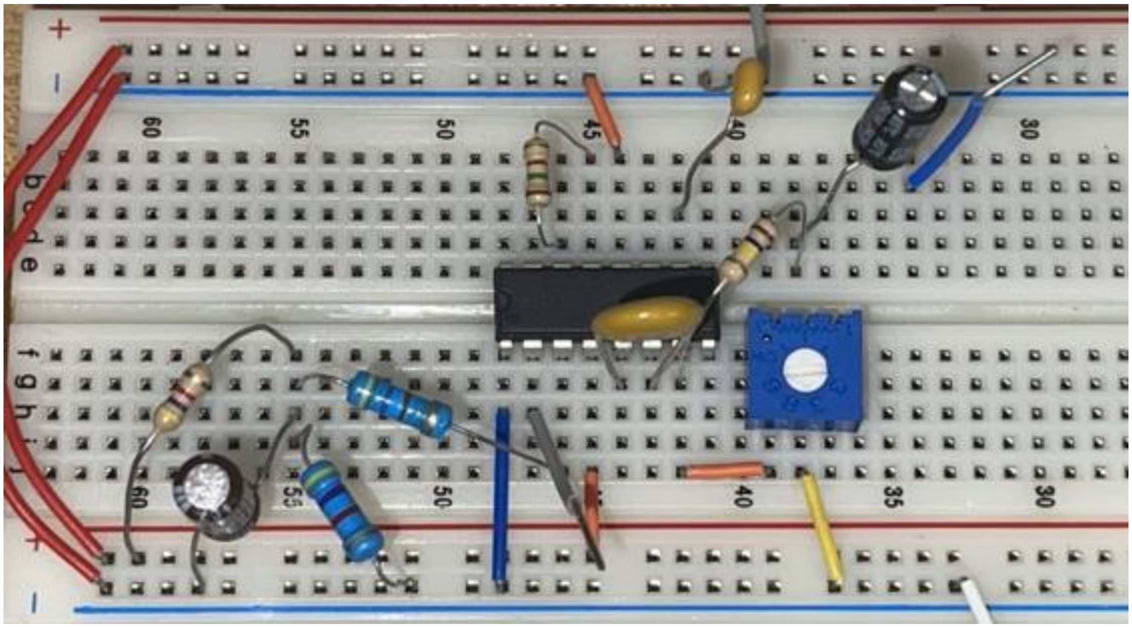

Figure 2 - FM Circuit Bench.

2. **Connect Measurement Instruments:**

    - Connect a frequency counter and oscilloscope to the 2206 output at pin 2.

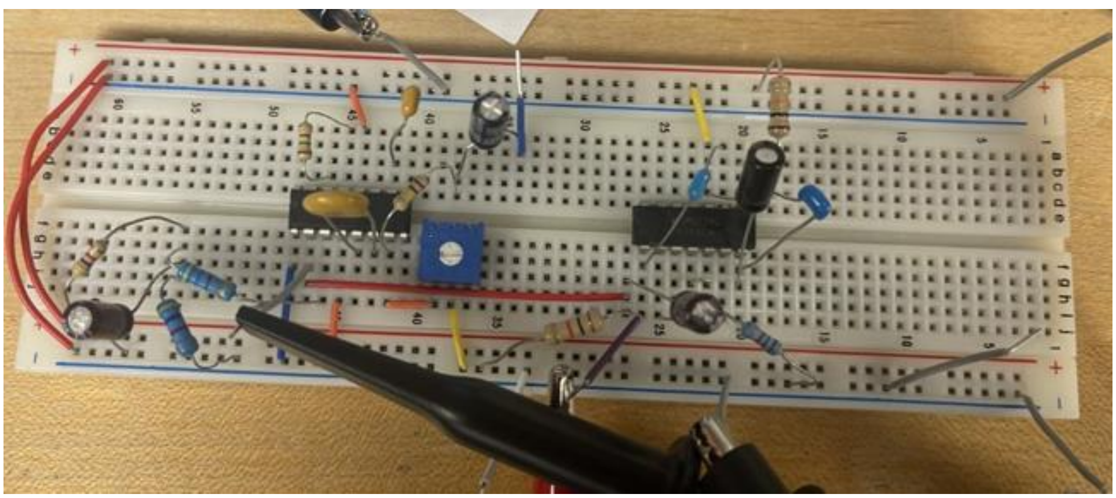

Figure 3 - Bench FM Demodulation PLL Circuit.

- Reduce the modulating input signal to zero.
- Adjust the 100-kΩ potentiometer for a carrier frequency of 30 kHz.

Figure 4 - Carrier frequency adjusted to 30 kHz

3. **Adjust PLL Circuit:**
    - Connect the frequency counter and oscilloscope to the PLL output at pin 5 on the 565.
    - Adjust the 10-kΩ potentiometer for a frequency of 30 kHz.
    - Ensure that the 565 PLL is locked to the 2206 output by observing the PLL output at pin 5 while varying the 100-kΩ potentiometer on the 2206.
    - Re-adjust the 100-kΩ potentiometer for an output of 30 kHz.
4. **Apply Modulating Signal:**
    - Apply a modulating signal from the external function generator to the 2206 FM generator.
    - Use a frequency range of 200 to 400 Hz.
    - While observing the output of the 2206 at pin 2, increase the amplitude of the modulating signal until an FM signal is obtained.

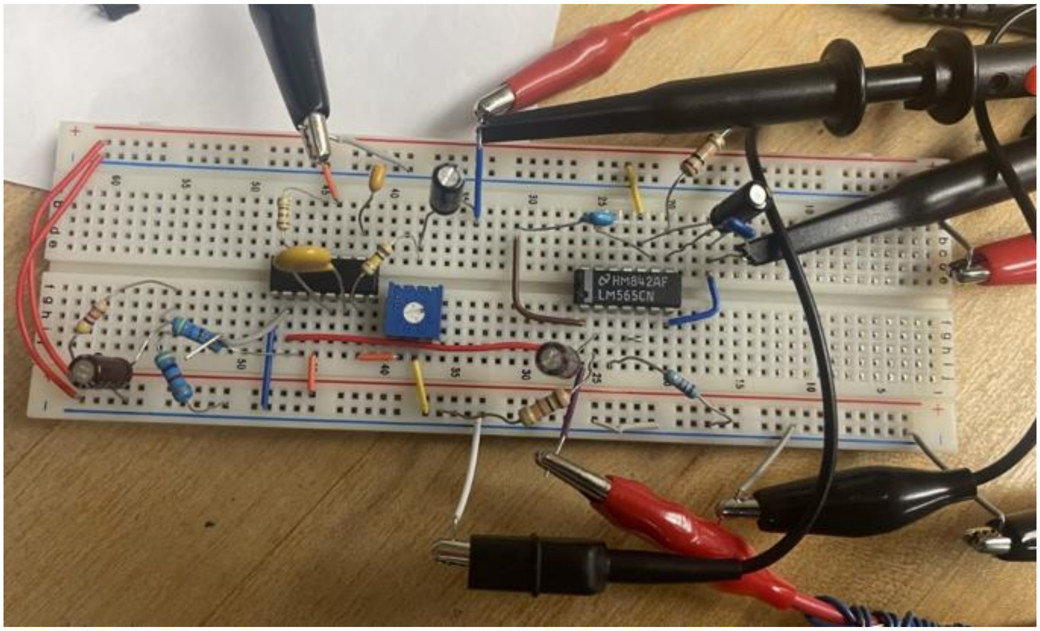

Figure 5 – Connecting oscilloscope to the PLL output at pin 7 on the 565.

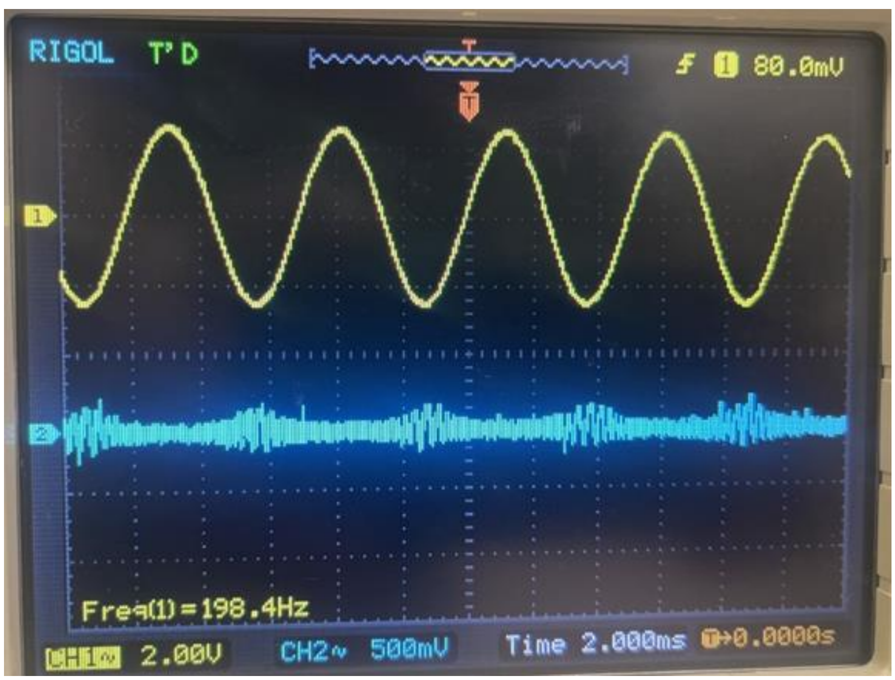

Figure 6 - Initial unrecovered signal prior to adjusting carrier amplitude and frequency.

5. **Observe Recovered Signal:**
   - Observe the PLL loop filter output at pin 7 on the 565 to see the recovered signal.
   - Compare this recovered signal to the modulating signal applied to the 2206.

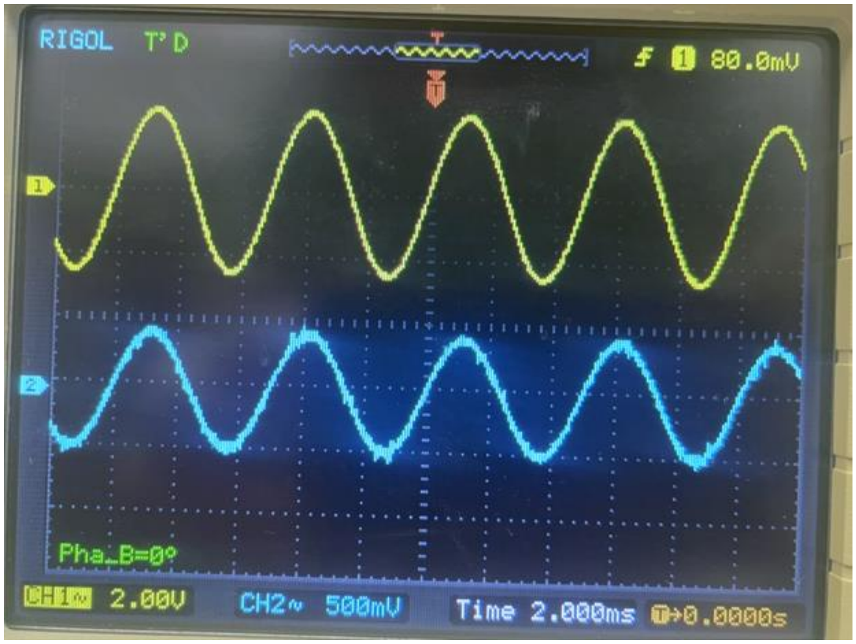

Figure 7 - Recovered signal with a phase shift of 0°.

Data & Observations

Observations:

1. **Initial Setup and Carrier Frequency Adjustment:**
    - The 2206 FM generator was set up with a modulating input signal reduced to zero. The 100-kΩ potentiometer was adjusted to achieve a carrier frequency of 30 kHz as observed on the oscilloscope.
2. **PLL Circuit Adjustment:**
    - The frequency counter and oscilloscope connected to the PLL output at pin 5 of the 565 showed that the PLL was able to lock onto the 2206 output when the 10-kΩ potentiometer was adjusted to also achieve a frequency of 30 kHz.
    - The PLL output tracked the 2206 output, maintaining a steady frequency of 30 kHz.
3. **Application of Modulating Signal:**
    - When the modulating signal from the external function generator was applied to the 2206 FM generator, the output at pin 2 showed a frequency-modulated signal.
    - Increasing the amplitude of the modulating signal resulted in clear frequency modulation as observed on the oscilloscope.

4. **Recovered Signal Observation:**
    - The recovered signal was observed at pin 7 of the 565 PLL loop filter output. This signal closely resembled the original modulating signal applied to the 2206, indicating successful demodulation.
    - However, the amplitude of the recovered signal was observed to be half of the original modulating signal. This amplitude reduction indicates some loss during the demodulation process.
5. **Varying Modulating Signal Frequency and Amplitude:**
    - Varying the frequency and amplitude of the modulating signal showed corresponding changes in the recovered signal at pin 7 of the 565. The recovered signal accurately tracked the changes, further validating the effectiveness of the PLL in demodulating FM signals.

Discussion of Experimental Results:

- The experiment successfully demonstrated the ability of the 565 PLL to demodulate FM signals. The recovered signal matched the original modulating signal in frequency, confirming the theoretical principles of PLL operation. However, the observed amplitude of the recovered signal was half of the modulating signal, which suggests an amplitude attenuation during the demodulation process.
- The high fidelity of the recovered signal, despite the amplitude reduction, indicates that the PLL effectively filters out noise and maintains the integrity of the frequency characteristics of the modulating signal.

Sources of Error:

- Potential sources of error include inaccuracies in setting the exact frequencies and amplitudes on the function generators. Ensuring precise calibration of the equipment is crucial for accurate observations.
- Electrical noise and interference could affect the measurements, but the PLL's noise suppression capabilities helped mitigate these effects.
- The amplitude reduction in the recovered signal could be due to losses in the PLL circuit or imperfect matching of the components.

Accuracy of Measurements:

- Although the experiment focused on qualitative observations, the oscilloscope displays provided clear and accurate visual evidence of the FM modulation and demodulation process.

- The consistency of the recovered signal's frequency with the original modulating signal indicates a high degree of accuracy in the PLL's performance. However, the amplitude reduction needs to be considered for precise applications.

Answers to Lab Questions:

1. **The recovered output from a PLL demodulator appears at the output of the ________.**
    - a. Phase detector
    - **b. Loop filter**
    - c. VCO
    - d. RC timing network

The recovered output signal from a PLL demodulator appears at the output of the loop filter. The loop filter removes high-frequency components from the error signal, leaving a low-frequency signal that represents the demodulated output.

2. **(True or False) The PLL VCO output signal tracks the FM input.**
    - **True**

The PLL VCO output signal tracks the FM input because the VCO adjusts its frequency to match the input frequency. This tracking is a key feature of PLL operation, allowing the demodulation of FM signals.

3. **The signal controlling the VCO in the PLL is the ________.**
    - a. FM signal
    - b. Carrier
    - **c. Phase detector output**
    - d. Original modulating signal

The signal controlling the VCO in the PLL is the output of the phase detector. This signal is a voltage that represents the phase difference between the input FM signal and the VCO output, which is then used to adjust the VCO frequency.

4. **If the modulating signal is removed from the modulator circuit, the loop filter output of the PLL will be ________.**
    - a. The carrier

- b. The modulating signal
- c. The free-running VCO frequency
- **d. Zero**

If the modulating signal is removed, the loop filter output will be zero. Without the modulating signal, there is no frequency deviation for the PLL to track, resulting in a zero output.

5. **To what frequency should the PLL VCO free-running be set when the demodulator is used in a superheterodyne receiver?**

    - **a. The input carrier frequency**
    - b. The manufacturer's recommended frequency
    - c. The receiver intermediate frequency
    - d. Any frequency higher than the highest-frequency modulating signal

The PLL VCO free-running frequency should be set to the input carrier frequency. This allows the PLL to lock onto the carrier signal and demodulate it accurately.

Conclusion:

In this experiment, the operation of a phase-locked loop (PLL) as a demodulator for frequency-modulated (FM) signals was successfully demonstrated using the 565 PLL IC and the 2206 FM modulator. The objective was to observe how the PLL can accurately recover the original modulating signal from the FM input. The experiment yielded the desired results, with the PLL effectively demodulating the FM signal and producing a recovered signal that closely matched the original modulating signal.

The 2206 FM generator produced a frequency-modulated signal that was accurately tracked by the 565 PLL. The recovered signal from the PLL's loop filter output closely resembled the original modulating signal, confirming successful demodulation. However, the amplitude of the recovered signal was half of the original modulating signal, indicating some loss during the demodulation process.

The high fidelity of the recovered signal demonstrates the PLL's capability to maintain the integrity of the modulating signal's frequency characteristics, despite the amplitude reduction. This reduction could be due to losses in the PLL circuit or imperfect matching of the components. Further investigation is required to identify the exact cause.

This experiment provided valuable insights into the practical application of PLLs in FM signal demodulation, highlighting their advantages in terms of fidelity and noise suppression. For future work, it is recommended to explore the causes of amplitude reduction in the recovered signal and implement measures to minimize this loss. Ensuring proper calibration of the equipment and minimizing electrical noise through better shielding and grounding can further improve the accuracy and reliability of the results.

Overall, the experiment successfully demonstrated the principles of PLL operation in FM demodulation, providing a deeper understanding of its practical applications and effectiveness.