Lab 9
Phase-Locked Loop and Frequency Modulation and Demodulation

In this lab you will use a phase-locked loop to demodulate a frequency modulated signal generated with a voltage-controlled oscillator. There are three sections to this lab: building the VCO which creates the frequency-modulated signal, building the phase-locked loop which demodulates the signal, and finally testing the assembly.

NOTE 1: use the 4046A chip, not the 4046B.

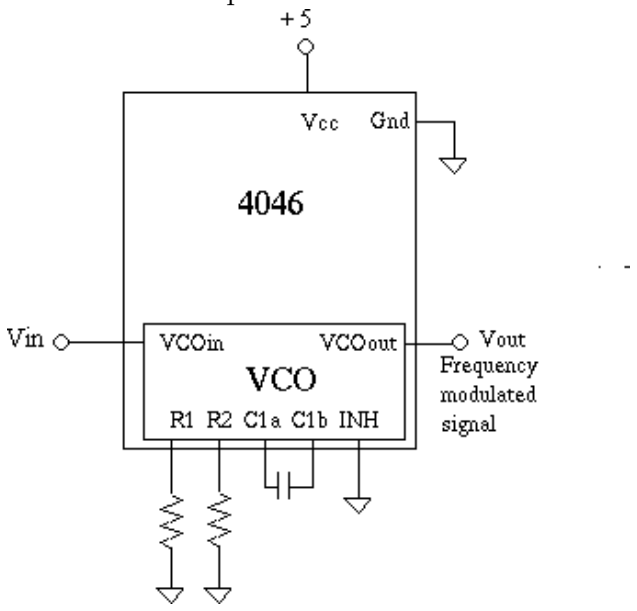
NOTE 2: if you are short on time (and only then) then skip some of the more detailed intermediate tests. It is more important to make it to the end of the lab than to spend much time on characterizing the VCO and PLL beyond verifying that they function.

Pre-lab

1. Read the data sheet for the 4046A. The full name is probably 74HC4046A (read it off the chip and find the data sheet on DigiKey)
2. Select component values for the VCO.
3. Derive the transfer function of the LP filter and select component values for it.

Voltage-Controlled Oscillator

Use the VCO portion of one 4046A chip to create a VCO.



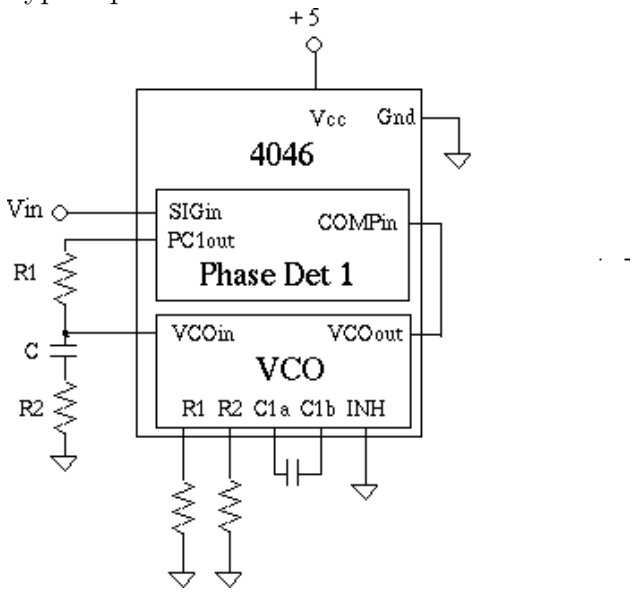
1. Design the VCO such that it will have a frequency range of approximately 10 kHz centered around 50 kHz over the input voltage range 1 V to 4 V (Use $V_{CC} = 5\,\text{V}$). The frequency range of the VCO is selected with two resistors.

2. Test the VCO. Plot the output frequency as a function of the input voltage and compare to the programmed range.

3. Apply a square wave to the input at the full voltage range of the VCO, and of high enough frequency so that you can see the packets of high and low frequency on the oscilloscope. The difference in frequency will be small, only about 20% difference. Plot the output together with the controlling signal.

Phase-Locked Loop

Use the VCO and the Type 1 phase detector of a second 4046A to build a PLL.



4. Make another VCO with the same frequency range as above.

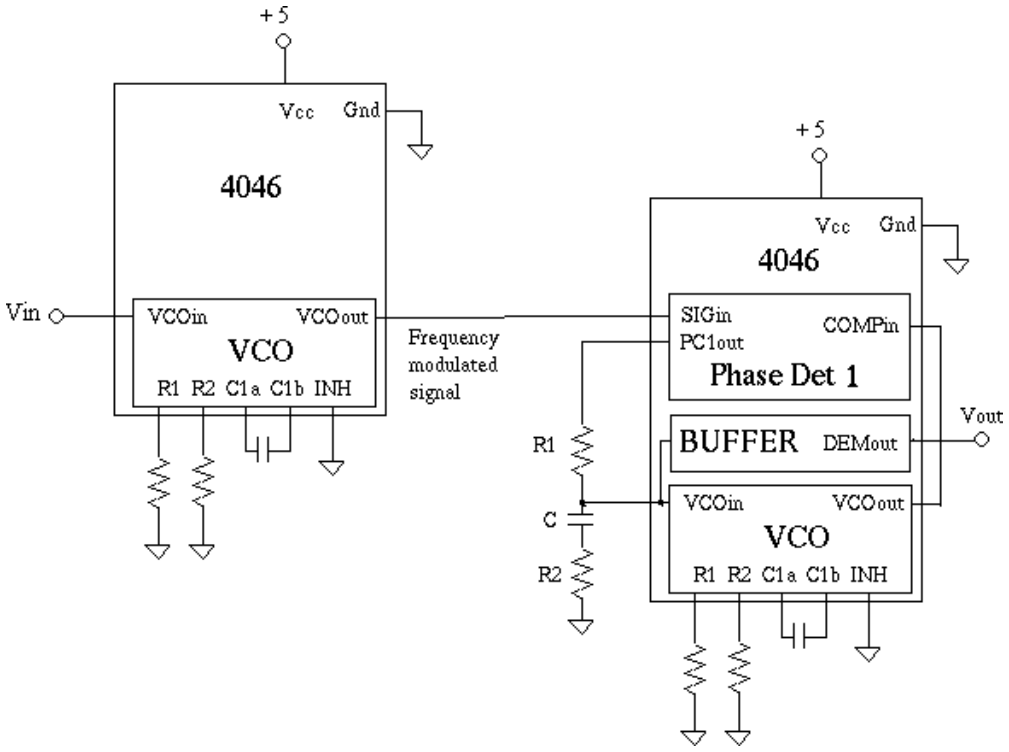
5. Test that this VCO produces approximately the same range of frequency for the same range of DC input voltages. Exact match is not necessary.

6. Design the LP RCR filter and connect the Type 1 phase detector to the VCO as shown on the figure.

7. Supply a input square wave from 0 to 5 V of varying frequency in the designed frequency range and verify that the output, `VCOout`, is of the same frequency. What is the phase difference between the two signals as a function of frequency? What happens if you input a frequency outside the designed range?

Frequency Demodulation

Connect the VCO and the PLL together to make a frequency demodulation circuit.



8. Design the low-pass filter to have a critical frequency of 3 kHz and $Q = 0.7$.

9. The output of the demodulator is the control voltage input to the PLL side VCO, provided through a buffer.

10. Experiment with this circuit providing different inputs to the modulator and comparing that to the demodulator output.

11. Try different input amplitudes, different shapes (sine, square, triangle, sawtooth), and different frequencies.

12. Discuss the results of your experimentation, including a few important plots. For example, how does the circuit perform as the modulated signal frequency is increased, or as its amplitude is decreased? Which modulated signals are reproduced best, at what frequencies, and amplitudes? Does any of this match your expectations? Why?

13. Specifically, what is the settling time for square wave modulation and how does that compare to the characteristic frequency of the LP filter?