To complete this lab you need to build the circuit as described in the manual. Follow the instructions and take snapshots as indicated. Record your findings whereever the manual asks you to. Make sure you number all your answers and your snapshots according to the question.

NAME ______________________________ DATE ______________

Chapter 5

Fundamentals of Frequency Modulation

PROJECT 5-1 FREQUENCY MODULATION

OBJECTIVE

To demonstrate frequency modulation with a voltage-controlled oscillator.

REQUIRED

You will need the 2206 function generator circuit you constructed previously, plus an oscilloscope, a frequency counter, and an external function generator. You will also need a 10-μF capacitor and a 100-kΩ resistor.

INTRODUCTION

Read carefully!

In frequency modulation, the modulating signal varies the frequency of the carrier. The carrier amplitude remains constant, but the increasing and decreasing amplitude of the modulating signal causes the carrier to deviate from its center frequency. The amount of deviation is a function of the amplitude of the modulating signal. The rate of deviation is proportional to the frequency of the modulating signal.

There are many different ways to produce frequency modulation. Today, one of the easiest ways is simply to apply a modulating signal to a voltage-controlled oscillator (VCO), and numerous IC VCOs are available. The 2206 function generator IC you have used in past experiments uses a VCO as the primary signal-generating circuit. This oscillator can easily be frequency-modulated simply by applying the appropriate modulating signal. In this experiment you will demonstrate frequency modulation with the 2206.

PROCEDURE

1. The circuit for this experiment is shown in Fig. 5-1. This is the same 2206 function generator you have used previously, but note that you will add a 10-μF capacitor and a 100-kΩ resistor to pin 7. To the capacitor you will connect an external function generator to serve as the modulating signal.
2. Apply power to the circuit. Reduce the modulating signal amplitude from the external function generator to zero, and then observe the carrier output at pin 2 of the 2206. Adjust the 100-kΩ pot on the 2206 for a frequency of approximately 30 kHz. Set the horizontal sweep controls on the oscilloscope to display approximately three cycles of the carrier wave. Snapshot
3. Slowly increase the amplitude of the modulating signal from the external function generator, and set the frequency of the signal to approximately 200 Hz. As you increase the modulating signal amplitude, note the display on the oscilloscope. You should see the carrier wave begin to "vibrate," which indicates a change in frequency with the modulating signal. You

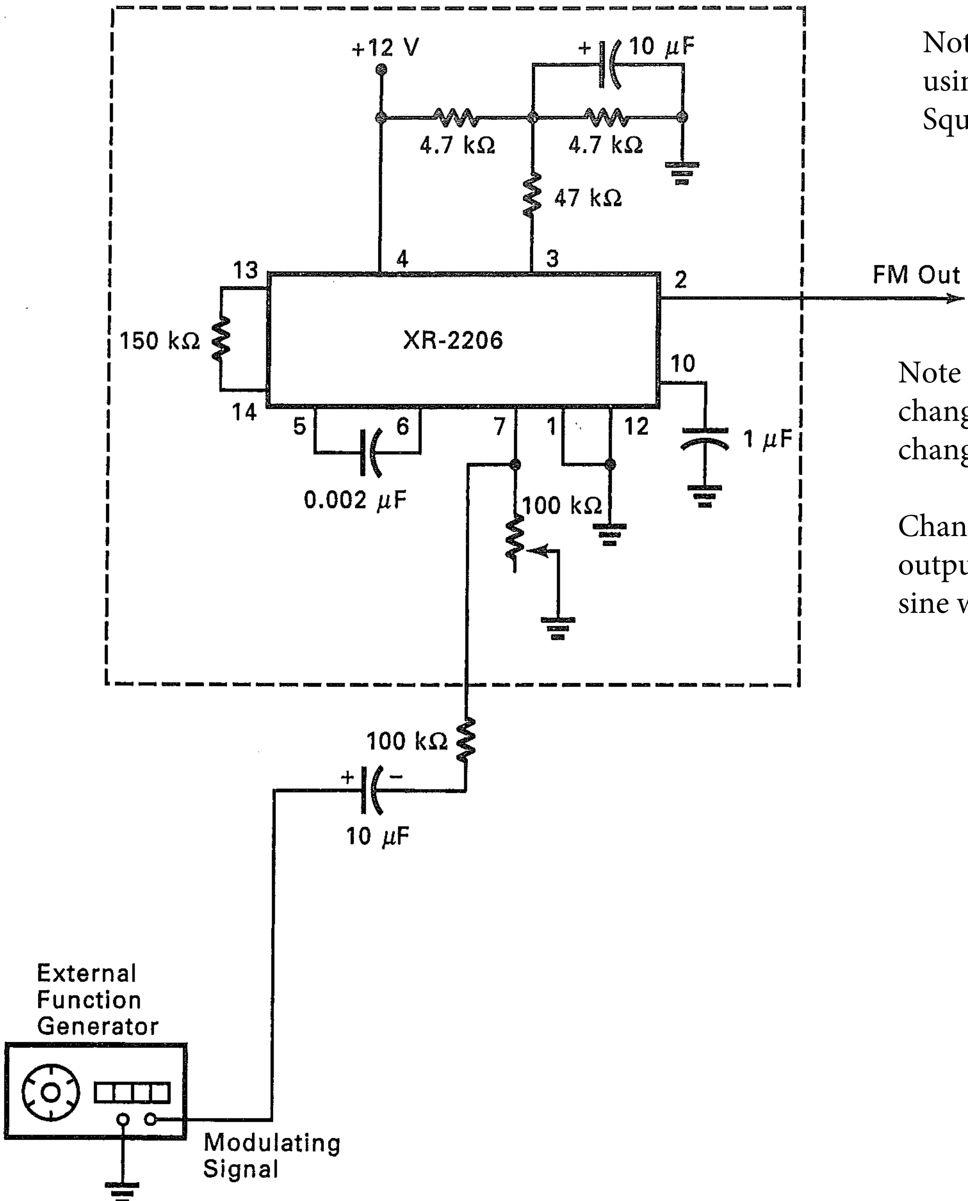

Fig. 5-1 Frequency modulation of the 2206.

Note that if you can pull up PIN 11 using a 10K resistor. You should see a Square waveform.

Note that the value of 4.7K can be changed to 30K and 150 K can also be changed to 200 ohms.

Changing these values will result the output signal to become more like a sine waveform.

Snapshot

should observe a waveform that looks approximately like the one shown in Fig. 5-2. Continue slowly increasing the modulating signal amplitude and note the effect on the carrier wave. If you have difficulty obtaining a stable display, use the triggered sweep function on the oscilloscope. Manipulate the trigger and horizontal frequency controls until a stable waveform is obtained. What you are seeing is the carrier frequency being instantaneously changed by the modulating signal. While varying the amplitude of the modulating signal and observing the resulting FM output, determine the relationship between the frequency deviation and the modulating signal amplitude.

Snapshot

4. Set the amplitude of the modulating signal at the 10-μF capacitor to 2 $V_{p\text{-}p}$, and then observe the carrier output on the oscilloscope. You will see the waveform shown in Fig. 5-2, indicating frequency deviation. Now, while observing the waveform, vary the frequency of the modulating signal. Note the effect on the waveform. How does the deviation change with respect to the modulating signal frequency?

Question: Change the value of the POT and determine the MIN and MAX achievable frequencies

Question: What is the minimum operating voltage for XR chip?

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Question: What is DeltaF? That is the maximum frequency deviation.

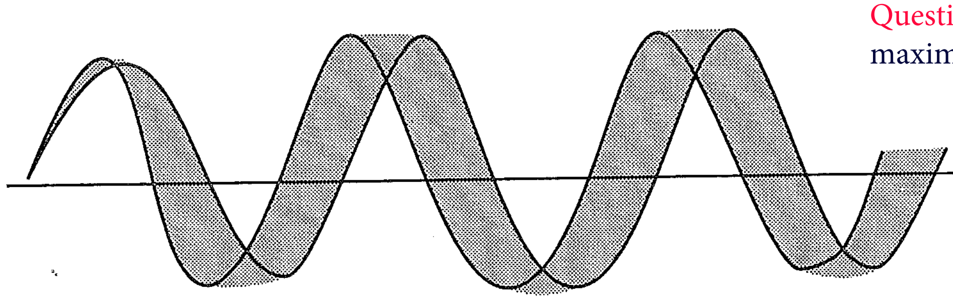


Fig. 5-2 How FM looks on an oscilloscope.

QUESTIONS Answer the questions!

1. Which of the following is the most correct statement with regard to the relationship between the carrier frequency deviation and the amplitude of the modulating signal?
   a. Decreasing the modulating signal amplitude increases the carrier deviation.
   b. Decreasing the modulating signal amplitude decreases carrier deviation.
   c. Carrier deviation is not affected by the amplitude of the modulating signal.
   d. The frequency deviation varies in direct proportion to the modulating signal frequency.
2. Varying the frequency of the modulating signal causes the frequency deviation of the carrier to ________ .
   a. Increase
   b. Decrease
   c. Remain the same
   d. Drop to zero
3. The type of modulation produced by the VCO in the 2206 IC is ________ .
   a. Frequency modulation
   b. Phase modulation
   c. Indirect FM
   d. FSK
4. What is the deviation ratio of an FM system in which the maximum permitted frequency deviation is 10 kHz and the maximum modulating frequency is 3 kHz?
   a. 0.3
   b. 1
   c. 3
   d. 3.33
5. The number of sidebands produced by a sine-wave carrier being frequency-modulated by a single-frequency sine-wave tone is ________ .
   a. 1
   b. 2
   c. 4
   d. Infinite

PROJECT 6-2 PHASE-LOCKED LOOP OPERATION

OBJECTIVE

To demonstrate the operation and determine the lock and capture ranges of a phase-locked loop.

REQUIRED

1 oscilloscope (dual-trace)
1 frequency counter
1 function generator (sine wave)
1 power supply (±12 V dc)
1 565 IC PLL
1 0.001-μF capacitor
1 0.01-μF capacitor
1 0.1-μF capacitor
1 10-μF electrolytic
2 1-kΩ resistors
1 2.7-kΩ resistor

INTRODUCTION Read carefully!

A phase-locked loop (PLL) is an electronic feedback-control system used in a variety of applications. It consists of an error detector, a loop filter, and a voltage-controlled oscillator (VCO). See Fig. 6-1.

A phase-locked loop will track or follow the frequency of an input signal. The input signal frequency is compared to the VCO frequency in the phase detector, and an error signal is generated. This error signal from the phase detector is filtered into a dc voltage that controls the VCO. Changes in the input frequency develop an error signal that will cause the VCO's output frequency to change in such a direction as to follow the input signal frequency exactly. Frequency changes of the input are interpreted as phase changes which cause the VCO to readjust. The VCO output frequency is equal to the PLL input frequency, but there is a phase shift between the input and VCO signals. It is this phase shift that generates the error signal and the dc voltage that keeps the phase-locked loop locked. In this experiment, you will demonstrate PLL operation by using the popular 565 IC phase-locked loop.

In the 565 integrated circuit phase-locked loop, the VCO is of the multivibrator type and produces both triangular and square-wave outputs. The frequency is determined by external values of resistance and capacitance. The approximate free-running frequency is computed with the formula

$$f_0 = \frac{1.2}{4R_1C_1}$$

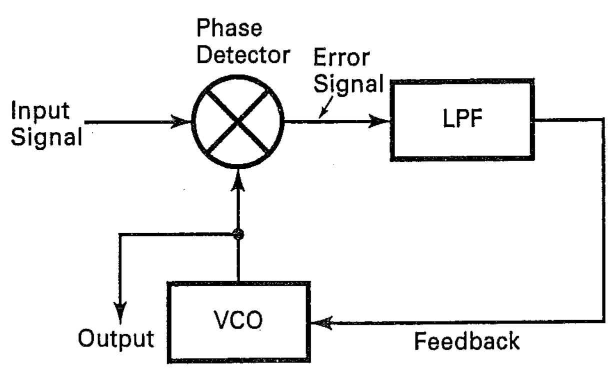


Fig. 6-1 Phase-locked loop.

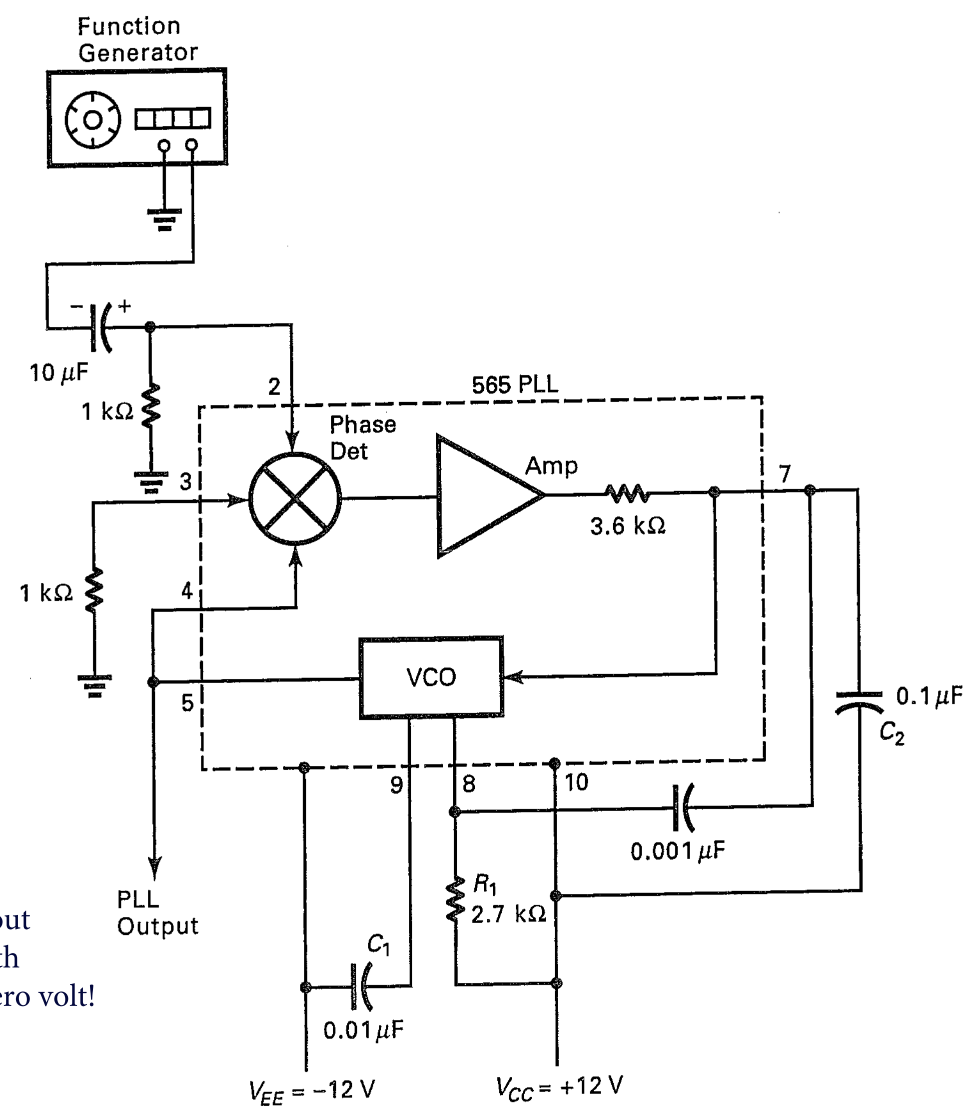
Refer to Fig. 6-2, which shows the 565 and the related components.

The frequency range over which the VCO is capable of tracking the input signal is known as the lock range. It is primarily a function of the range of the VCO, and it is centered around the free-running frequency of the VCO. For the 565 PLL, it is computed with the formula

$$f_L = \frac{\pm 8 f_0}{V_s}$$

where f_L is one-half the lock range, f_0 is the free-running VCO frequency, and V_s is the total supply voltage. In this circuit, there is a $+V_{cc}$ supply and a $-V_{EE}$ supply for a total of $12 + 12 = 24$ V. The total lock range is $2f_L$.

The capture range is the range of frequencies over which the PLL will lock onto an input signal. When an input signal is applied to the VCO, it must be within the capture range in order for the circuitry to "capture" the signal. A signal whose frequency is outside the capture range will simply cause the PLL to remain unlocked, and the VCO will operate at its free-running frequency. The capture range is usually narrower than the lock range, which causes the PLL to act like a very selective band-pass filter.



This is about 10KHz with offset of zero volt!

Fig. 6-2 Phase-locked loop circuit.

In this experiment, you will demonstrate PLL operation and measure the phase shift between the input signal and the VCO during the locked state. You will also demonstrate how the VCO output tracks a variable-frequency input. Finally, you will calculate and measure the free-running frequency and the lock range of the 565 PLL.

PROCEDURE

1. Connect the circuit shown in Fig. 6-2. An external function generator with variable-frequency capability is connected as the PLL input. Reduce the amplitude to zero for now.
2. Use the formula for the free-running frequency of the VCO, given earlier, to calculate that frequency by using the values of R_1 and C_1 in Fig. 6-2.
3. Apply power to the circuit shown in Fig. 6-2. By using a frequency counter, measure the output frequency of the VCO at pin 5 on the 565 IC. Observe the output signal with an oscilloscope.
4. Compare your computed and measured values of free-running frequency and explain any difference.
5. Adjust the function generator input to the PLL input for an amplitude of 1 V each peak to peak of sine wave. Set the external function generator for a frequency approximately equal to the free-running frequency of the VCO.
6. Use an oscilloscope and/or frequency counter to measure the function generator output frequency and the VCO output frequency at pin 5. Are the two frequencies the same? Why or why not?
7. Use a dual-trace oscilloscope to display the function generator and VCO output signals simultaneously. Measure the amount of phase shift between the two. You can do that by measuring the time shift t between corresponding parts of the two waveforms and then using the formula

$$\text{Phase shift, in degrees} = \frac{360t}{T}$$

   where T is the period of the signals.
8. While continuing to observe the function generator and VCO output signals on the dual-trace oscilloscope, vary the function generator frequency above and below the free-running value. Note the effect on the VCO output. Describe the relationship between the function generator input and the VCO output signal frequencies.
9. Use the formula given earlier to compute the lock range for the PLL. Record your value.
10. Assuming that the lock range is centered on the free-running frequency of the VCO, calculate the upper and lower lock range limits. Is the difference between the upper and lower lock values equal to the lock range?
11. By using the circuit shown in Fig. 6-2, you will now measure the lock range. First, however, set the function generator input frequency to the PLL free-running frequency to ensure initial lock.
12. Begin decreasing the function generator input frequency while observing the VCO output. At some point, you will notice a frequency variation or jitter. Stop decreasing the frequency exactly at that point and measure the function generator frequency. It is the lower lock limit of the PLL. Record it.
13. Increase the input frequency while observing the VCO output. Lock will occur. Keep increasing the frequency. Again you will reach a point where the VCO output begins to jitter. Reduce the input frequency to just below the point at which the jitter ceases. Then measure the function generator output frequency. This is the upper lock limit of the PLL. Record it.
14. By using the experimental data you collected in steps 11 through 13, calculate and record the measured lock range. How does it compare to your calculated value?

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QUESTIONS

Answer the questions

1. Varying the PLL input frequency causes the PLL output to ________.
   - a. Track the input
   - b. Remain constant at the free-running frequency
   - c. Vary inversely
   - d. Drop to zero
2. The error signal is generated by what characteristic of the input and VCO signals?
   - a. Frequency
   - b. Phase shift
   - c. Amplitude difference
   - d. Rise time
3. What is the relationship between the capture f_c and lock f_L ranges of the PLL?
   - a. $f_c = f_L$
   - b. $f_c > f_L$
   - c. $f_c < f_L$
   - d. $f_c = 2f_L$
4. To increase the free-running or center frequency of the PLL, what changes should be made in R_1 and/or C_1?
   - a. Increase R_1
   - b. Increase C_1
   - c. Decrease R_1
   - d. Decrease C_1
   - e. Both **a** and **b**
   - f. Both **c** and **d**
5. If the input frequency to the PLL is outside the capture and lock ranges, the VCO output is the ________.
   - a. Upper lock frequency
   - b. Free-running frequency
   - c. Lower lock frequency
   - d. Input frequency

Your Report For each Section:

SECTION 5-1

1- Make sure you have a cover sheet - name of authors, date, course

2- Purpose: What is the purpose of this section?

3- Components: List all the parts you used for this section

4- Circuit: Draw the Schematic

5- Circuit Description: Provide a detailed DESCRIPTION of the schematic. What did you learn about the schematic?

6- XR-2206: Write one paragraph about XR chip. What does it do - link to its spec sheet

7- Discussions: Place each snapshot in your document and carefully explain it. Explain how you measured the signal and what does it indicate. Each snapshot must have a figure number.

8- Final questions: Answer the questions at the end of each section

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1- Purpose: What is the purpose of this section?

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5- 565 PLL: Write one paragraph about XR chip. What does it do - link to its spec sheet

6- Discussions: Place each snapshot in your document and carefully explain it. Explain how you measured the signal and what does it indicate. Each snapshot must have a figure number.

7- Final questions: Answer the questions at the end of each section

Reference:
Principles of Electronic Communication Systems Experiments Manual