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Experiment 5: FM Demodulation

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15 October 2024

1 Introduction

We use IC 565 to perform frequency demodulation of an FM signal and observe the output waveforms in the time and frequency domains. We also observe the waveforms on the DSO and perform FFT analysis.

2 Objectives

2.1 Task 1

Without providing the FM Input, check the internal VCO Output Waveform of the PLL IC on the oscilloscope. Adjust the potentiometer at R1, to set the frequency of VCO output to 10 KHz. (10 KHz is the carrier frequency chosen for modulation)

2.2 Task 2

Provide the FM Input at pin 2 of PLL IC and observe the PLL O/p waveform at pin no 7 of IC. An additional low pass filter can be added to the circuit to eliminate frequency components other than modulating signal frequency 1 KHz from PLL output.

2.3 Task 3

Apply a square wave message m(t) to the point Vc of the circuit and observe the frequency-modulated signal at the output pin on DSO. (Take modulating signal's fm = 1KHz). Demodulate the FM-modulated signal to get back the square wave message signal, without using any IC, but only using standard components.

2.4 Task 4

Demodulate the FM-modulated sinusoidal signal to get back the sinusoidal message signal, without using any IC, but only using standard components.

3 Instruments and Materials Used

1. RIGOL Signal Generator

2. ScientiFIC SMO10C Digital Signal Oscilloscope

3. +12V, -12V DC source and ground

4. Resistors

5. Capacitors

6. Diodes

7. Breadboard

8. Connecting wires

9. IC 565

10. Potentiometer

4   Theory

The peak deviation frequency is denoted by

$$\Delta f = f_{max} - f_c \tag{1}$$

and the modulation index(m) is given by

$$m = \frac{\Delta f}{f_m} \tag{2}$$

The carrier frequency without modulating the signal can be adjusted by tuning the potentiometer and is guided by the following relation

$$f_c = \frac{1}{RC} \tag{3}$$

The instantaneous carrier frequency after modulation is guided by the following relation(VCO)

$$f_c = \frac{1}{RC}\left[1 + \frac{R}{R_c}\left(1 - \frac{V_c}{3}\right)\right] \; Hz \tag{4}$$

where V_c is the control voltage guided by a message signal connected through the resistance R_c to pin 7.
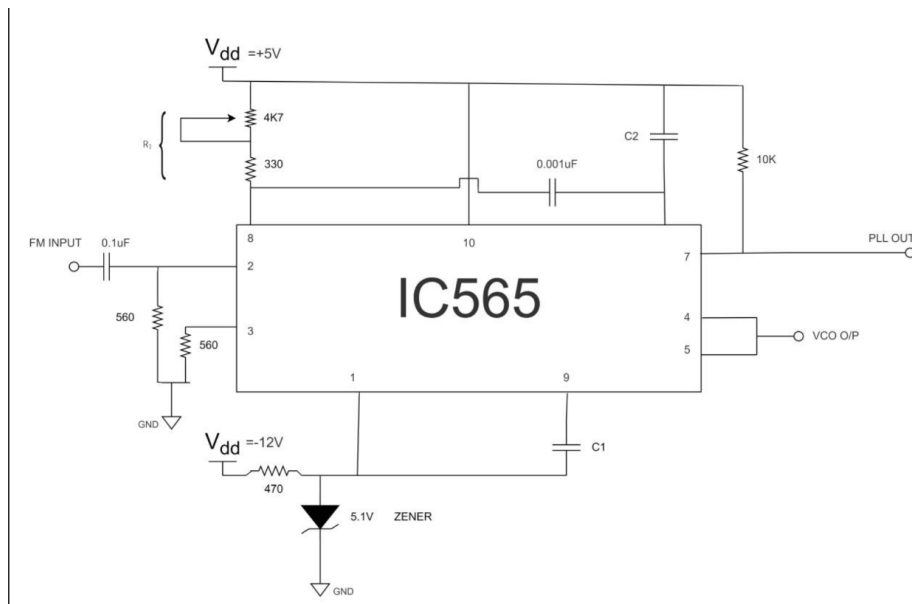
4.1   Circuit Diagram

Figure 1: Circuit Diagram

4.2   Calculations

The free running frequency of VCO is $f_0 = 10 \ kHz$ (Centre Frequency)

$$f_0 = \frac{1}{4R_1C_1} \tag{5}$$

taking $R_1 = 4k\Omega$, we get $C_1 = 6.2nF$

For the internal low-pass filter design

$$f = \frac{1}{2\pi 3.6k\Omega C_2} \tag{6}$$

Taking $C_2 = 0.033\mu F$, we get $f = 1.3kHz$
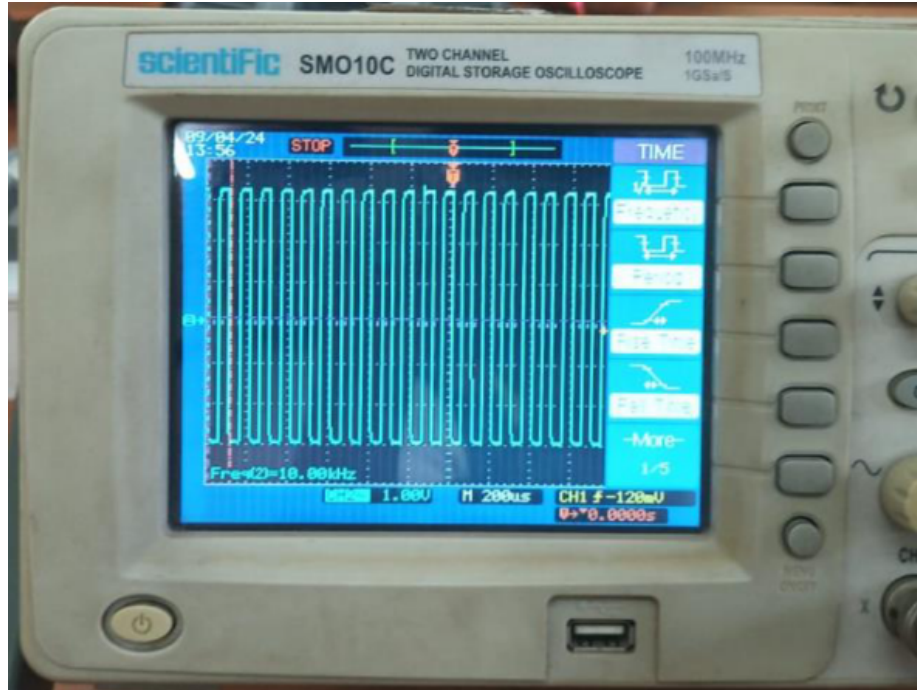
5   Observations

5.1   Task 1

Figure 2: DSO showing the free running frequency of the VCO at f=10kHz

5.2   Task 2

We apply the frequency-modulated input at pin 2, and observe the demodulated PLL output waveform at pin no 7 of IC. An additional low pass filter is added to the circuit to eliminate frequency components other than modulating signal frequency 1 KHz from PLL output so that we get a cleaner demodulation.
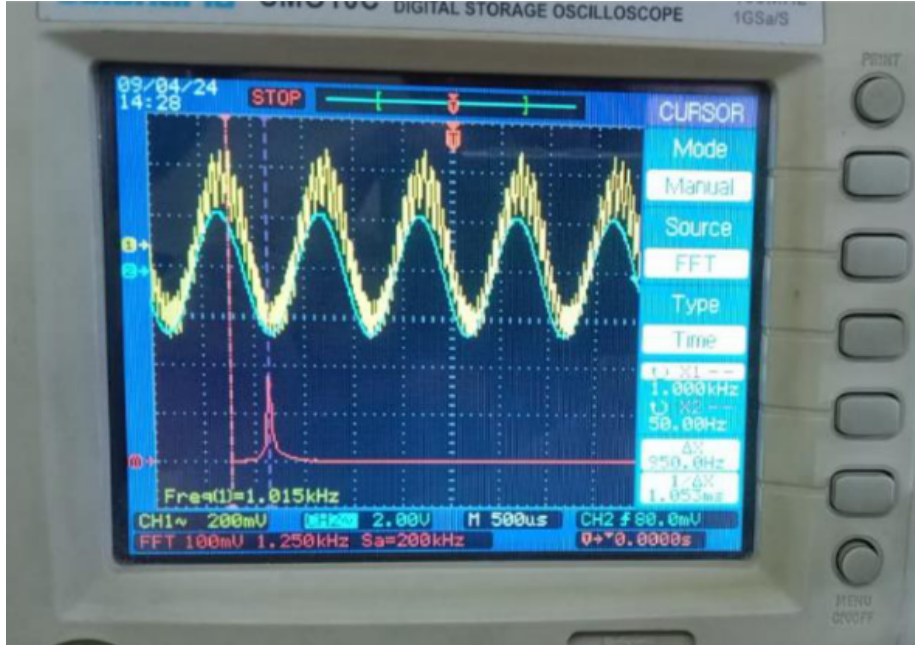

Figure 3: Demodulated output without applying the lowpass filter

We observe a phase shift and the DSO showing the frequency at 995 Hz, slightly below our original signal at $f_m = 1000\ Hz$.

5.3   Task 3

Here we couldn't use an IC to demodulate the signal and had to use standard components to decode a square signal. This is the circuit that we came up with:

From the DSO output and FFT analysis, we observe that the output frequency of the demodulated waveform is 1.07 kHz(slightly bigger than 1kHz, but acceptable). The FFT analysis, shows the proper frequency spectrum of the demodulated output waveform for a square wave.
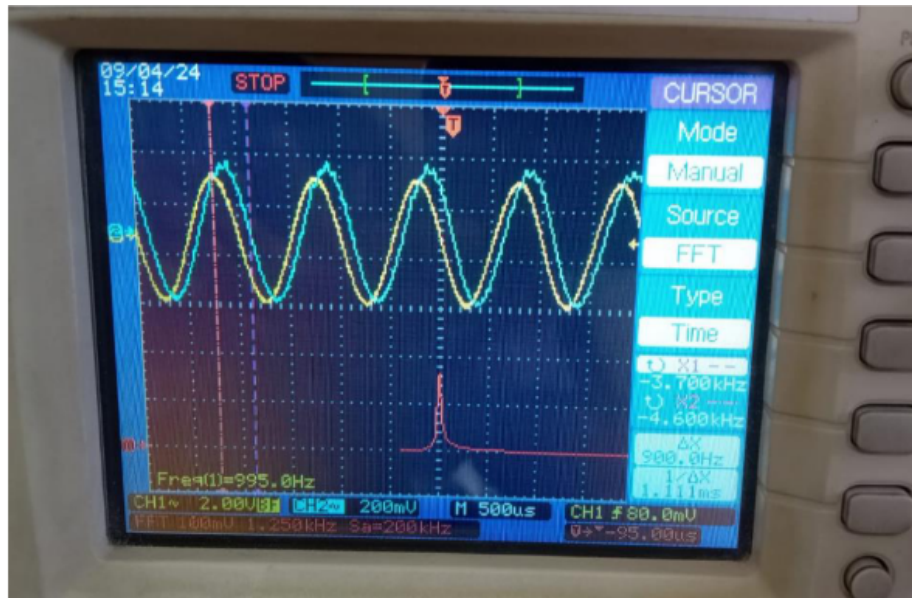
Figure 4: Demodulated output after applying the lowpass filter, on top of the original message signal
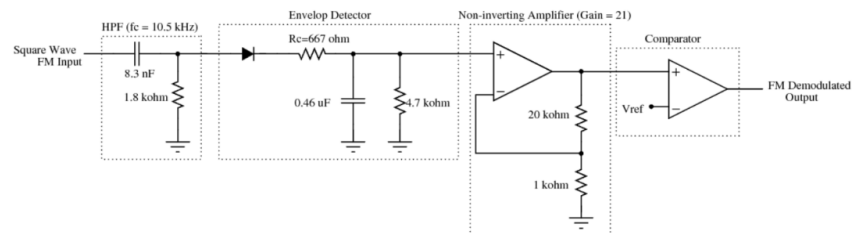

Figure 5: The circuit for demodulating an FM modulated square signal input using standard components
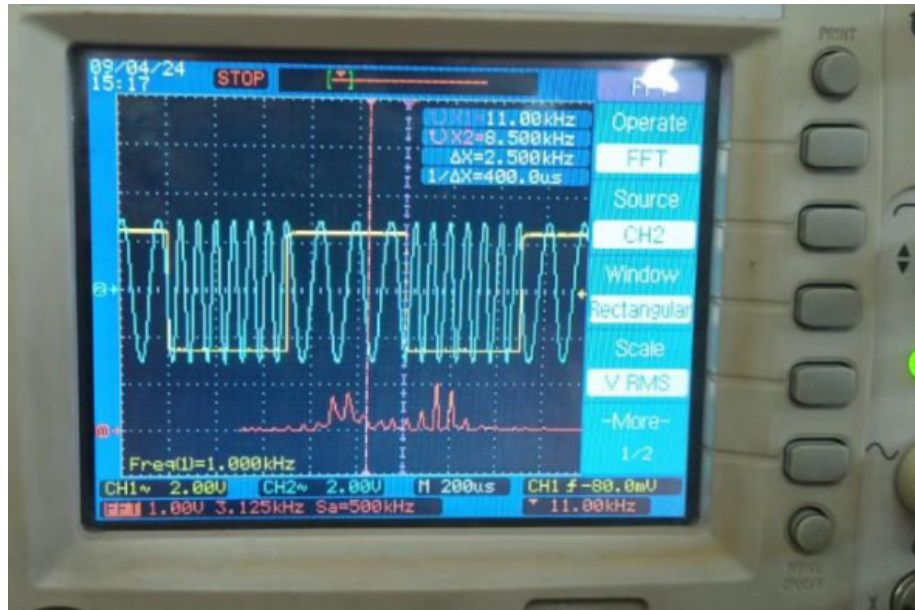
Figure 6: FM Modulated Input to the circuit superimposed on top of the original square wave signal

Figure 7: Demodulated output of the circuit superimposed on top of the original square wave signal

7

5.4   Task 4

Here we had to design a demodulator for a sinusoidal signal without using an IC, and this is the design we came up with, which is essentially a differentiator followed by an envelope detector:
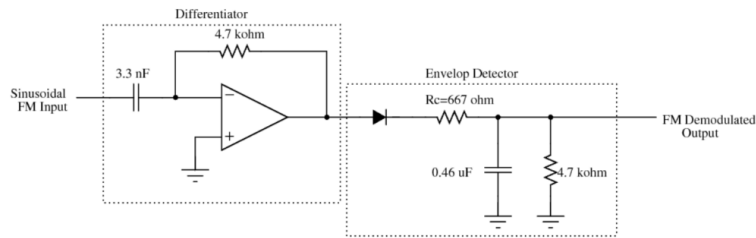

Figure 8: The circuit for demodulating an FM modulated sinusoidal signal input using standard components
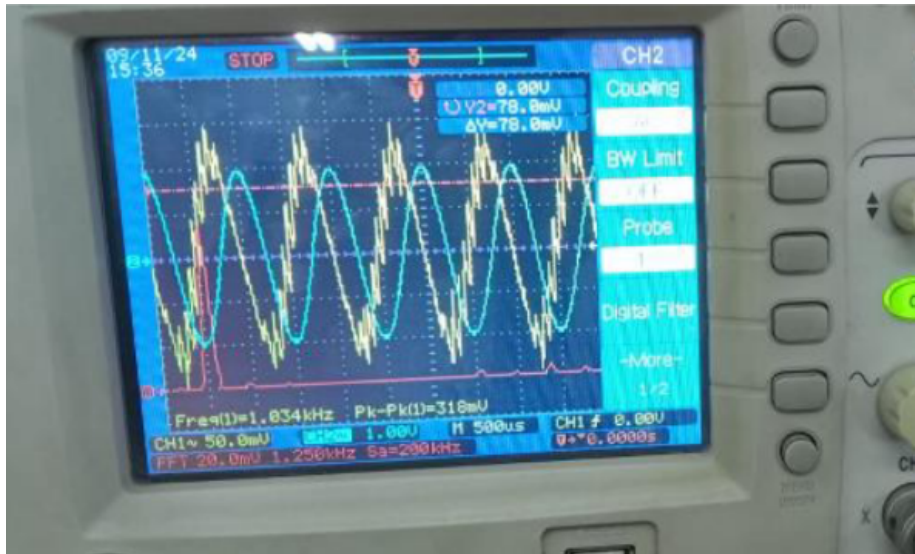

Figure 9: FM demodulated signal superimposed on top of the original signal

We can again see from DSO analysis that the output frequency of the demodulated waveform is 1.034 kHz(slightly bigger than 1kHz but acceptably small error), and that the FFT is also proper for this demodulated output

6 Discussion

6.1 Samyak Sheersh, 22EC30045

1. We observed that the frequency-modulated waveform is out of phase with the modulated input signal. We tune the potentiometer to adjust the output frequency and it provides the desired control voltage to the VCO for generating that frequency. As this bias level approaches $\frac{V_{dd}}{2}$, the phase of the output signal is reversed, and the amplitude goes through zero.

2. We used a steep High pass filter in the case of square signal to discriminate between the lower and higher frequencies of the signal and thus apply the comparator to result it back into a square signal with 1 representing the pass frequencies which are higher than the stopped frequencies which are lowered.

3. We used a differentiator in the sine wave signal because when we differentiate the signal, the term varying with time(which in our case is the message signal) comes out:

$$\frac{d}{dt} A \sin(\omega(t) \cdot t + \phi_0) = \omega(t)(A \sin(\omega(t) \cdot t + \phi_0)) \tag{7}$$

and thus this acts like an Amplitude modulator, on which we apply the Envelope detector to recover the signal back.