Experiment No. 3
Phase Locked Loops and Frequency Modulation

Complete Experiment No. 3 Pre-Lab Before Beginning Experiment

Include all measured data in a report to your lab instructor. The report is a discussion of your results following the guidelines given at the end of the experiment. You may add additional comments as desired. Be sure to discuss how your results differed from the results you expected from the pre-lab.

Part A: Phase Locked Loop Operation

Objective: To investigate the operation of a phase locked loop and measure the capture and lock in range

Connect the circuit shown in the figure.

The CD4046B PLL IC is contained within the larger rectangular block. The two smaller blocks in the diagram are interior to the IC and are shown only to clarify the function of the system. It is only necessary to connect the resistors, capacitors and power supplies exterior to the pins shown in the diagram. Leave the jumper wire connected between pins 3 and 4 disconnected to start.
1) Use a 100kΩ potentiometer for R1 and 250pF for C1. R1 adjusts to the VCO center frequency. Set the power supply voltage to +10V. Adjust the value of R1 for a frequency of 50 kHz at pin 4.

2) Connect a jumper between pins 3 and 4. Connect the function generator to the input terminal and set it for a 50 kHz sine wave at 1 V p-p.

3) Observe the waveform at pin 4. The VCO output at pin 4 is a square wave. The square wave should be phase locked to the function generator signal. To prove that it is, observe both waveforms at the same time using each oscilloscope channel.

4) Determine the phase difference between the waveforms by triggering on the positive leading edge of the square wave and measure the time difference between the positive leading edge of the square wave and the positive zero crossing of the sinewave. The phase difference is the time difference times the frequency times 360 degrees.

5) Vary the function generator frequency up and down a small amount while observing the phase change. The waveforms should remain synchronized but the phase will change. The phase comparator output voltage controls the VCO frequency to maintain phase lock.

6) The hold-in range (also called lock range) is the range of frequencies at which the PLL can maintain lock. Adjust the frequency generator to find the upper and lower boundaries of the hold-in range. Record each frequency. At these frequencies the PLL will lose lock and the VCO will be free running. The phase will be changing at a frequency equal to the difference between the function generator and VCO frequencies.

7) Calculate the measured hold-in range by subtracting the lower limit of hold-in from the upper limit and compare this to the predicted hold-in range.

8) The capture range is the range of frequencies at which the PLL can regain lock. Adjust the frequency generator to find the upper and lower boundaries of the capture range. Record these values. Calculate the measured capture range and compare this to the predicted capture range.

**Part B: Frequency Modulation**

Objective: To measure the frequency deviation and frequency spectrum of an FM signal for different modulation conditions

1) Set the function generator to a 50 kHz sinewave with amplitude of 200 mV p-p. Select the FM function by pressing Shift FM and you should see FM displayed on the front panel readout. The default modulation waveform is sine wave. To verify sine wave modulation press Shift and then Menu button and the display should read A:Mod Menu. Press ▼ (down arrow) once to enter Mod Menu then press < until the display reads 3: FM Shape. Enter this option by pressing ▼ and you should see Sine.
2) Press **Shift Freq** to set the modulating frequency to 8 kHz. Press **Shift Level** to set the peak frequency deviation to 30 kHz.

3) Connect the oscilloscope to the function generator and observe the FM waveform. Set the oscilloscope’s time scale to 25 µs / division and hit the Stop button. Observe the period of the signal getting larger and smaller at the modulating frequency rate. This is indicative of frequency modulation. Vary the modulation amplitude and frequency slightly and observe the changes in the FM waveform.

4) Set the modulation frequency to 2 kHz and the deviation to 5 kHz. Set the oscilloscope to the FFT mode and observe the spectrum of the FM waveform. Identify the 50 kHz carrier peak, which should have several sideband peaks around it, and center it on the screen. Use the **Zoom** function to spread the spectrum to better observe the sidebands. Based on the modulation index for the modulation frequency and deviation set, verify that there are about the same number of sidebands and that they are at about the same relative amplitudes as predicted. Use the Bessel function coefficient table from the book.

5) Change the frequency deviation to 100 Hz and observe that the spectrum has changed. Calculate the modulation index. You should see a spectrum not unlike an AM spectrum. What is the name given to this type of FM signal?

6) Experiment with other frequency deviations and also vary the modulation frequency to see the effects on the spectrum. You should also exit the FFT mode and observe the FM waveform as you vary the modulation frequency and deviation. An interesting picture appears when you set the modulation frequency below about 10 Hz since your eyes can easily follow the frequency variations. This is also interesting to view in the FFT mode.

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**Part C: FM Demodulation**

Objective: To observe the 565 PLL as an FM demodulator

1) Readjust the modulation frequency to 500 Hz and the deviation to 5 kHz. Connect the function generator to the input of the PLL circuit and observe the output. You should see the 500 Hz modulation sine wave at the PLL output. This is your demodulated waveform. The signal variation will be small compared to the DC level so use AC coupling the output. If high frequency noise is present you can add an RC low pass filter (10kΩ and 5nF are suggested).

2) The PLL must be locked throughout the frequency variation of the input for proper demodulation. You may need to adjust R₁ if you are losing lock. Note that to maintain lock, the PLL must change phase as the input frequency changes. The output voltage is the amplified phase detector output and therefore changes with the input frequency.

3) Vary the modulation frequency and frequency deviation of the function generator and observe the changes in the PLL output. You should see the output signal vary in frequency and amplitude according to the generator frequency and deviation changes.
Submit a discussion of results to your lab instructor following the guidelines below. Include all measured data. Be sure to discuss how your results differed from the results expected from the pre-lab.

Part A:
Discuss the differences between and the limitations of capture and hold in range in a PLL.

Part B:
Discuss the relationships between frequency spectrum and frequency deviation in FM.

Part C:
Discuss the relationships between the modulating signal frequency and amplitude and the frequency deviation in FM.