ANALOG TELECOMMUNICATION (FM)

Changing of the carrier signal frequency depending on the data signal is called frequency modulation (**FM**). When doing the frequency modulation, all of the carrier signal, data signal and the obtained modulated signal are sinusoidal signals.

As we already know, the carrier (Fc) signal has the highest frequency among the signals used in the telecommunication systems. Frequencies of the carrier signals used in our experiment set are kept as low as possible for easy follow up in the oscilloscope screen. Still, it is very difficult to see the variable signals in normal oscilloscopes. Therefore it is necessary that at least 2x40MHz double channel storage oscilloscope is used in these experiments.

EXPERIMENT: 3.1
EXAMINATION OF FREQUENCY MODULATION (FM)

PREPARATION DATA

If the signals in a frequency modulator are examined, the wave forms like in Figure 3.1.1 are seen. As we already know, all of the signals are sinusoidal.

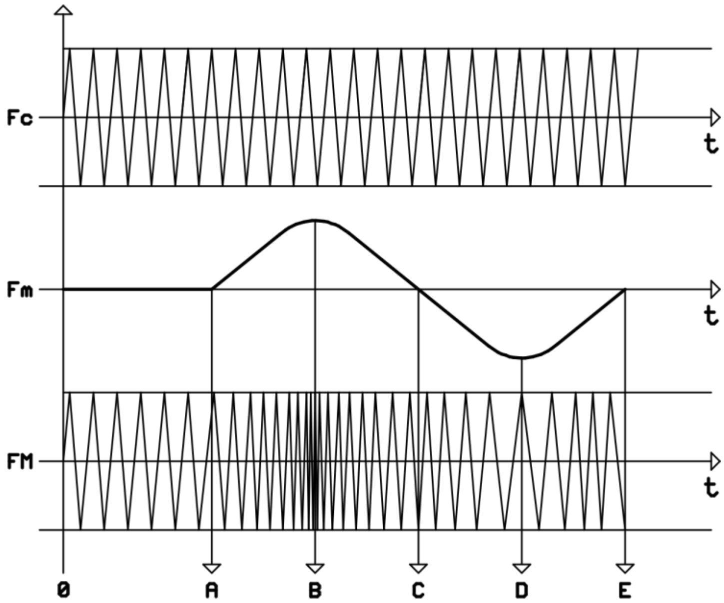


Figure 3.1.1

Carrier signal (**Fc**) amplitude and frequency are constant sinusoidal signals. Data signal (**Fm**) amplitude and frequency is sinusoidal signals that vary within the limits sensed by humans. Let us examine the modulated signal (Fm) on the time axial in certain intervals.

There is no data signal between the points **"0-A"**. The modulated signal is the same as the carrier signal until the point **"A"**.

The interval between the points **"A-B"** is the rising time of positive alternations of the data signal. Amplitude of the modulated signal is constant and its frequency increases depending on the data signal's amplitude. Point **"B"** is the point where the modulated signal frequency is higher than the carrier signal frequency.

The interval between the points **"B-C"** is the decreasing time of the positive alternations of the data signal. The amplitude of the modulated signal is constant and its frequency decreases depending on the data signal's amplitude. There is no data signal at point **"C"**. At this point, the modulated signal is the same as the carrier signal.

The interval between the points **"C-D"** is the time for increasing of data signal in a negative direction. Again, the amplitude of the modulated signal is constant, and its frequency decreases depending on the data signal's amplitude. The point **"D"** is the point where the frequency of the modulated signal is less than the carrier signal's frequency.

The interval between the points **"D-E"** is the time when the data signal decreases in a negative direction. Again, the amplitude of the modulated signal is constant and its frequency increases depending on the amplitude of the data signal. There is no data signal at the point **"E"**. At this point, the modulated signal is the same as the carrier signal.

In conclusion, the amplitude of the carrier signal is constant always. Frequency of the carrier signal at positive alternations of data signal increases depending on the amplitude of the data signal. This increase is maximum at the positive peak value of the data signal. Frequency of the carrier signal at the negative alternations of the data signal decreases depending on the data signal's amplitude. This decrease is maximum at the peak negative value of the data signal.

(**Fc**) frequency of the carrier signal is called the center frequency. Change of frequency by the data signal is called frequency deviation. Frequency deviation is shown with (ΔF). Frequency spectrum of the frequency modulated sign is shown in Figure 3.1.2.

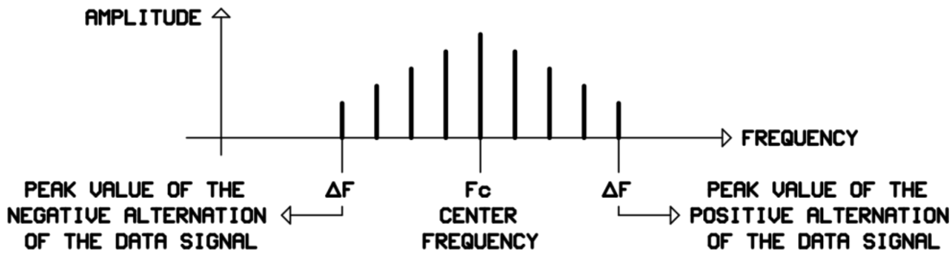


Figure 3.1.2

Numerous side bands are formed in the frequency modulation. Effectiveness of side bands depends on their amplitudes. Side bands whose amplitude is smaller than 1% of the carrier amplitude are not used. The frequency width of side bands that are used determine the band width of the frequency modulated sign. Band width is as a formula;

$BG = 2.(\Delta F + Fm)$'dir.

The band width (**88MHz–108MHz**) that is required in frequency modulated radio transmitters which broadcast music is 100KHz.

Frequency modulation is made by many methods. The essence of all methods is the change of an oscillator frequency by the data signal.

Some of the methods which do frequency modulation are as follows.

1-Capacitive microphone method
2- Variable capacitor diode method
3-Voltage controlled oscillator (VCO) method

Voltage controlled oscillator method is the most widely used method. In our experiment set, this method is examined.

CAPACITIVE MICROPHONE METHOD

This method explains how the frequency modulation is made in the easiest way. The characteristic of capacitive microphone is that is shows capacitor property at its output pins and it changes the capacity of this capacitor according to the sound waves coming to the microphone.

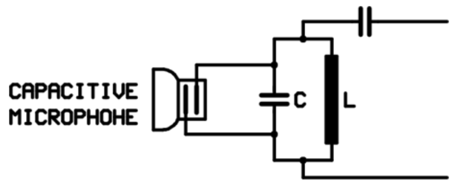


Figure 3.1.3

Figure 3.1.3 shows an oscillator tank circuit with an **"L"** inductor and **"C"** capacitor. Capacitive microphone is connected to the capacitor of tank circuit in a parallel fashion. Sound waves arriving the capacitive microphone change the capacity of the capacitive microphone. This capacity change in turn changes the total capacity of the tank circuit and therefore the oscillation frequency of the oscillator changes. The audio signals coming to the capacitive microphone are data signals. The change of oscillator frequency is directly proportional to the amplitude of the data signal.

VARIABLE CAPACITOR DIODE METHOD

Variable capacitor diodes are surface connecting silicon diodes. Variable capacitor diodes work under reverse polarization and show capacitor characteristic at its pins. The capacity shown by variable capacitor diodes is inversely proportional to the voltage applied to the capacity pins.

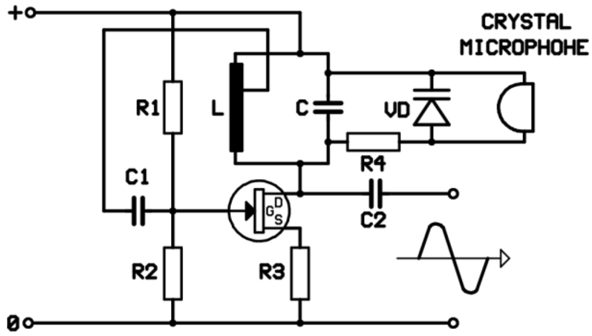


Figure 3.1.4

In Figure 3.1.4, variable capacitor diode (VD) and crystal microphone is connected as parallel to the serial Hartley oscillator's tank circuit capacitor. Variable capacitor diode is under reverse polarization. Sound waves coming to the crystal microphone generate an electric signal at the ends of the crystal microphone. This signal voltage is at the ends of variable capacitor diode therefore it changes variable capacitor diode's capacity. Changing of variable capacitor diode capacity changes the total capacity of tank circuit and accordingly the oscillation frequency of the oscillator changes. Sound waves are again data signals. Oscillator frequency change is again directly proportional to the amplitude of the data signal.

VOLTAGE CONTROLLED OSCILLATOR (VCO) METHOD

Voltage controlled oscillators are used frequently today because their assembly is easy and they have a few peripheral components. Voltage controlled oscillators are integrated circuits. There are voltage controlled oscillators whose output signals are square, triangle and sine at the same time. In Figure 3.1.5, a frequency modulator made by **VCO**=**V**OLTAGE **C**ONTROLLED **O**SCILLATOR is shown.

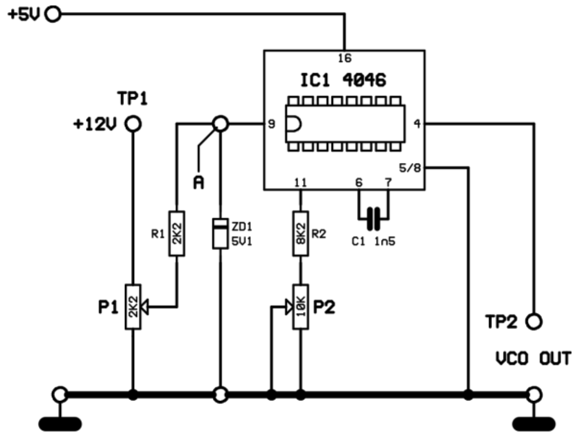


Figure 3.1.5

IC1=4046 integration consists of one VCO and two PHASE COMPARATORs. VCO section of 4046 and terminal connection of this section is shown in Figure 3.1.6

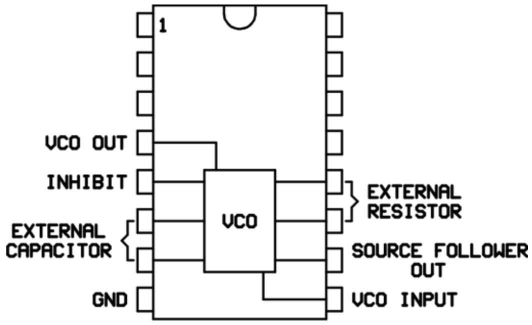


Figure 3.1.6

Output sign of the data signal 4046 applied to VCO input terminal is received from VCO output terminal. When there is no signal at VCO input terminal, a square wave signal is generated at VCO output terminal. This signal’s frequency is determined by the values of C1 capacitor, R2 resistor and P2 potentiometer. This signal is used as the carrier signal (Fc) of the frequency modulator. This signal’s frequency can be adjusted by P2 potentiometer in a certain interval. This adjusted frequency is called center frequency (F0). If a data signal (Fm) is applied to the circuit, the signal frequency at VCO’s output terminal at positive alternations of the data signal increases. This increase is directly proportional to the amplitude of the data signal. The frequency of the signal at VCO’s output terminal at negative alternations of the data signal decreases. This decrease is again directly proportional to the amplitude of the data signal.

EXPERIMENTAL PROCEDURE

Mount Y-0024/003 module to its place. Make the circuit connections as in Figure 3.1.7. Apply energy to the circuit.

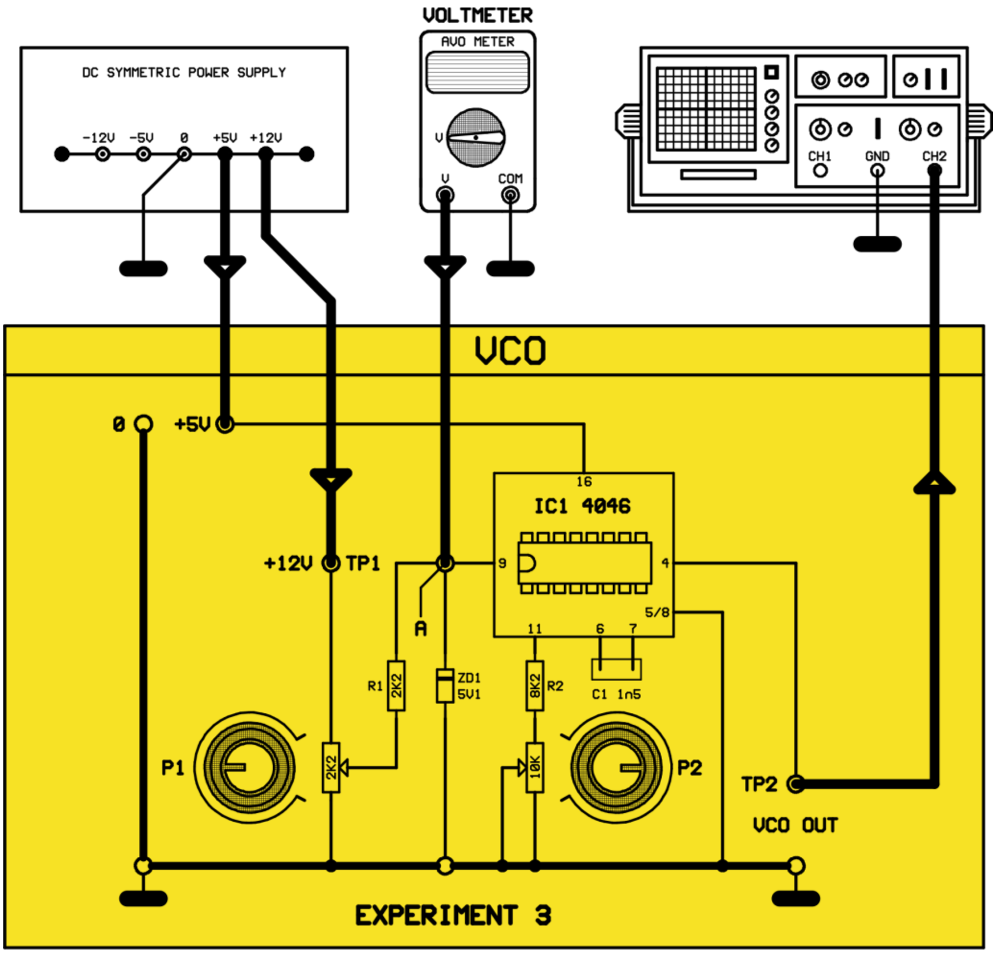
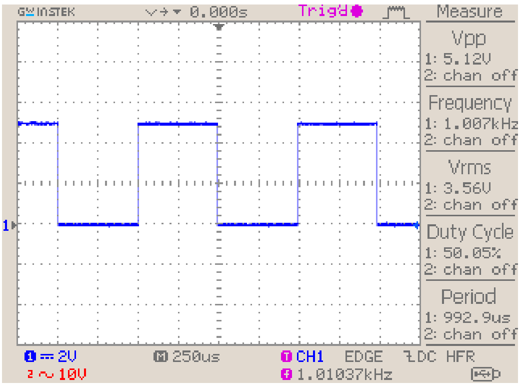


Figure 3.1.7

1. Adjust P1 potentiometer. See 1,5 Volts at TP1 A. Adjust the output sign’s frequency to 10KHz by P2 potentiometer.



2. Adjust the voltage at socket A to the values in Figure 3.1.8 by P1 potentiometer without distorting the position of P2 potentiometer and write down the output sign frequency at each step. Interpret the change in output sign.

A POINT (VOLT)	F(KHz)
1.5	10
2.0	17
2.5	25
3.0	33
3.5	40
4.0	47
4.5	54

Figure 3.1.8

Amplitude of the output sign is constant at each step. Its frequency changes directly proportional to the voltage at VCO input.

3. Adjust the voltage at socket A by P1 potentiometer to the values in Figure 3.1.9 and adjust the middle terminal of P2 potentiometer to the bottom first and then to the top. Write down frequency values at each step.

A POINT (VOLT)	F_{MIN}(KHz)	F_{MAX}(KHz)
1.5	8	15
2.0	14	25
2.5	20	37
3.0	25	48
3.5	31	58
4.0	37	68
4.5	42	78

Figure 3.1.9

EXPERIMENT: 3.2
EXAMINATION OF FREQUENCY MODULATION MADE BY VCO (VOLTAGE CONTROLLED OSCILLATOR)

PREPARATORY INFORMATION

A frequency modulator made by VCO=VOLTAGE CONTROLLED OSCILLATOR is shown in Figure 2.4.1.

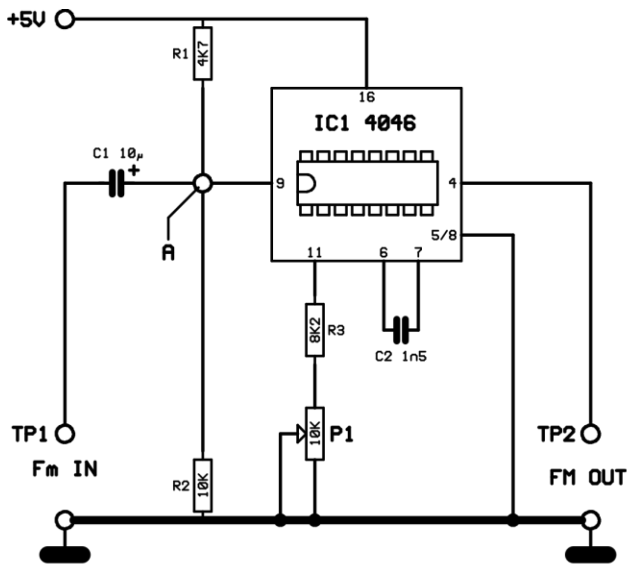


Figure 2.4.1

The output sign of the data signal 4046 applied to VCO input terminal is received from VCO output terminal. When there is no signal at VCO input terminal, a square wave signal whose frequency is determined by the values of C1 capacitor, R3 resistor and P1 potentiometer is generated at VCO output terminal. The frequency of this signal is called "free operation frequency". This signal is used as the carrier signal (Fc) of the frequency modulator. The frequency of this signal can be adjusted by P1 potentiometer in a certain interval. This adjusted frequency is called center frequency (F0). If a data signal (Fm) is applied to the circuit, the frequency of the signal at the output terminal of VCO at the positive alternations of the data signal increases. This increase is directly proportional to the amplitude of the data signal. The frequency of the signal at the output terminal of VCO at the negative alternations of the data signal decreases. This decrease is directly proportional to the amplitude of the data signal again.

EXPERIMENTAL PROCEDURE

Plug Y-0024/003 module. Make the circuit connections as in Figure 3.2.2. Apply energy to the circuit.

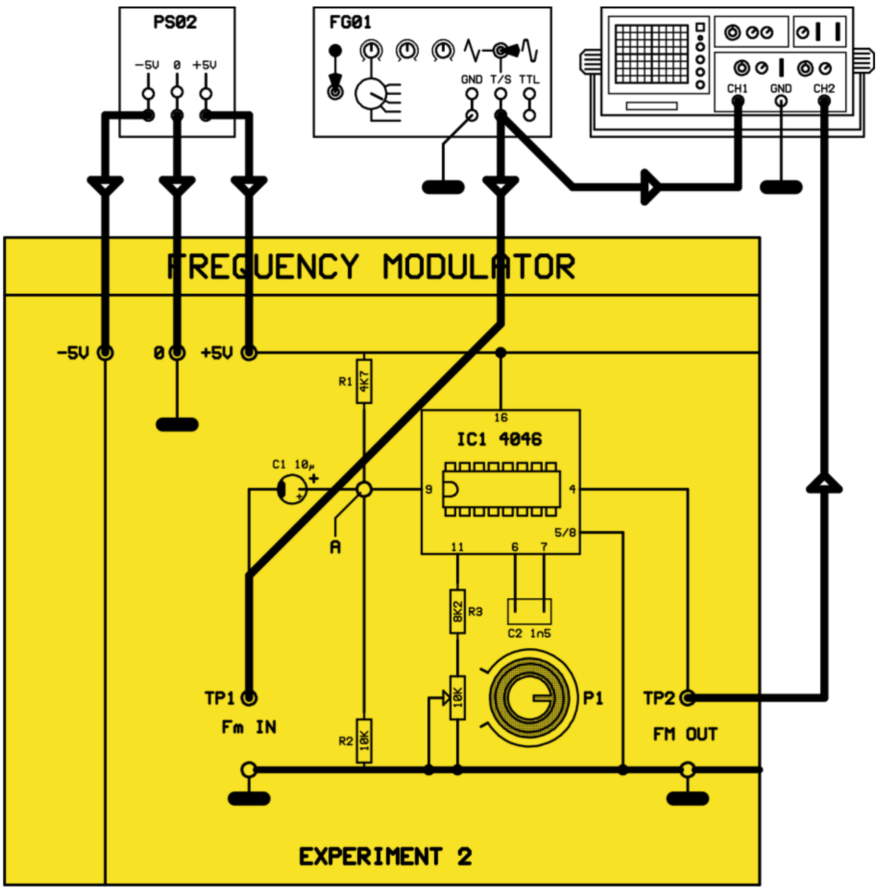
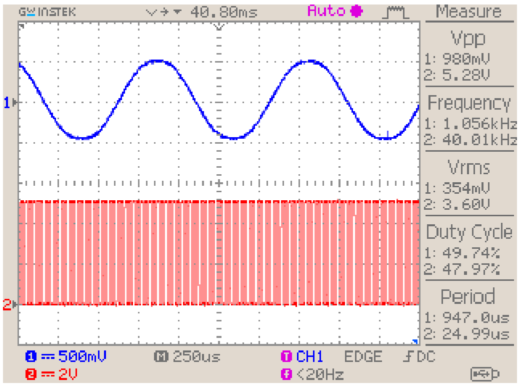
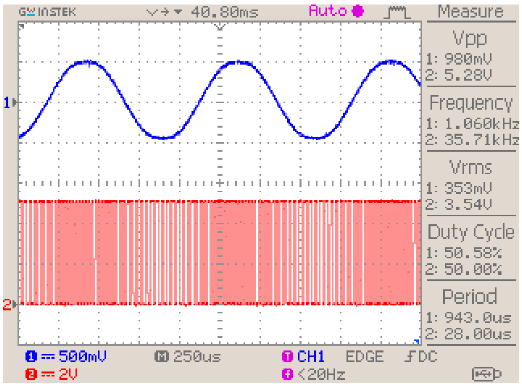


Figure 3.2.2

1. Adjust the function generator's output sign to a sine, its frequency Fm=400Hz and its amplitude 1Vpp. Separate the signal input from Fm IN (TP1) socket. Connect CH2 channel to Fm OUT (TP2) socket. At this moment, adjust P1 potentiometer until you see 40KHz at Fm OUT (TP2) socket and see the shapes of the two signs.



2. Connect the output of function generator to Fm IN (TP1) socket. See the shapes of the two signs and interpret them.



A frequency modulated sign (FM) is generated at Fm OUT (TP2) socket which is the modulator output. The frequency increased at the positive alternations of FM sign and the frequency decreased at the negative alternations.

EXPERIMENT: 3.3
EXAMINATION OF PLL (PHASE LOCKED LOOP) SHIFT

PREPARATORY INFORMATION

Amplitude is constant in a frequency modulated sign and frequency shifts based on the data signal. Frequency demodulators are circuits changing the frequency shift of the sign at the input to a linear voltage shift. Two methods are used for frequency demodulation. These are;

1- Discriminatory method
2- Phase locked loop method

DISCRIMINATORY METHOD

These are circuits where a frequency modulated sign is changed to an amplitude modulated sign and then a data sign is obtained again by passing it through a diode or transistor amplitude demodulator.

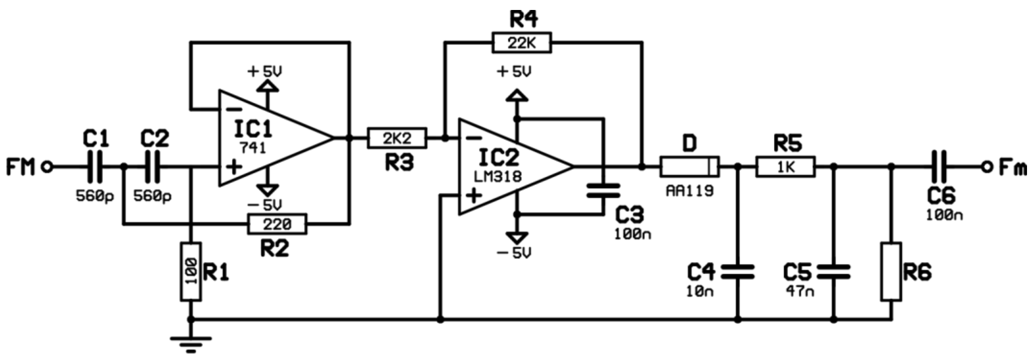


Figure 3.3.1

In Figure 3.3.1, IC1, C1, C2 and R2 are derivative receiver circuits. If the frequency modulated sign’s derivation is taken, it turns to an amplitude modulated sign. IC2, R3 and R4 are inverting amplifier circuits. Amplitude of the amplitude modulated sign at the output of the inverting amplifier is obtained as increased. D, R5, R6, C4 and C5 are diode amplitude demodulators. The positive envelope of the amplitude modulated sign is perceived and the data signal is obtained here again. C6 capacitor is used to zero DC offset voltage. Discriminatory method is not used frequently.

PLL=PHASE LOCKED LOOP METHOD

Phase locked loop circuit is basically a feedback circuit. Feedback circuits apply a section of the output sign to the input again and constantly control the system operation. Three basic circuits are necessary for phase locked loop. These are;

1- PHASE COMPARATOR
2-VCO=VOLTAGE CONTROLLED OSCILLATOR
3-LPF=LOW PASS FILTER

Operation of phase locked loop can be understood by the simple block diagram shown in Figure 3.3.2.

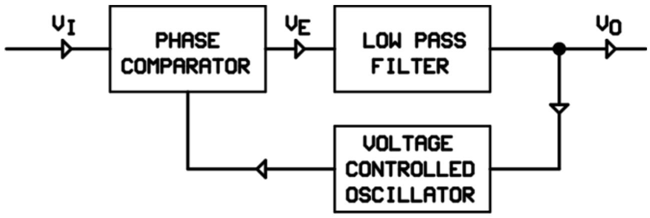


Figure 3.3.2

Voltage controlled oscillator produces a square wave signal with a frequency determined by peripheral components when there is no signal at the input terminal. This frequency value is called free operation frequency or center frequency (Fo). This signal is applied to the phase comparator. When a signal is applied to the input terminal, the phase comparator compares these two signals and a third signal made of a pulse series is obtained. This signal is called ERROR signal. The signal applied to the comparator determines the phase and frequency of the error signal. The error signal has direct voltage characteristics. The error signal is shown by VE. The error signal goes through the low pass filter and then applied to VCO input.

If the frequency of the input signal decreases, the error voltage forces to reduce the frequency of the voltage controlled oscillator. When the frequency of the voltage controlled oscillator approximates sufficiently to the frequency of the input signal, a phase locked shift occurs. The frequencies of the two signs become equal at this instant. The time passing for locking at the operation moment is very short.

If the frequency of the input signal increases, the error voltage forces to increase the frequency of the voltage controlled oscillator. When the frequency of the voltage controlled oscillator approximates the frequency of the input signal, again a phase locked loop occurs.

The frequency band where the phase locked loop is generated is examined in two situations.

1st situation is the determination of the frequency band where the locking is distorted as a result of the decrease or increase of the input signal frequency when there is a phase lock. This band is called "lock-out frequency band".

2nd situation is the determination of the band between the smallest frequency and the greatest frequency where the 1st situation phase lock starts. This band is called "lock frequency band".

These tow frequency bands in PLL circuits are different from each other. This difference is shown in Figure 3.3.3.

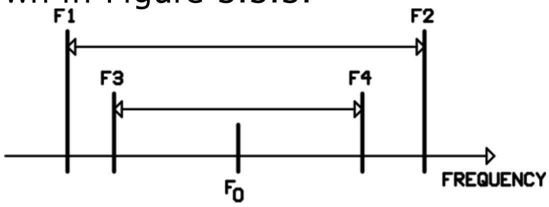


Figure 3.3.3

Between F1-F2= Lock-out frequency band
Between F3-F4= Lock frequency band

Lock-out frequency band is greater than lock frequency band in PLL circuits generally.

If the frequency of the sign at the inputs of PLL circuits is changed in the scope of the lock band, a voltage is obtained with the amplitude directly proportional to the input sign frequency at the output terminals. In other words, PLL circuit works like a frequency/voltage converter at this frequency interval. This characteristic ensures the PLL circuits to be used as a frequency demodulator. The experiment scheme in our set is shown in Figure 3.3.4.

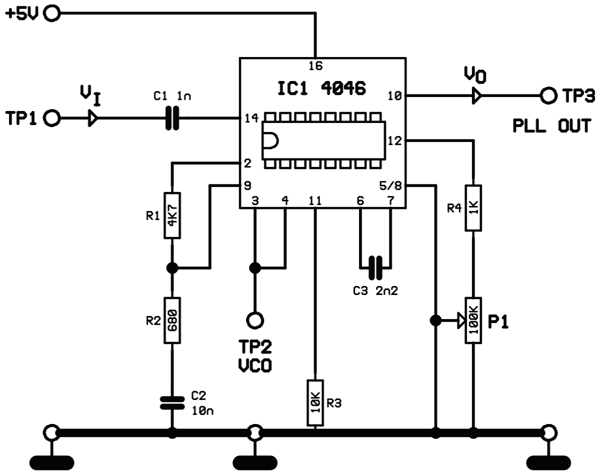


Figure 3.3.4

IC1=4046 integration consists of two phase comparators and one voltage controlled oscillator. The terminal connection and inner structure of 4046 integration is shown in Figure 3.3.5

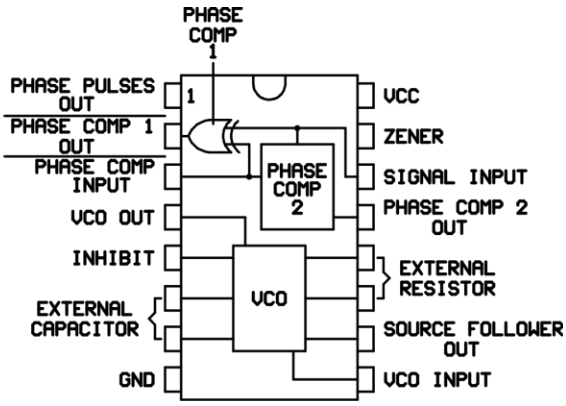


Figure 3.3.5

EXPERIMENTAL PROCEDURE

Plug Y-0048/009 module. Make the circuit connections as in Figure 3.3.6. Give energy to the circuit. Adjust the amplitude of the square wave output sign of the function generator to +5Volts.

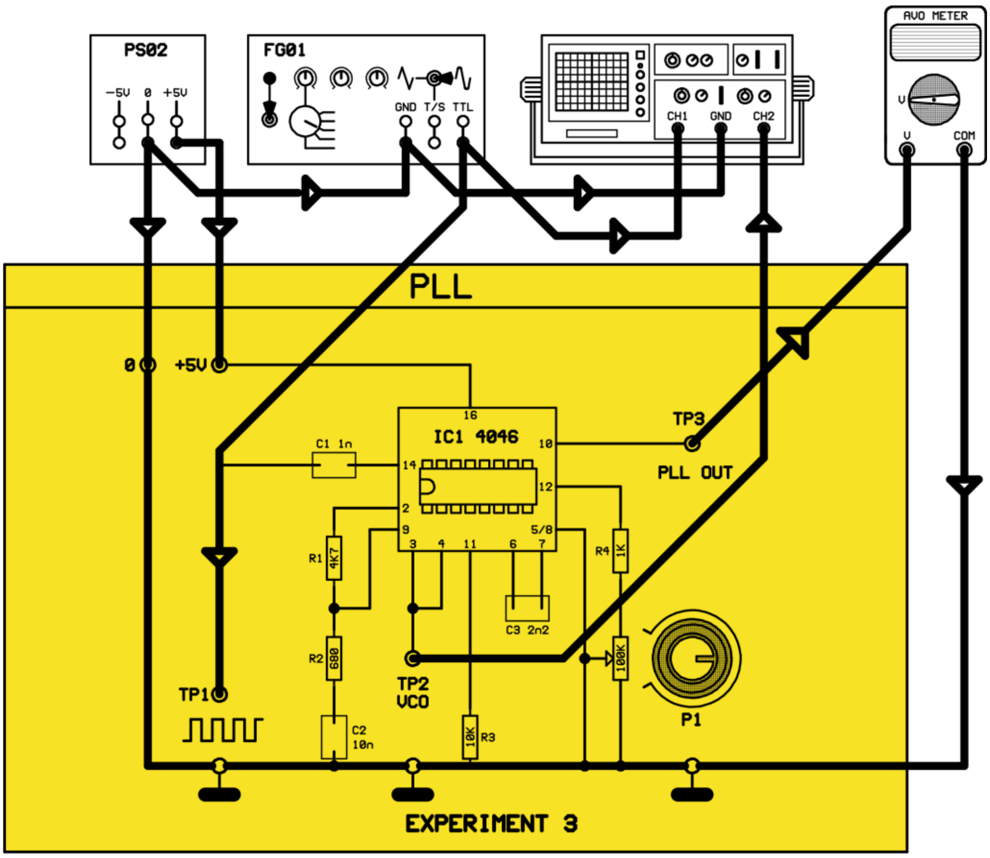


Figure 3.3.6

1. Adjust the output frequency of the function generator to 40KHz.

2. Bring the input sign and VCO sign to the phase shown in Figure 3.3.7 by P1 potentiometer in order to see all signs and values easily.

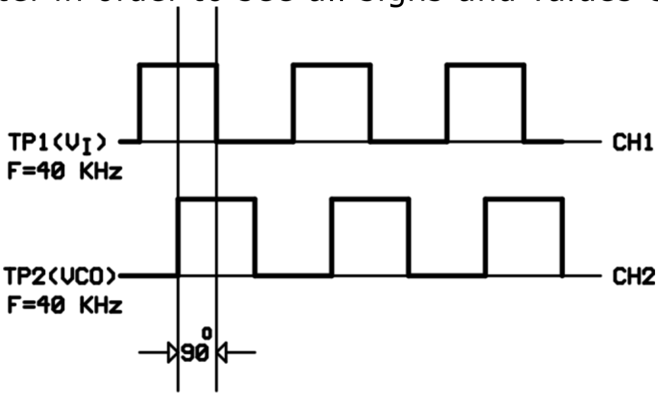
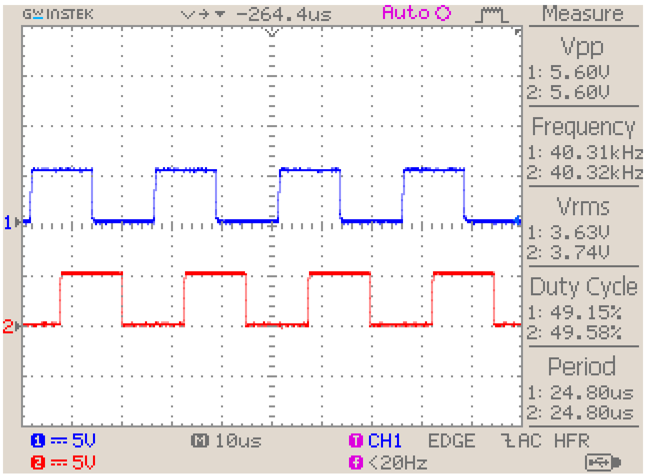


Figure 3.3.7



Note: Don't disarrange the position of P1 potentiometer until the experiment is completed.

3. Decrease the output sign of the function generator gradually and write down the frequency value (F1) where locking is distorted.

Approximately F1=20KHz

4. Increase the output sign of the function generator gradually and write down the frequency value (F2) where locking is distorted.

Approximately F2=60KHz

5. What is the band called between F1 and F2 frequencies?

This band is called "lock-out frequency band" of PLL.

6. Gradually increase the frequency of the output sign of the function generator. Write down the value of the frequency (F3) where locking occurred.

Approximately F3=20KHz

7. Gradually decrease the output sign frequency of the function generator starting at 100KHz. Write down the frequency value (F4) where locking occurred.

Approximately F4=50KHz

8. What is the band between F3 and F4 frequencies called?

This band is called "lock frequency band" of PLL.

9. Show lock-out and lock frequency bands on the frequency axis.

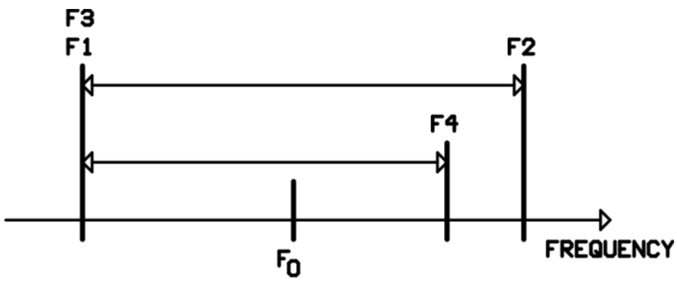


Figure 3.3.8

Between F1-F2= Lock-out frequency band
Between F3-F4= Lock frequency band

10. Bring the output frequency of the function generator in turn to the frequencies in the table in Figure 3.3.9. Write down the voltage value at each step at PLL output.

F_{F0} (KHz)	PLL OUT (VOLT)
25	0.9
30	1.3
35	1.7
40	2.1
45	2.4
50	2.8
55	3.0

Figure 3.3.9

EXPERIMENT: 3.4
EXAMINATION OF FM (FM DEMODULATION)

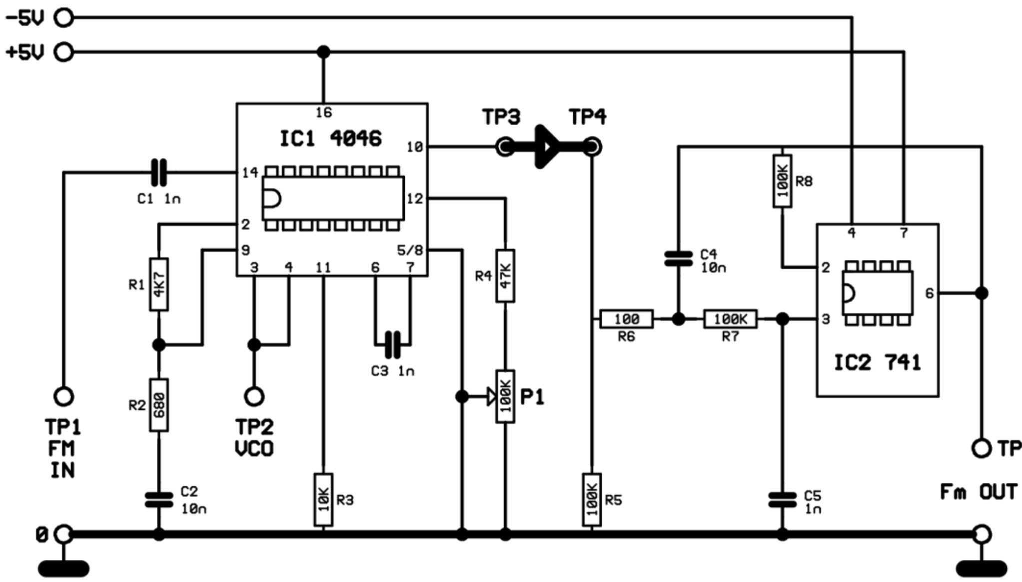


Figure 3.4.1

A frequency demodulator circuit most frequently used today is shown in Figure 3.4.1. The circuit should be examined in two sections.

1. Section is a frequency demodulator operating with PLL method. This section consists of 4046 integration and peripheral components. When a frequency modulated sign is applied to the input terminal (TP1), P1 potentiometer is adjusted and an Fm (message-data) sign without distortion or with the least distortion is obtained at PLL output terminal (TP3). In this case, the sign at the input terminal and the sign at VCO terminal (TP2) are the same.

2. Section is an LPF=LOW PASS FILTER working actively. Fm sign applied to LPF input terminal (TP3) is sorted from spurious and an Fm without distortion is obtained at the output terminal (TP5). This section consists of 741 integration and peripheral components.

741-integration is one of the most frequently used operational amplifiers.

Terminal connection of 741 and its symbol used in electronic circuit schemes are shown in Figure 3.4.2.

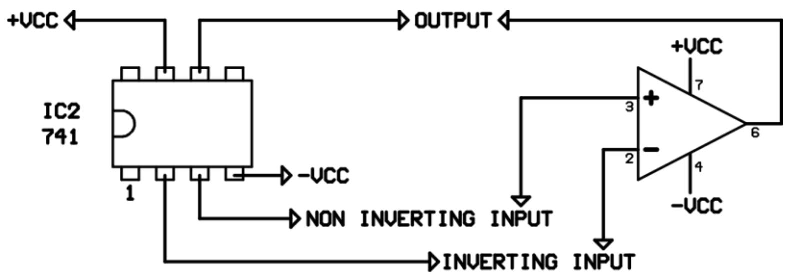


Figure 3.4.2

EXPERIMENTAL PROCEDURE

Plug Y-0024/003 module. Make the circuit connections as shown in Figure 3.4.3. Give energy to the circuit.

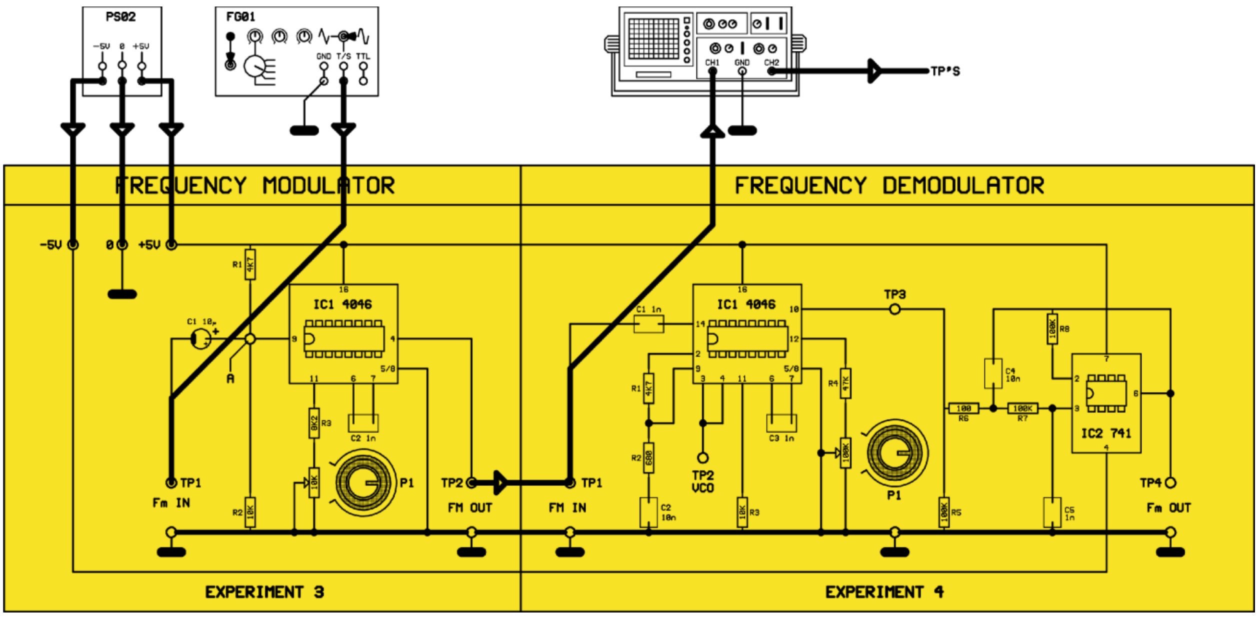
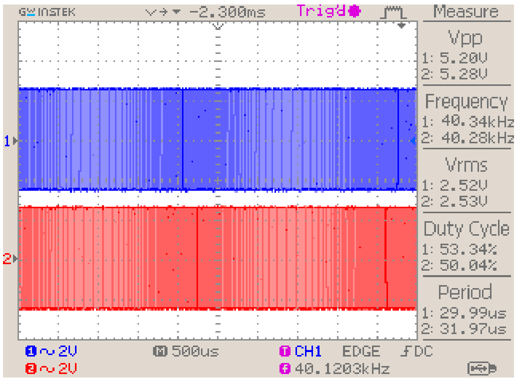
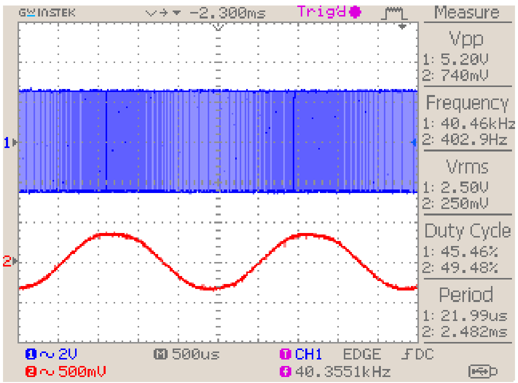


Figure 3.4.3

1. Connect CH1 channel of oscilloscope to the socket (TP1) . Connect CH2 channel to (TP2) socket of VCO.

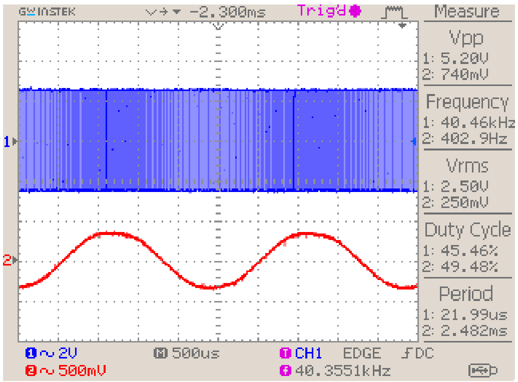


2. Connect the output of the function generator to Fm IN (TP1) socket, see the shapes of the two signs and interpret them.



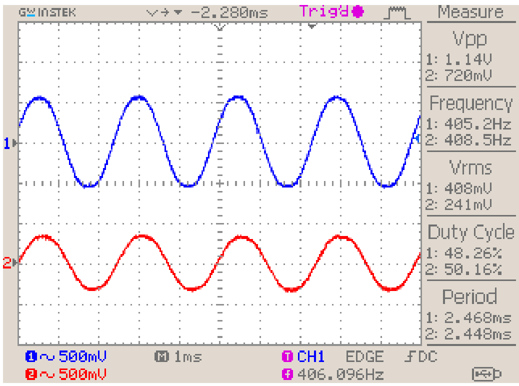
A frequency modulated sign (FM) is generated at FM OUT (TP2) socket which is the modulator output. The frequency increased at the positive alternations of FM sign and the frequency decreased at the negative alternations.

3. Connect CH1 channel of oscilloscope to the socket of FM demodulator (TP1). Adjust until you see a sine at (TP4) socket of the demodulator by P1 potentiometer. Explain the process.



The input sign of PLL circuit is locked to its frequency by the adjustment of P1 potentiometer at the demodulator.

4. Connect CH1 channel of oscilloscope to (TP1) socket and CH2 to (TP4). See the two sign simultaneously and interpret them.



The data sign is obtained again at Fm OUT (TP4) socket of the demodulator. The amplitude of the obtained signal decreased somewhat. This signal can be increased by a voice amplifier if necessary.