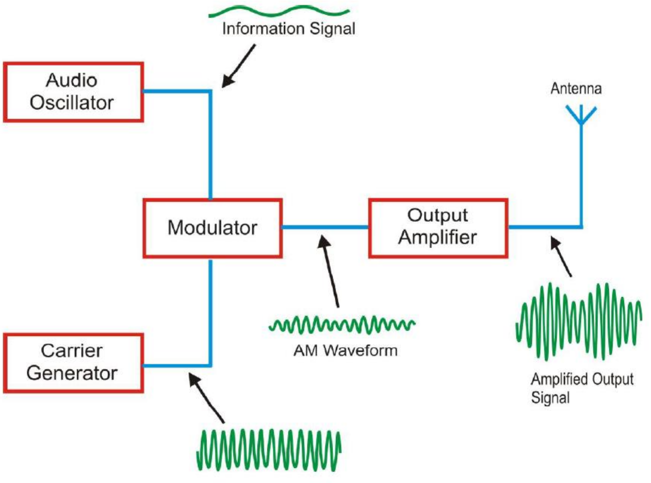
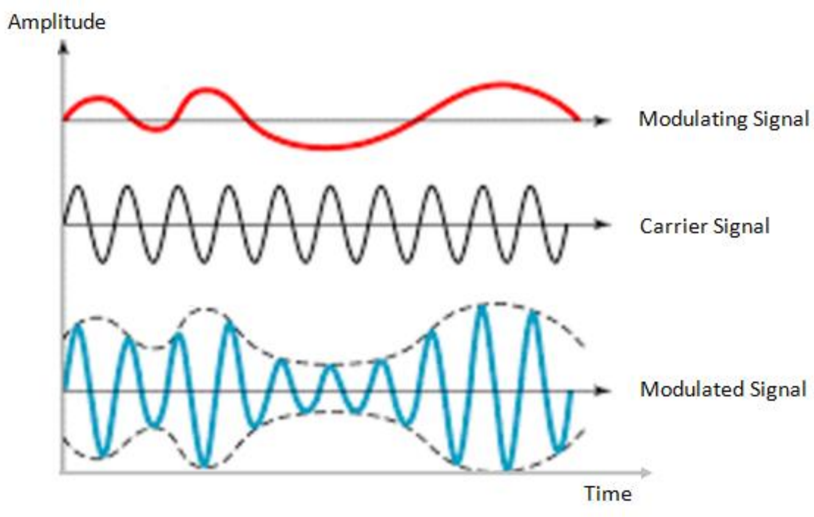
AM -TRANSMITTER

Introduction

The amplitude-modulated (AM) transmitter produces an electromagnetic carrier wave whose amplitude is modulated (varied at an audio rate), and which travels through the other to a radio receiver. The transmitter contains a stable RF oscillator, usually crystal controlled; an audio amplifier; a modulator; RF amplifiers; and a connection to an antenna, whose length is determined by the frequency of transmission.



AM Transmitter System



Procedures:

AM-TX -DSB

1- First, try to find the blocks from fig.1 on the circuit diagram.

2- At Tp11, increase the input signal level (modulation level VR1) so that the valley of the AM wave starts to form a straight line at the output.

3- Draw & measure amplitude for the waveforms at TP1, TP4.

4- At Tp11 draw & measure antenna frequency& modulation index by using $M = \frac{[e(\max) - e(\min)]}{[e(\max) + e(\min)]}$.

5- Connect the (channel 1) of the oscilloscope's audio signal and connect (channel 2) of the oscilloscope's to TP11, set the oscilloscope to operate in X-Y mode, Draw the trapezoid pattern

6- Adjust both the oscilloscope's vertical and horizontal gains to obtain a trapezoid pattern of (m=0, m= 0.1, m= 0.3, m=0.5, m=1, m>1), draw the pattern for each state.

7- Change the audio modulating signal to obtain over modulation, Draw the signal and measure the value of input signal.

8- To get on double sideband suppressed carrier (DSB-SC) rotate the (VR2) to either right or left with make the peaks of equal amplitude, draw the trapezoidal pattern of (DSB-SC) and draw the signal of AM-DSB-SC at Tp11

Report

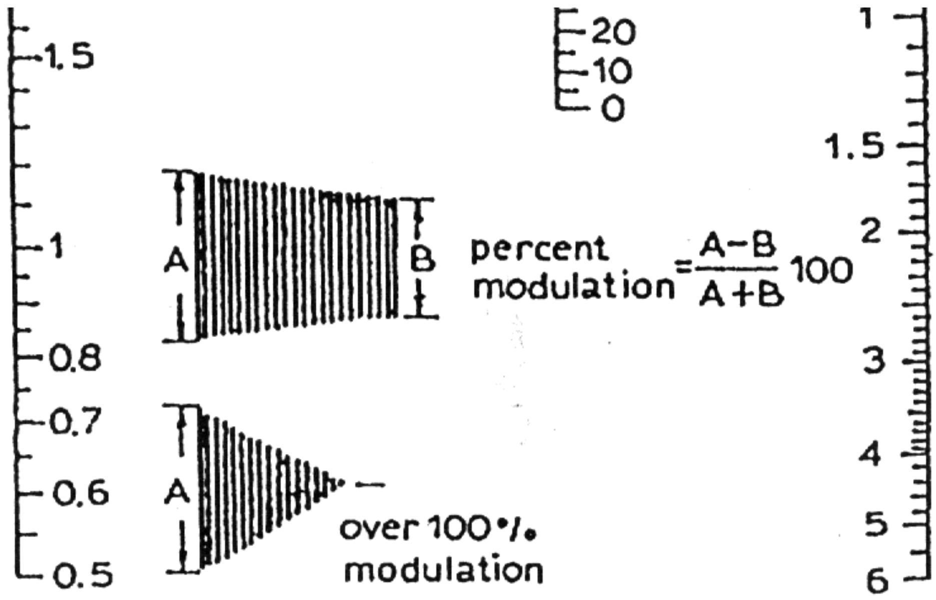
1- What is the meaning by modulation?

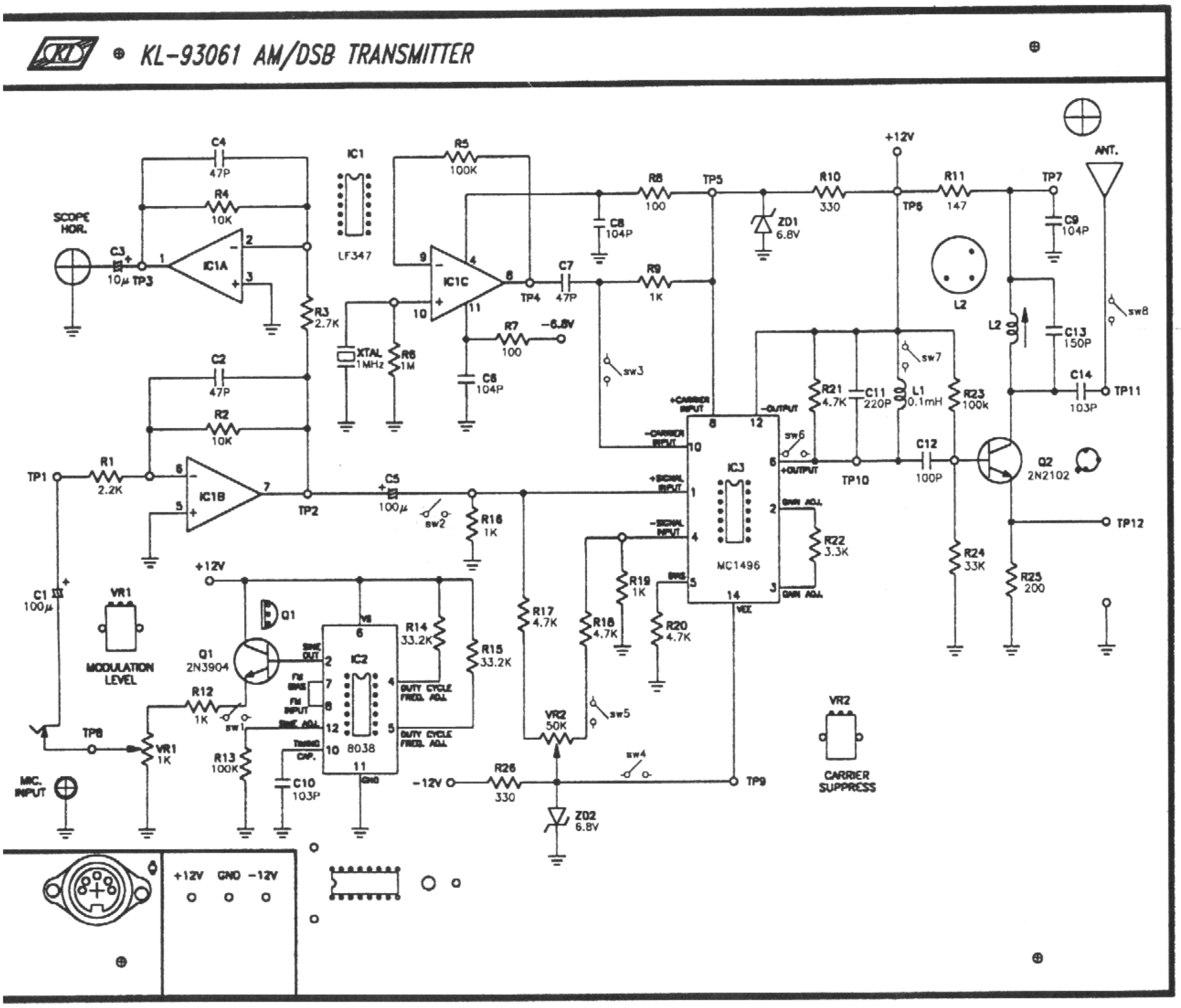
2- On what dependent the frequency of the antenna of AM-TX? Why?

3- What is the Effect of over-modulation on the information signal? How do you avoid the over- modulation?

4- From run 6, if the total power transmitted from AM-TX (DSB) is 5mw, calculate transmitted power in the carrier, upper sideband and the lower sideband for (m= 0, 0.1, 0.3, 0.5, 1). Explain effect the modulation index on the power transmitted in the carrier and sidebands?

5- Compare between the power transmitted in the (DSB-SC) and (DSB) if modulation index m=1.




KL-93061 AM/DSB TRANSMITTER
SCOPE HOR.
C3 10μ TP3
C4 47P
R4 10K
IC1A
IC1 LF347
R5 100K
IC1C
TP4
C7 47P
R8 100
TP5
C8 104P
R9 1K
R3 2.7K
XTAL 1MHz
R6 1M
R7 100
-6.8V
C6 104P
ZD1 6.8V
R10 330
+12V
TP6
R11 147
TP7
C9 104P
ANT.
sw8
L2
C13 150P
C14 103P
TP11
sw7
L1 0.1mH
R21 4.7K
C11 220P
R23 100k
sw3
C2 47P
R2 10K
TP1
R1 2.2K
IC1B
TP2
C5 100μ
sw2
R16 1K
+CARRIER INPUT
-CARRIER INPUT
+SIGNAL INPUT
-SIGNAL INPUT
-OUTPUT
+OUTPUT
GAIN ADJ.
BIAS
VEE
IC3
MC1496
sw6
TP10
C12 100P
Q2 2N2102
TP12
R22 3.3K
R24 33K
R25 200
R19 1K
R17 4.7K
R18 4.7K
R20 4.7K
C1 100μ
VR1
MODULATION LEVEL
+12V
Q1
Q1 2N3904
R12 1K
sw1
TP8
VR1 1K
R13 100K
MIC. INPUT
IC2
8038
SINE OUT
FM BIAS
FM INPUT
SINE ADJ.
TIMING CAP.
DUTY CYCLE FREQ. ADJ.
R14 33.2K
R15 33.2K
C10 103P
VR2 50K
sw5
sw4
-12V
R26 330
TP9
ZD2 6.8V
VR2
CARRIER SUPPRESS
+12V GND -12V

Amplitude modulation
"Super heterodyne receiver"

Introduction:

The AM super-heterodyne receiver convert incoming AM-signal to a lower frequency that known as the intermediate frequency (IF=455 KHz). The AM super-heterodyne receiver can best have understood by analysis of the block diagram shown in Figure 1.

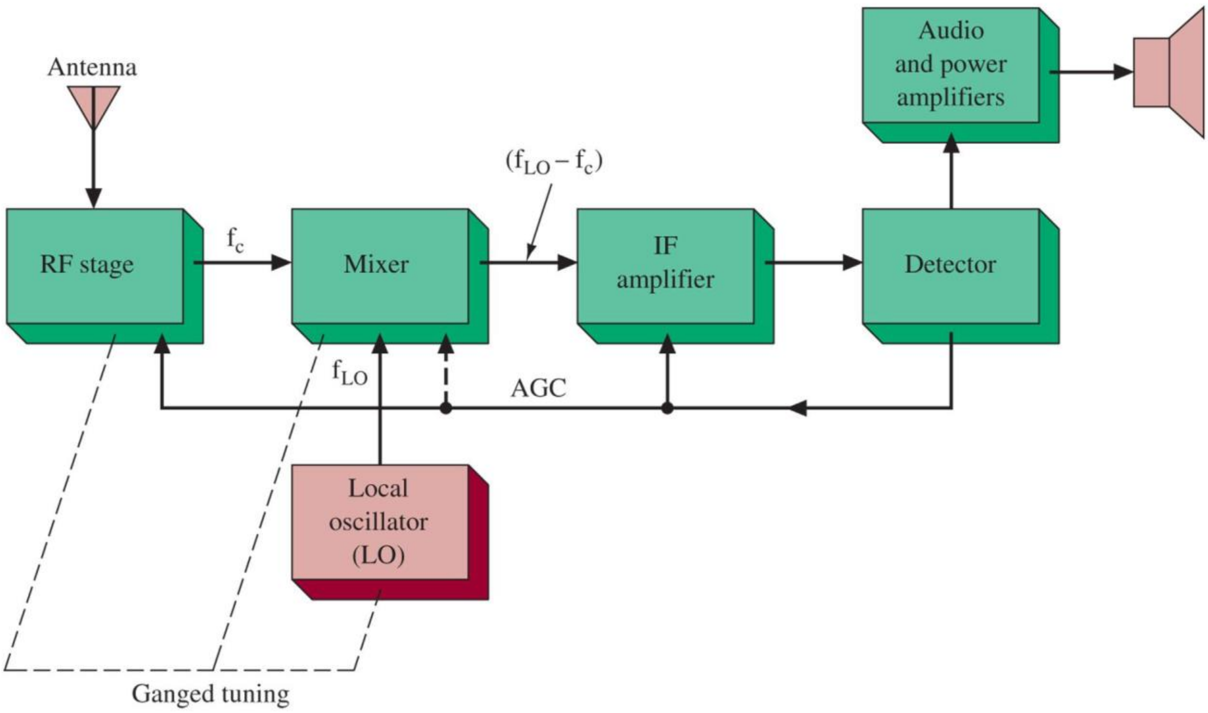


Figure (1) super-heterodyne receiver

Antenna. When the radio wave passes through the antenna, it induces a small voltage across the antenna coil.

A parallel tuned circuit has its greatest impedance at resonance and decreases at higher and lower frequencies. If the tuned circuit is included in the circuit design of an amplifier, it results in an amplifier which offers more gain at the frequency of resonance and reduced amplification above and below this frequency. This is called Selectivity. Center frequency of tuned circuit at front end of IF Amplifier is always constant (455 KHz). Center frequency of tuned circuit at front end of Mixer is adjusted to select incoming radio station. Local frequency tracks tuned frequency to keep a constant difference of 455 KHz.

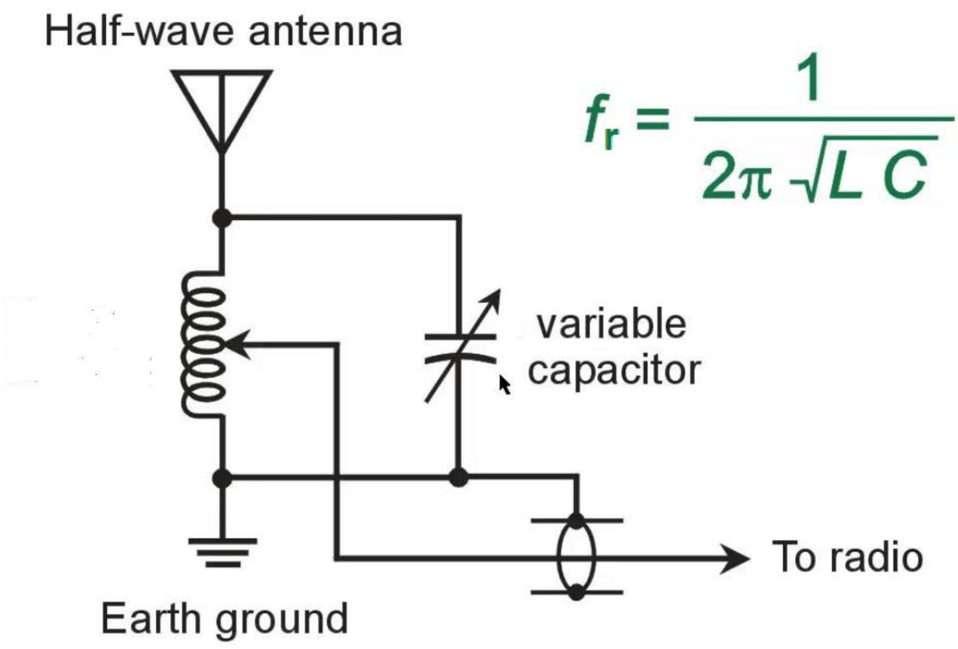


Figure (2) Tuned circuit with antenna.

Mixer and oscillator The operation of the mixer is basically to shift the wanted signal down to the IF frequency, irrespective of the position of the tuning dial. This is achieved in two stages mixer and oscillator The voltage is coupled from antenna to the mixer, or converter, stage to be changed to a frequency of 455 kHz. This change is accomplished by mixing the radio frequency signal with the oscillator signal. By mixing the local oscillator's signal (sine wave) with R.F signal (output of tuned circuit). This produces three frequency components:

f_{local} =The local oscillator frequency

f_{RF}= Radio frequency that received by antenna

IF=intermediate frequency=455 KHz for AM receiver

$f_{local} = f_{RF} + IF$

$f_{sum} = (f_{local} + f_{RF})$

$f_{diff} = (f_{local} - f_{RF}) = IF$

After mixer and oscillator stage completed one signal of the output of mixer selected. By strongly attenuating all components except the difference frequency, IF this is done by putting a narrow-bandwidth band pass filter on the mixer's output. The end result of this process is that the carrier frequency of the selected AM Station is shifted down to 455 KHz (the IF Frequency), and the sidebands of the AM signal are now either side of 455 KHz. The example in the following figure (3) block diagram explain proses convert the radio frequency for AM signal to intermediate frequency

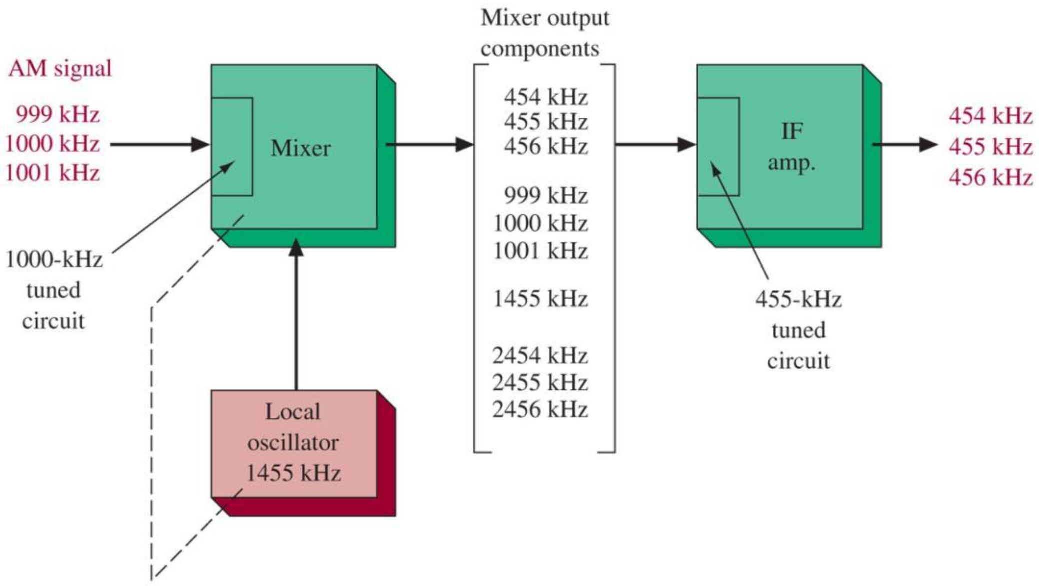


Figure (3) Frequency conversion process

First IF amplifier, which has a variable gain that depends on the AGC voltage, received from the AGC stage. The first IF amplifier is also tuned to 455 kHz and has a 3dB bandwidth of approximately 6 kHz.

AGC (automatic gain control) circuit is feeds back a DC voltage to the first IF amplifier in order to maintain a near constant level of audio at the detector.

Second IF amplifier. The second IF amplifier is tuned to 455 kHz and has a fixed gain. The 3dB bandwidth of this stage should be approximately 6 kHz.

Detector circuit The detector converts the amplitude modulated IF (intermediate frequency) signal to a low-level audio signal as explain in the following figure (4).

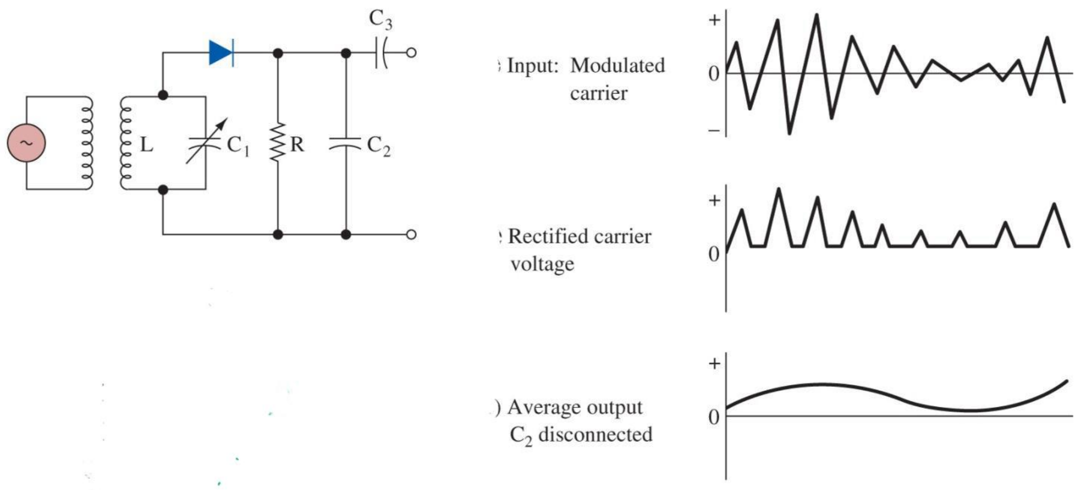


Figure (4) tuned circuit and diode detector (envelope detector).

Audio Amplifier Stage, is to increase the power of the audio signal received from the detector to a power level capable of driving the speaker.

Each of these blocks will be explained in detail in the Theory of Operation given before the assembly instructions for that stage.

Procedures:

1- Set the AM signal generator to 1MHz carrier signal, 1 KHz modulated signal (message signal), 60% modulation index and maximum power, set switch (SW) into detector mode.

2- Adjust the tuning for the receiver to 1MHz; you must hear the 1 KHz tone on the speaker.

3- Draw the waveform at output of R.F. amplifier, then measure the frequency of this signal.

4- Draw the waveform at output of local oscillator, then measure the frequency of this signal.

5- What are the frequencies present at the mixer? Draw the output.

6- Draw the waveform at I.F. amplifier first stage, then measure the frequency of this signal.

7- Draw the waveform at I.F. amplifier second stage, then measure the frequency of this signal.

8- Draw the waveform at diode detector, then measure the frequency of this signal

9- Draw the audio signal, then measure the frequency.

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Report:

1- What is purpose of using super-heterodyne receiver?

2- What is the function of tuned circuit? Draw the its circuit

3- Identify and sketch the detector circuit used in AM super-heterodyne receiver board?

4- Explain convertor proses RF received signal into intermediate frequency signals

5- For the figure (2), if AM signal with carrier frequency is 1600 KHz and the message signal with 3.4 KHz. Calculated the local oscillator frequency and all frequency components output of the mixer if the intermediate frequency is 455 KHz.

6- Explain can we use the super-hytrodyne receiver to detection the message signal from amplitude modulation double sideband suppressed carrier (AM-DSB/SC). why?

Frequency Modulation

Introduction:

Angle modulation includes frequency modulation (FM) and phase modulation (PM). FM and PM are interrelated; one cannot change without the other changing. As figure (6-1) illustrates, when the message signal amplitude is zero, there is no change in the FM carrier frequency; the carrier is at its center frequency which is the unmodulated carrier frequency. The positive or negative change in the carrier frequency from its center frequency is called frequency deviation.

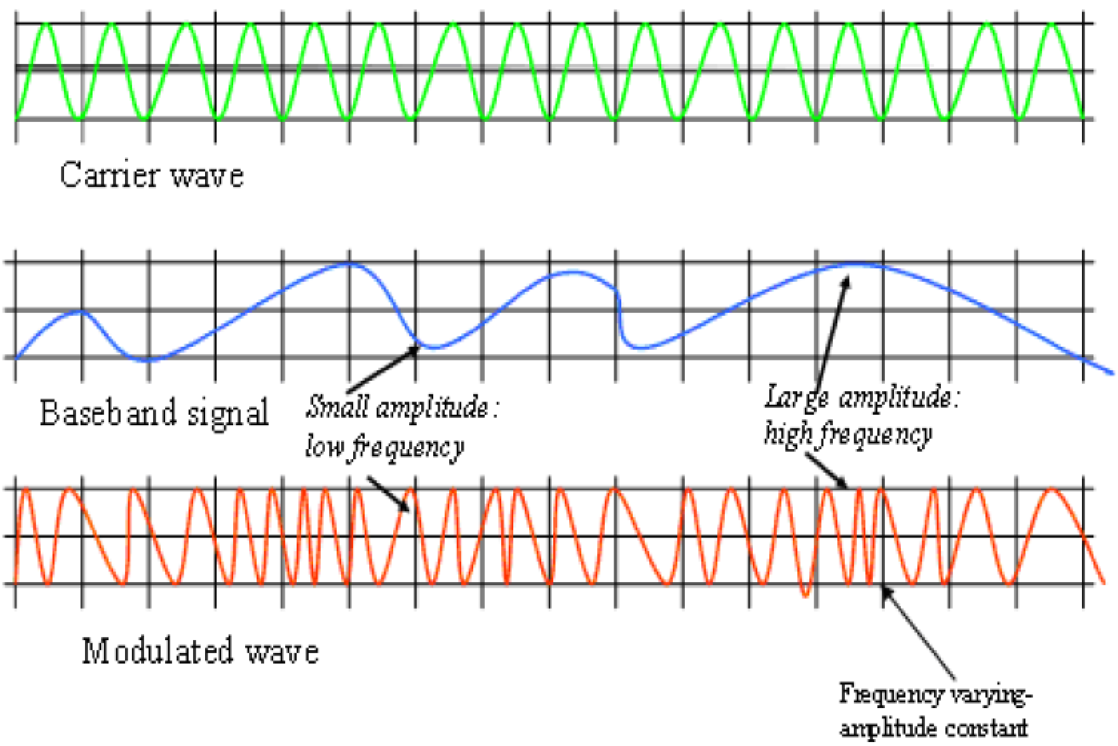


Figure (1)-massage, carrier and FM signals.

In FM the frequency deviation (Δf) of a sine wave carrier deviates from its center frequency by an amount that is proportional to the message signal amplitude figure (2). and the message signal frequency does not affect the magnitude of the (Δf) carrier frequency deviations.

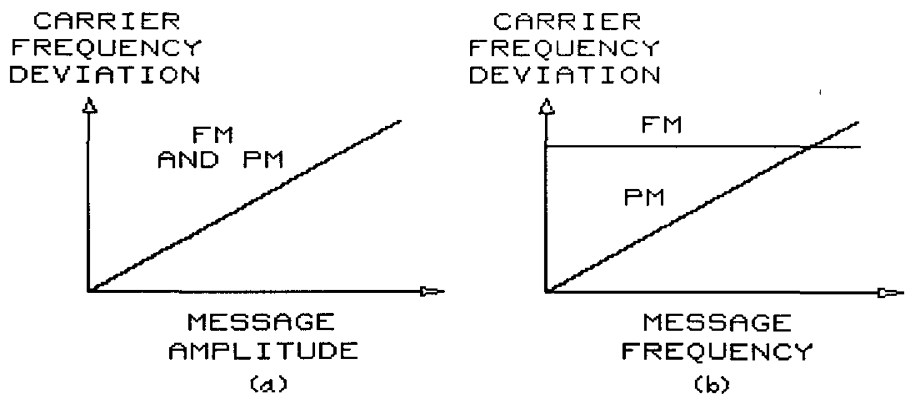


Figure (2)-Effect the amplitude and frequency of message signal on frequency deviation

FM transmission provides better random noise rejection than AM transmission. Because of better noise rejection in the receiver, FM provides a greater transmission distance than AM for the same frequency and transmitter power.

$$e_{FM}(t) = A_C \cos(wct + \beta \sin(wmt))$$

Ac: peak amplitude of the carrier signal.
fc: frequency of the carrier signal.
Am: amplitude of the message signal.
fm: frequency of the message signal.
β: modulation index of FM signal.

Frequency and Phase Modulation:

Following are the three frequency modulation concepts you need to remember.

1. The carrier signal frequency deviates only with the message signal amplitude.
2. The message signal's frequency does not deviate the carrier signal's frequency but does affect the rate of deviation.
3. Any amplitude variations of the FM carrier contain no message signal intelligence; only frequency deviations contain the intelligence.

In figure (3) the FM carrier's amplitude can be limited within desired values. Consequently, noise amplitude spikes can be reduced by limiter circuits..

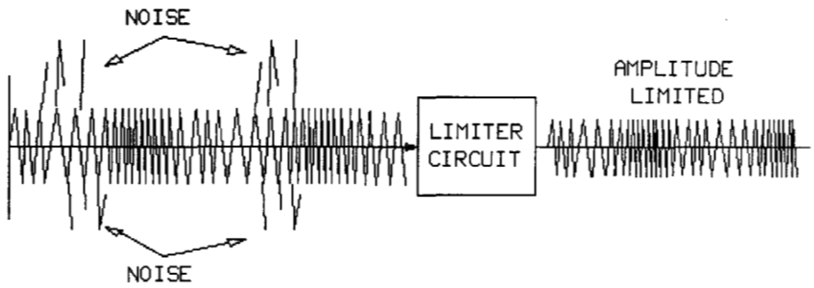


Figure (3)-Limiter circuit.

If the frequency deviation is held to a minimum, only two FM sidebands are produced therefor become narrow bandwidth NBFM, but as the message signal amplitude increases, additional significant sidebands above and below the carrier center frequency are produced and become wide bandwidth WBFM.

The bandwidth required for an FM signal depends upon two factors:

i. The message signal amplitude.
ii. The message signal frequency.

The energy contained in each sideband pair decreases as the sideband pairs are removed from the center frequency. A point is reached at which a sideband pair contains so little energy that they can be disregarded. The point is determined by the modulation index.

The modulation index of FM signal (β) is the ratio of the amount of carrier frequency deviation Δf to the message signal frequency fm.

$$\beta = \frac{\Delta f}{fm}$$

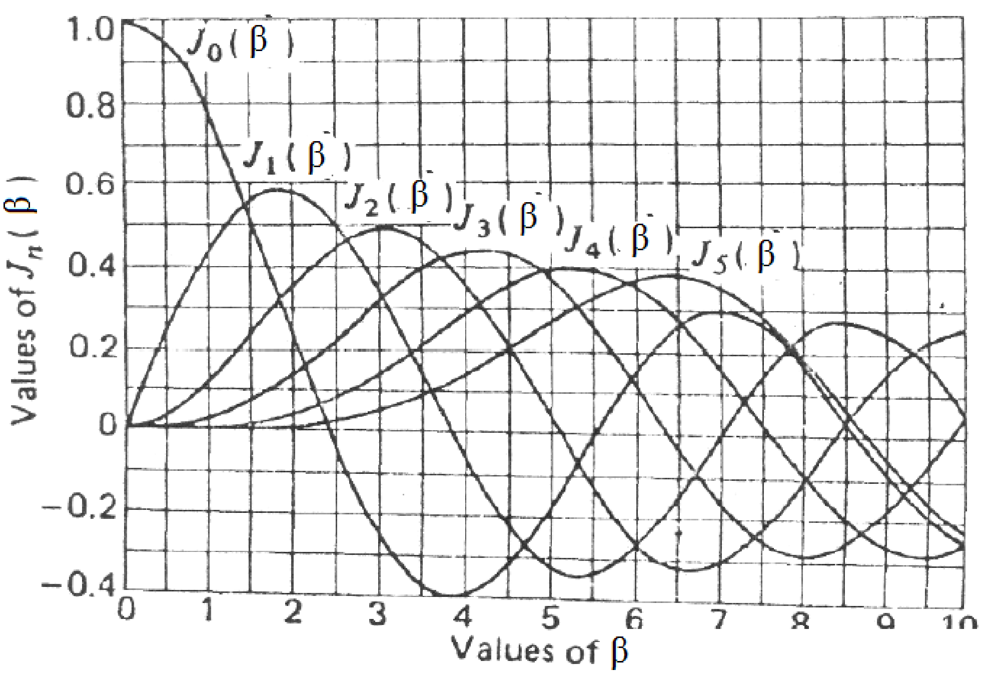
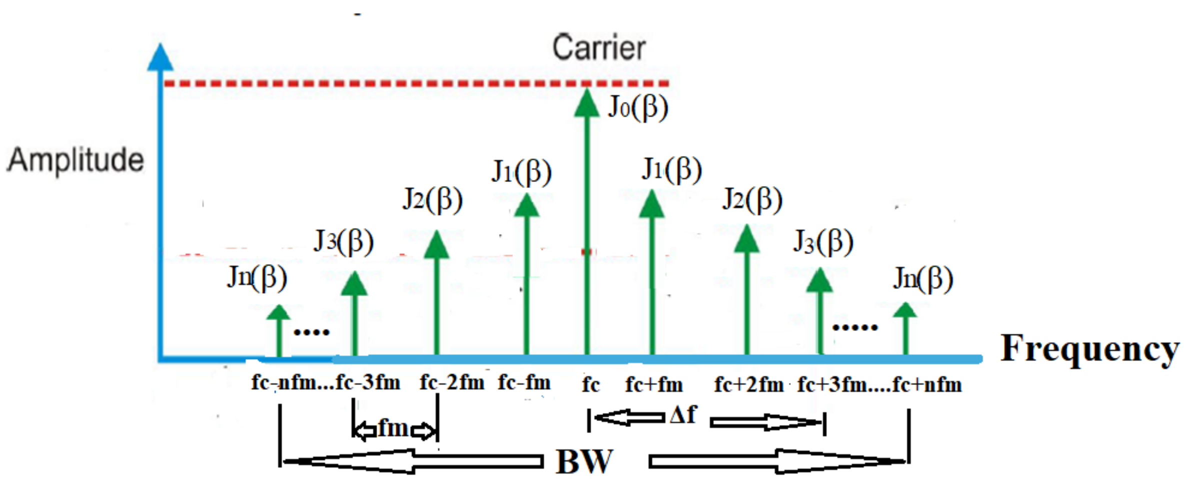


Figure (4). Bessel function that given Jn(β) with β

Table (1) shows the significant sideband pairs for FM signals with modulation indexes.



Example:
The FM signal with a modulation index of β=2 would have 4 significant sideband pairs. If such a 450 kHz FM carrier signal were modulated by a fm= 5 kHz message signal, it would have the sidebands spaced 5 kHz apart for 20 kHz on each side of the 450 kHz center frequency, even though the frequency deviation is ± 10 kHz, the FM bandwidth would be 40 kHz (430 kHz to 470 kHz).

MODULATION INDEX	SIGNIFICANT SIDEBAND-PAIRS
1	3
2	4
3	6
4	7
5	8
6	9
7	11
8	12
9	13
10	14
11	15
12	16
13	17
14	18

Table (1)-Modulation index of FM with significant sideband pairs(SSP)

The average power for frequency modulated signal can be calculated by.

$$P_t = \frac{A_c^2}{2} \sum_{n=-\infty}^{n=\infty} J_n^2(\beta)$$

Where n is number of the sideband. The average power in each sideband is equal ($\frac{A_c^2}{2} J_n^2(\beta)$).

Frequency Modulation (FM) Generation:

In this procedure section, you will frequency modulate a carrier signal, measure its parameters, and observe its characteristics. The potentiometer knob on the VCO-LO circuit block adjusts the output amplitude. To adjust the VCO-LO output frequency, you will adjust the negative supply knob on the left side of the base unit.

A simplified schematic of the VCO-LO circuit block is shown in figure (5) the oscillator consists of two transistors that are connected in a cross-coupled oscillator configuration. The oscillator's frequency is determined by the tuning of the LC network. The frequency response of LC circuit is given by:

$$f_{LC} = \frac{1}{2\pi\sqrt{LC}}$$

You can tune the LC network by changing the value of the negative supply voltage at the anode of varactor diode CR2.

Varactor Diode.

The Varactor diode is a semiconductor diode that is designed to behave as a voltage controlled capacitor. When a Varactor diode is reversing biased its work as variable capacitance. The value of the negative voltage affects the CR2 capacitance, which, in turn, affects the tuning of the LC network. As the negative supply voltage becomes more negative, VCO-LO's output frequency increases. (VCO-LO range frequency).

At 0 DC voltage, the output frequency is about 310 kHz.

At -10 DC voltage, the output frequency is about 510 kHz.

A buffer is between the oscillator and the VCO-LO potentiometer. You adjust the potentiometer to set the VCO-LO output amplitude. **At test point T**, you can measure the dc voltage at CR2's anode.

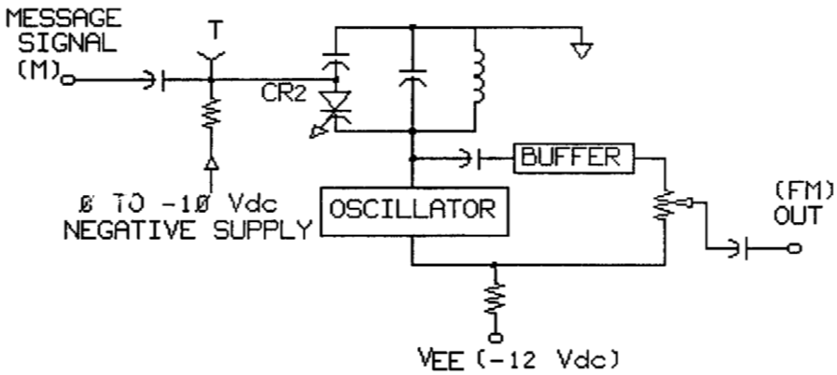


Figure (5) VCO-LO circuit block schematic

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Procedures:

1. On the VCO-LO circuit block, insert the two-post connector in the 452 kHz. Set the VCO-LO amplitude potentiometer fully CW. Connect the oscilloscope channel 1 probe to (FM) OUT. Connect the dc voltmeter to T point.

2. Measure the range of the unmodulated FM carrier signal or (frequency of oscillator and LC circuit) by adjust the NEGATIVE SUPPLY.

3. Set the voltage at point (T) at -4 DC voltage, then measure the frequency of the unmodulated FM carrier signal.

4. **Suppose that** (افرض أن) the message signal sine wave applied on the VCO-LC at point (M) with 2Vp-p and 5 KHz.

5. Determine the frequency deviation of the FM carrier when the message signal amplitude changes by -1 DC voltage. Adjust the NEGATIVE SUPPLY knob to change the voltage at T on the VCO-LO circuit block to -5.0 DC voltage, measure the frequency of the modulated FM carrier signal.

6. Determine the frequency deviation of the FM carrier when the message signal amplitude changes by 1 DC voltage. Adjust the NEGATIVE SUPPLY knob to change the voltage at T on the VCO-LO circuit block to -3.0 DC voltage, measure the frequency of the modulated FM carrier signal.

7. Calculate FM frequency deviation depended on step 5 and 6.

8. Return the carrier frequency to the center frequency, change the voltage at T point -4.0 DC voltage.

9. Connect the signal generator at point (M) on the VCO-LO circuit block and use same the signal used in (step 4), you will now observe the effect of a 2 Vp-p, 5 kHz message signal on the FM carrier frequency.

10. Set the oscilloscope to **MATH** and **draw** the frequency domain for FM signal and **measure** the frequency deviation Δf.

11. Calculate the modulation index (β) for an FM signal,

12. Select the number of significant sideband pairs (SSP) from Table1. If the β is not a whole number (عدد صحيح), use the next highest β.

13. Calculate the bandwidth of FM modulated signal by using the following equation ($Bw = 2*f_m*SSP$)

Report: -

1. What is the advantage of angle modulation for (noise and interference), the bandwidth of transmission and the average power of the transmission? comparison with the amplitude modulation
2. Explain briefly when the frequency modulation can be NBFM and WBFM? Explain effected NBFM and WBFM on the bandwidth for transmitted signal?
3. In the FM transmitted signal used to modulated message signal with 3 KHz and the frequency deviation is changed to get on the amplitude of the first sideband equal maximum amplitude, used the figure (4), calculate β and calculate the bandwidth of the FM carrier
4. For step (9) calculated the frequency component, the amplitude, average power for each sideband pairs, then calculate the bandwidth that contain 80% of the total transmitted power, the load at transmitter is 1Ω, suppose that Ac=1volt.

Frequency (KHz)	Amplitude	Average power
fc		
fc±fm		
fc±2fm		
..		
..		
..		
fc±nfm		
		Sum of Pt=80%

5. An FM carrier signal a frequency deviation of ± 12 kHz with 4 kHz message signal calculate β, then use Table (1) to determine the number of significant sideband pairs (SSP), draw the frequency spectrum of this modulation signal using figure (4) of Bessel function, calculate the average power for each sideband, the load at transmitter is 1Ω and calculate the bandwidth of the FM carrier.

FM-Demodulation
"Quadrature Detector"

Introduction: -

FM demodulators are referred to as discriminators or frequency detectors. A quadrature detector is one of several circuits that can demodulate FM signals. Other FM demodulator circuits include the Foster-seeley discriminator, the ratio detector, the pulse counting detector, and the phase-locked loop detector. All of these circuits convert FM frequency variations into the amplitude and frequency of the message signal.

The FM discriminator on the circuit board is a quadrature detector. The QUADRATURE DETECTOR circuit block as shown in figure (1) includes a PHASE SHIFTER/LIMITER, a PHASE DETECTOR and a FILTER. A simplified schematic of the quadrature detector is shown in figure (2).

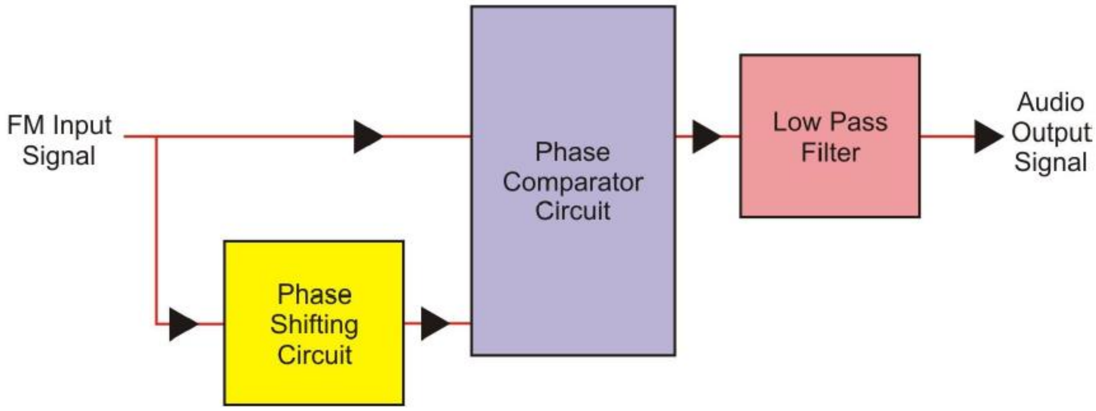

Figure (1)- Quadrature Detector block schematic.

The degree of phase shift that occurs is determined by the exact frequency of the signal at any particular instant. The rules for the degree of phase shift are:

- If the carrier is un-modulated, the phase shift is 90°.
- If the carrier increases in frequency the phase shift is less than 90°.
- If the carrier decreases in frequency, the phase shift is greater than 90°.

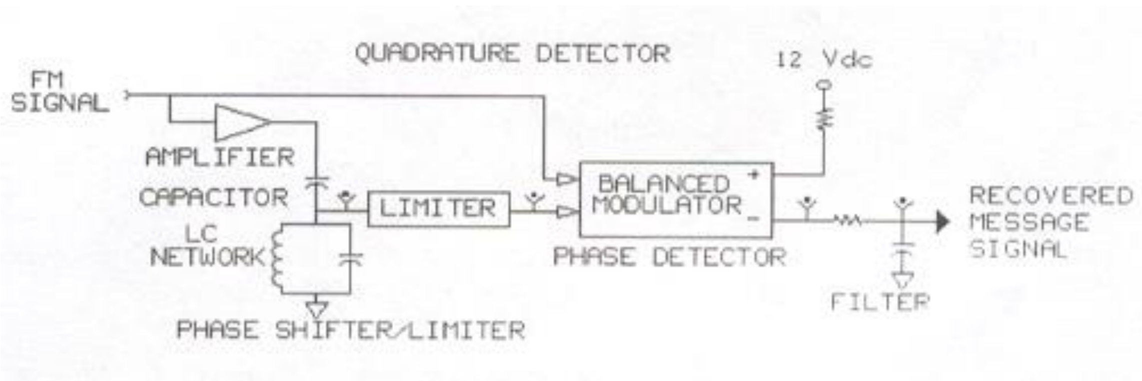

Figure 2. Quadrature Detector circuit.

At the quadrature detector's input, the FM signal take two paths. One FM signal is input to a

PHASE SHIFTER/LIMITER circuit is composed of an amplifier, a capacitor, an LC network, and a limiter circuit, which converts frequency deviations into phase deviation with about a 90° phase shift.

Signals are in quadrature when they have a phase difference of 90º. The original FM signal and phase-shifter/limiter FM signal are input to a phase detector, which is a **balanced modulator**.

Phase detector outputs a signal with a frequency that is twice the FM frequency and a dc voltage that varies with the phase difference between the two inputs.

Because the phase difference between the phase detector's input signals varies with the FM signal's frequency deviations, the dc output voltage from the phase detector changes with the amplitude and frequency of the FM message signal.

A low pass filter at the phase detector's output removes the high-frequency signal and passes the varying dc output voltage as the recovered message signal.

The FM signal takes two paths at the quadrature detector's input. One FM signal to the amplifier, which is a non-inverting op amp with a gain of about two. The capacitor shifts the FM signal by 90º. Because the resonant frequency (fr) of the LC network equals the FM center frequency. Consequently, the 90º phase shift of the center frequency is not affected by the LC network. However, frequencies greater than or less than fr are shifted less or more than 90º, respectively, from the original FM signal, frequency deviations on each side of the FM center frequency will be greater than or less than 90º out of phase because the frequency deviations are connected to the phase deviations.

The phase-shifted FM signal is input to the limiter. As figure (3) shows, the limiter has two diodes connected from the output to ground with their polarities reversed. The reversed-polarity diodes limit the output amplitude.

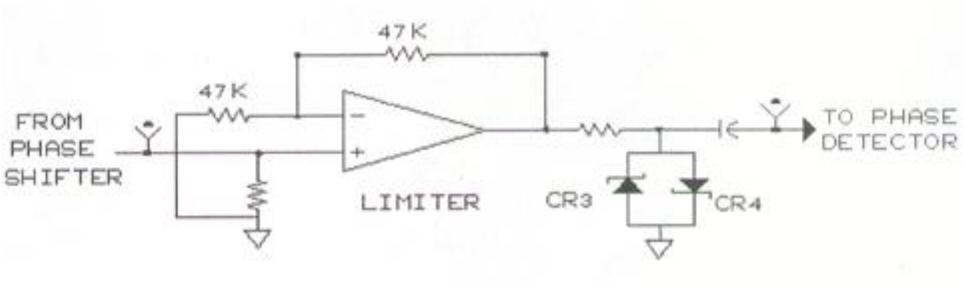

Figure (3)-Limiter circuit

Procedure: -

1- Connect the following block.

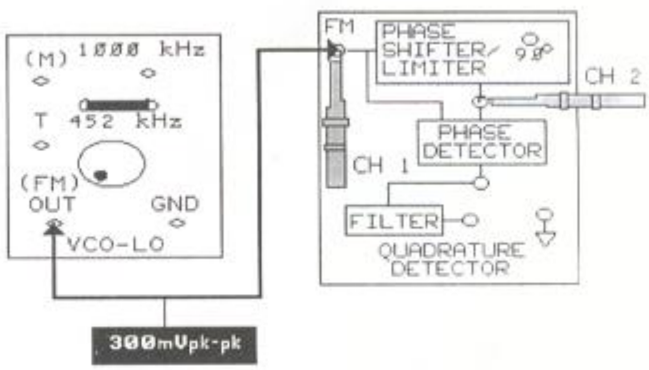

Figure (4)-VCO-LO with Quadrature detector

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2- Connect the output of the VCO-LO into the input of quadrature detector, set the carrier frequency of VCO-LO with 300 mvp-p of carrier signal. Connect the oscilloscope Ch1 probe to VCO-LO output.

3- Connect the oscilloscope Ch2 probe to the output of the phase shifter/limiter. Then adjust the FM frequency at VCO-LO by negative supply knob CW and CCW to vary the FM frequency. What do you notice between the ch1 and ch2?

4- Set ch1 and ch2 of oscilloscope at same scale, then adjust the negative supply knob until the waveform on Ch2 has maximum amplitude. Draw and measure the frequency for each probe Ch1and Ch2, then measure the phase shift between them.

5- Connect the Ch2 probe to the phase detector's output. Draw Ch1 and Ch2 signals then measure the frequency for both signals.

6- Measure the dc voltage on the output of phase detector by

7- voltmeter and why you get dc voltage in this in step?

8- Measure the output of the filter.

fi(KHz)	Vo(vp-p)	ϴLc	Vd-DC.

9- Connect the Ch2 probe to the output of the phase shifter/limiter and adjust the FM frequency with the negative supply so that the phase difference between the signals on Ch1 and Ch2 is 45º. Draw the two signals and measure the dc voltage on the phase detector's output.

10- Set the phase difference between the signals on Ch1 and Ch2 back to 90º.Modulate the FM carrier with a (500mvp-p 1 KHz) message signal. Connect the signal generator to (M) on the VCO-LO circuit block as shown in the figure (5). Connect the oscilloscope Ch1 probe to (M) and the oscilloscope Ch2 probe to quadrature detector's output (output of the filter). Then draw both of them.

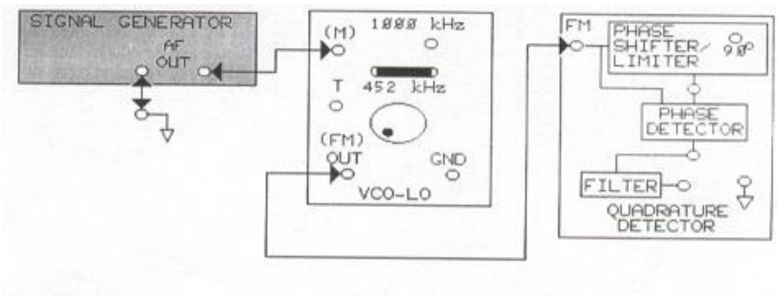


Figure (5)-VCO-LO with signal generator with quadrature detector

Report: -

1. Explain briefly the function of each stage in the Quadrature Detector?

2. In the Phase Shifter/limiter circuit, what component causes a phase shift of 90° between the input and output?

3. Explain by using the equations the output of the PHASE detectors for FM signal bellow
$$e_{FM}(t) = A_C \cos(wct + \beta \sin(wmt))$$

4. In the Phase Shifter/limiter circuit, what is the phase shift between the input and the output of LC network when the (fr) of the LC network equals to the frequency of input signal?

5. Explain briefly with draw the circuit of discriminators that used to convert the FM to AM for demodulation the FM signals?

6. For radio receiver device to received FM signal, what is the value of the intermediate frequency? Draw block diagram

Analysis of AM and FM waves

Part (A): - 1-Analysis of AM Wave

Amplitude modulation is a system of modulation in which the amplitude of the carrier is made proportional to the instantaneous amplitude of the modulating voltage.

Let the carrier voltage be: $e = E_c \sin(\omega_c t)$

In addition, the modulating voltage: $e = E_m \sin(\omega_m t)$

Then the amplitude of the amplitude-modulated voltage (A) will be:

$$A = E_c + E_m \sin(\omega_m t)$$

Or $A = E_c(1 + E_m/E_c \sin(\omega_m t))$ ……………………. (1)

$E_m/E_c = M$ Which is the modulation index and its value is usually between 0 and 1.

Putting M in equation 1 gives:

$$A = E_c(1 + M \sin(\omega_m t)) \text{ ……………………… (2)}$$

$$M = ka * Am \text{ …………………………..…. (3)}$$

modulation index where *ka* constant coefficient (1/volt)

The instantaneous voltage of the resulting amplitude-modulation wave:

AM wave = $A\sin(\omega_c t)$

$$= E_c(1 + M \sin(\omega_m t))\sin(\omega_c t) \text{ …………………..… (4)}$$

$$= E_c \sin \omega_c t + ME_c/2\cos(\omega_c - \omega_m)t - ME_c/2\cos(\omega_c + \omega_m)t \text{ ……..…. (5)}$$

The first term represents the un-modulated carrier; the two additional terms are the sidebands. Note that from equation (4), the maximum voltage in the AM wave is $e(\max) = E_c(1+M)$, the minimum voltage is: $e(\min) = E_c(1-M)$

So: $e(\max)/e(\min) = (1+M)/(1-M)$

Alternatively: $M = \frac{[e(\max)-e(\min)]}{[e(\max)+e(\min)]}$ …………………………………… (6)

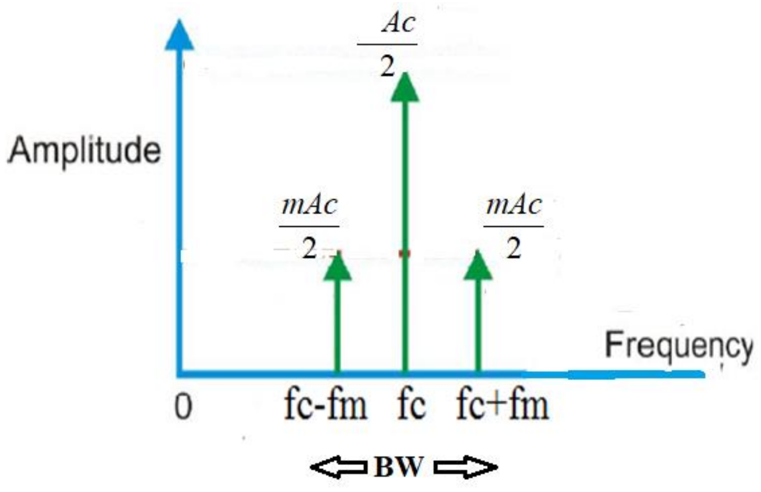
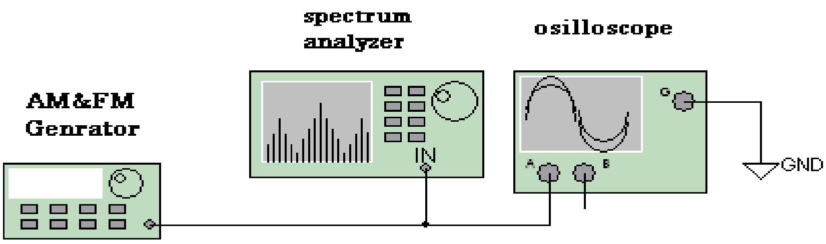


Figure (1). Frequency spectrum of AM wave.

Procedures:

1- Connect the equipments and switch them on.



2- Keep f_c constant at 1 MHz, f_m at (1 KHz). And change modulation index in steps (0, 0.2, 0.4, and 0.6) and in each draw the frequency spectrum using spectrum analyzer, then draw time domain using oscilloscope.

3- Change the setting of the function selector of the AM generator to Ext. input. Connect the signal generator to the input of the AM signal generator with M constant at (0.6) and change f_m in steps (3, 5 and 10 KHz) and in each case draw the frequency spectrum using spectrum analyzer and measure the bandwidth for each state.

4- Set modulation index at (60%), f_m at 3 KHz and set the amplitude of message signal A_m at 1 volt and 1.6 volt, draw the frequency spectrum using spectrum analyzer.

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Part (A): - 2-Analysis of FM Wave

In analogue modulation system, the information or baseband signal is transmitted by causing this signal to vary either the amplitude, frequency, or the phase of higher frequency carrier. FM modulation is none-linear (exponential) process, in which, the modulated wave in phase form is an exponential function of the message, that is:

$$S_{FM}(t) = Ac\,\mathrm{Re}\left\{e^{j2\pi fc}\, e^{j\beta \sin 2\pi fmt}\right\} \quad \text{.......................... (1)}$$

A_c = carrier magnitude.

$$\Delta f = kf * Am \quad \text{.. (8)}$$

frequency deviation   where *kf* frequency sensitive constant (1Hertz/volt)

f_c = angular frequency of un-modulated carrier.

fm = frequency of the signal.

$\beta = \dfrac{\Delta f}{fm}$ = modulation index... (9)

The equation (1) may be expanded using the Fourier- Bessel equation:

$$V_{FM}(t) = \mathrm{Re}\left\{A_o e^{j2\pi f_c t} \sum J_n(\beta) e^{jn2\pi fmt}\right\} \quad \text{........................ (10)}$$

Where $Jn(\beta)$ are Bessel function of the first kind of order n and argument β, taking a real part of (10) and expanding products of sines and cosines finally results in :

$$V_{FM}(t) = A_c \begin{Bmatrix} J_0(\beta)\cos 2\pi f_c t + J_1(\beta)[\cos(2\pi f_c + 2\pi fm)t] \\ + J_2(\beta)[\cos(2\pi f_c + 2\pi fm)t + \cos(2\pi f_c - 2\pi fm)t] \\ + J_3(\beta)[\cos(2\pi f_c + 3\pi fm)t - \cos(2\pi f_c - 3\pi fm)t] + ... \end{Bmatrix}$$

$$= A_c \sum_{n=-\infty}^{\infty} J_n(\beta)\cos(2\pi f_c + n2\pi fm)t \quad \text{..................... (11)}$$

Examining equation (11), we see that the FM spectrum consists of a carrier frequency line plus an infinite number of sideband lines of frequencies $(f_c + nf)$.

It is in contrast to Am waves of only two sidebands with single tone modulation. However, the magnitudes of spectral components of higher-order sidebands become negligible, and for all practical purposes the power is contained within a finite bandwidth:

$$BW = 2\,fm(1+\beta)$$
$$BW = 2(\,fm+\Delta f\,) \quad \ldots\ldots\ldots\ldots(12)$$

{(1+β) sidebands of FM wave containing the 99% power of un-modulated carrier}.

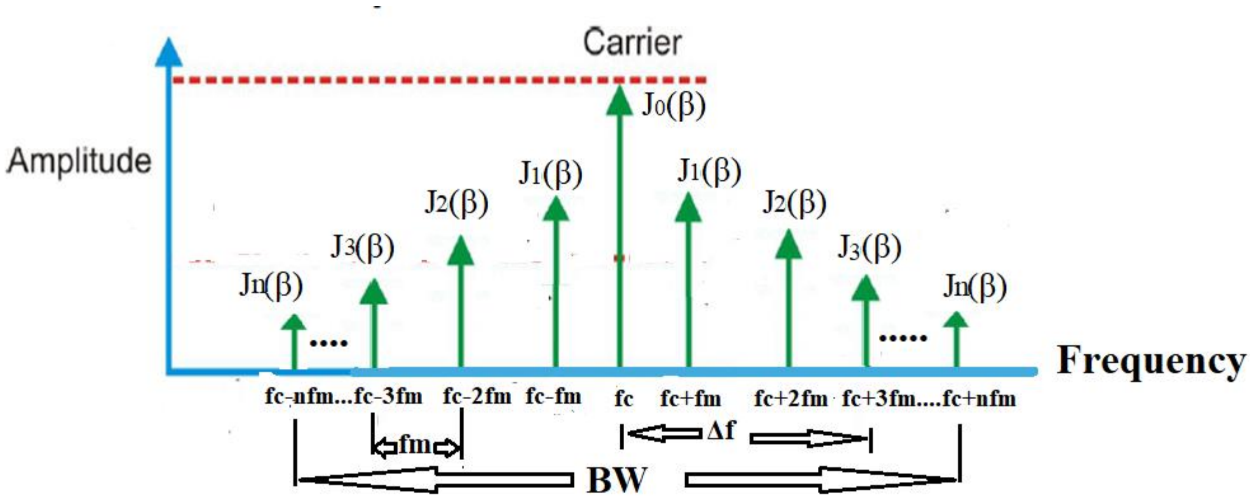

Figure (2). Frequency spectrum of FM wave.

Procedures:

5- Selected FM system from the generator, Set the carrier frequency to 1MHz.

6- Set Δf at 3 KHz, fm at 3 KHz and change A_m at (1.45, 2, 3.5, 5, 7) volt. In each state draw the frequency spectrum and measure the frequency deviation and the bandwidth.

Fourier Theory-Frequency Domain and Time Domain Simulation

Part (B): - Fourier Theory

Communications systems are normally studied using sinusoidal voltage waveforms to simplify the analysis. In the real world, electrical information signals are normally non-sinusoidal voltage waveforms, such as audio signals, video signals, or computer data. **Fourier theory** provides a powerful means of analyzing communications systems by representing a non-sinusoidal signal as a series of sinusoidal voltages added together. Fourier theory states that a complex voltage waveform is essentially a composite of harmonically related sine or cosine waves at different frequencies and amplitudes determined by the particular signal voltage wave-shape. Any non-sinusoidal periodic waveform can be broken down into a sine or cosine wave equal to the frequency of the periodic waveform, called the fundamental frequency, and a series of sine or cosine waves that are integer multiples of the fundamental frequency, called harmonics. This series of sine or cosine waves is called a **Fourier series.**

Useful equations:

$$f(x) = a_0 + \sum_{n=1}^{\infty}\left(a_n \cos nx + b_n \sin nx\right) \qquad \ldots\ldots (1)$$

$$a_0 = \frac{1}{T}\int_{--T/2}^{T/2} f(x)dx \qquad \ldots\ldots (2)$$

$$a_n = \frac{2}{T}\int_{-T/2}^{T/2} f(x)\cos nx\,dx \qquad \text{...... (3)}$$

$$b_n = \frac{2}{T}\int_{-T/2}^{T/2} f(x)\sin nx\,dx \qquad \text{...... (4)}$$

Square wave Fourier series:

$$v(t) = A\sin 2\pi ft + \frac{A}{3}\sin(3)2\pi ft + \frac{A}{5}\sin(5)2\pi ft + \frac{A}{7}\sin(7)2\pi ft + ... \qquad \text{...... (5)}$$

Triangular wave Fourier series:

$$v(t) = A\cos 2\pi ft + \frac{A}{3^2}\cos(3)2\pi ft + \frac{A}{5^2}\cos(5)2\pi ft + ... \qquad \text{...... (6)}$$

Procedures:

1- Draw the circuit shown in figure (3), then run the simulation. This circuit will generate square wave from these sinusoidal sources.

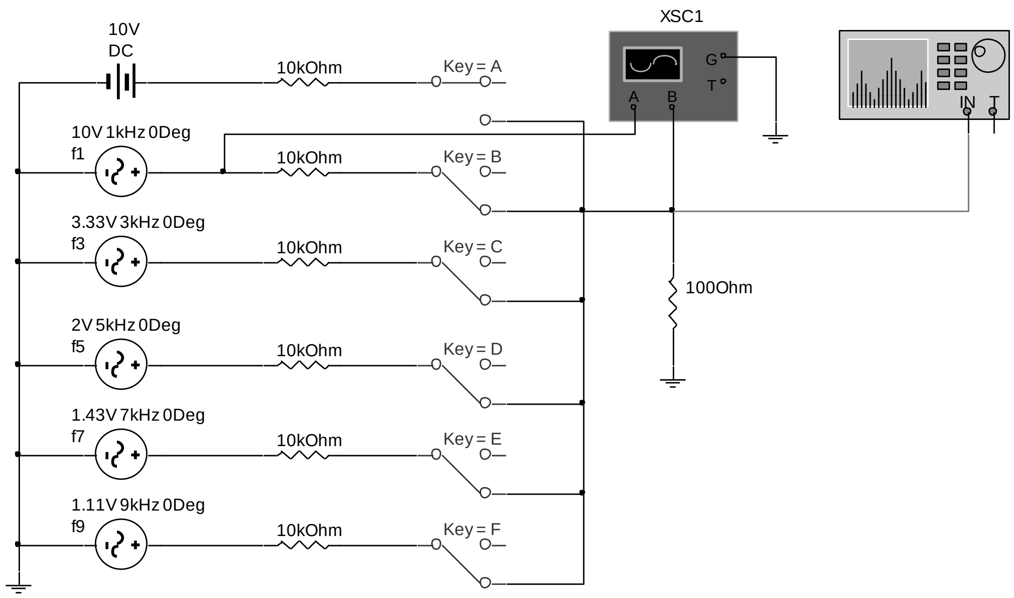

Figure. (3)

2- Now draw the oscilloscope and spectrum analyzer output.

3- Start closing the switches one by one and notice the effect of each one on the signal waveform and spectrum then record that.

4- Modify the circuit in figure (3) to be look like that in the figure (4) and compare the output of the two cases.

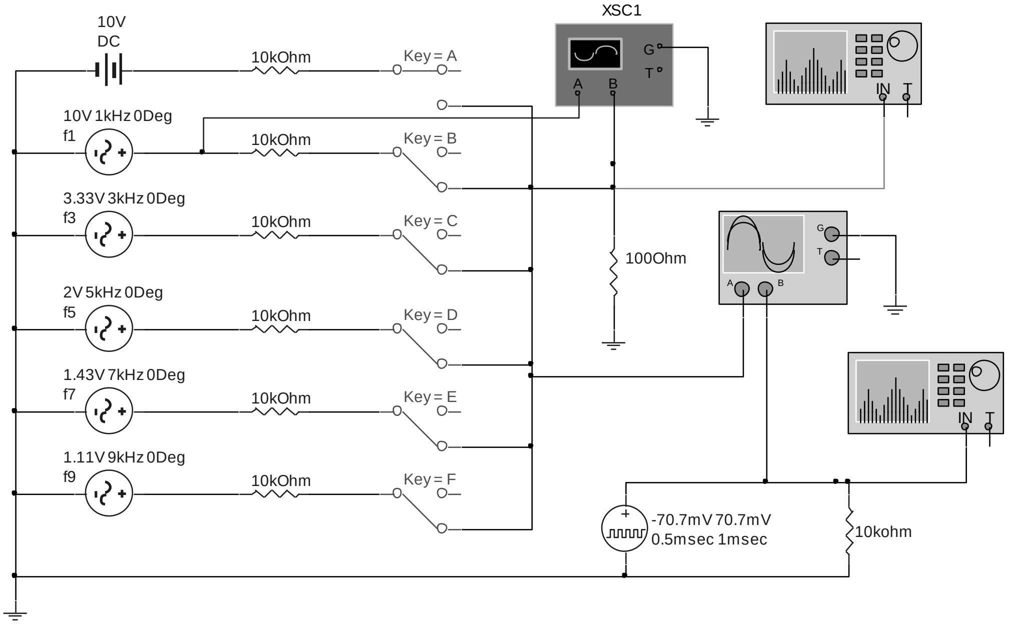

Figure. (4)

Report:

1- From run 2 and 3, calculate the bandwidth in each case and what is the effect of increasing M and f_m on the frequency spectrum for AM ?

2- From step 4, calculate the new modulation index for each state and what is the effect of increasing A_m on the frequency spectrum?

3- From step 6, calculate the bandwidth in each step.

4- From step 6, what is the effect of the amplitude and frequency of message signal A_m and fm on the carrier frequency deviation?

5- Compare between the bandwidth for AM &FM , if the message signal with A_m=1 volt and f_m=3.4 KHz , ka=1 for AM and for FM kf =2 KHz/1volt.Comment on the results.

6- Compare between the bandwidth for AM &FM , if the message signal with A_m=1 volt and f_m=3.4 KHz , ka=1 for AM and for FM kf =4 KHz/1volt. Comment on the results.

Operational Amplifier and Applications

Objective

The purpose of this experiment is to learn the basics of operational amplifier and its applications.

Theory

Introduction:

The operational amplifier (**OP-AMP**) has high input impedance and low output impedance. The gain of the amplifier is high if a proper feedback circuit is connected to the amplifier. It can be used also as impedance converter for matching.

The OP AMP can be used as an inverting and non-inverting amplifier; it can be proved that the gain of an inverting amplifier will be:

$$G = \frac{V_o}{V_i} = -\frac{R_F}{R_1}$$

Where: R_F is a feedback resister.

While the gain of a non-inverting amplifier equal:

$$G = \frac{V_o}{V_i} = 1 + \frac{R_F}{R_1}$$

Procedures:

Item 1: - Inverting Amplifier

1- Connect the circuit shown in figure (1).

2- Measure the gain of the amplifier and the phase shift for: $R_F = 10K\Omega$, $R_1 = 100\Omega$. Record your results in table 1.

3- With both values for R1, measure the frequency response of the amplifier, without **any distortion in signal in output**. Record your results in table 2& table 3.

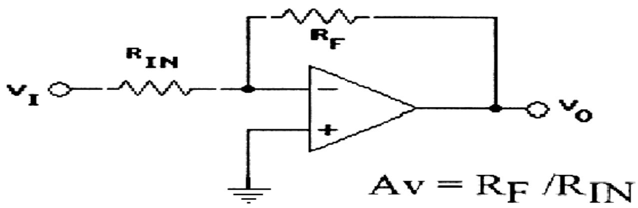

Fig.1

Item 2: - non-inverting amplifier

1-Connect the circuit of figure (2).

2-Measure the gain of the amplifier and the phase shift for: $R_F = 9K\Omega$, $R_1 = 1K\Omega$. Record your results in table 4.

3-Measure the frequency response for the amplifier. Record your results in table 5.

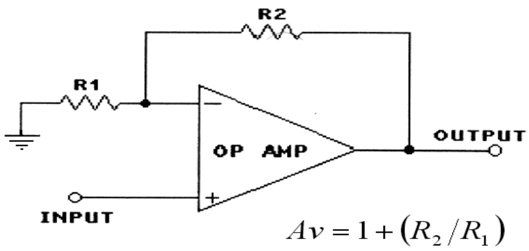

Fig.2

Item 3: - Inverting Summing Amplifier

1. Connect the circuit shown in figure (3).

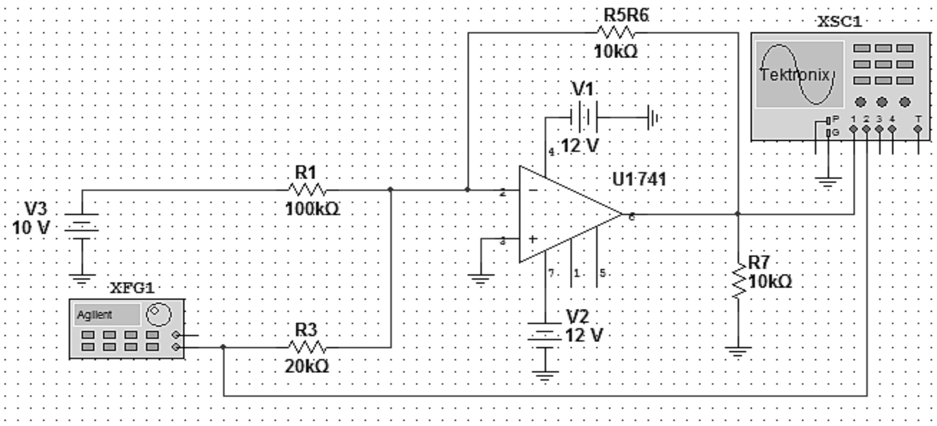

Fig.3

2. Adjust the function generator so that the input signal is 2Vp-p 1KHz.

3. Adjust the oscilloscope so that
Channel 1 (output): 500mV/Div. Coupling: DC.
Channel 2 (input) : 1v/div. Coupling DC.

3-Draw the input and output waveforms and explain how you get the output.

Item 4: Comparator.

1. Connect the circuit shown in figure (4).

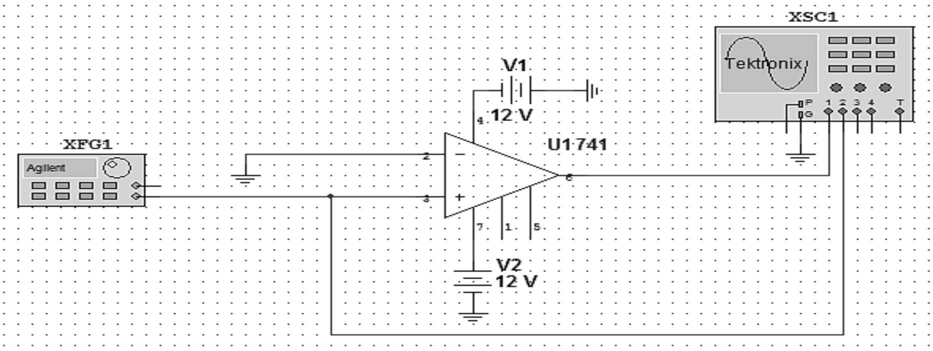

Fig.4

2. Adjust the function generator so that the input signal is 2Vp-p 1kHz.

3. Draw the input and output waveforms. and explain how you get the output.

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College: Electronics Eng.
Dept.: Communication Eng.

Communication Lab3
Exp. (6): OP-Amp. &App.
Set: (1)-2019-2020

Report:-

1- From run 3 & 6, plot the frequency response of the amplifier.

2- Calculate the **GBW** product of the amplifier in all cases.

3- Explain how the amplifier has inverting and non-inverting properties by **equations**.

4- What is advantage from determine frequency response of the amplifier.

5-Using multisim software:

a) Connect the circuit shown in figure (5).

b) Measure the DC voltage at the output using Agilent multi-meter?

c) Explain how you get the output of each circuit?

d) which type of amplifier?

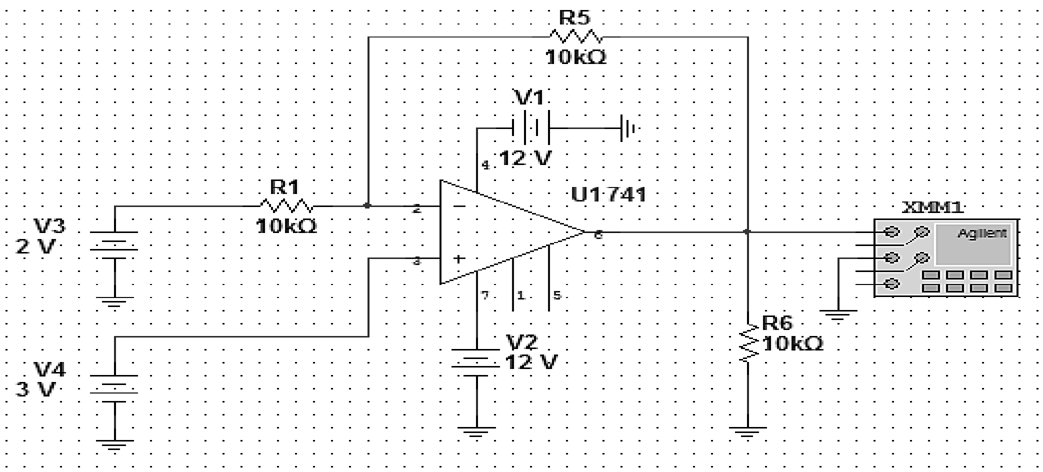


Fig.5

Results sheet (Operational amplifier)

R_F =10 KΩ and R_1=100Ω

Amplifier gain	
Amplifier phase shift	

R_F =10 KΩ and R_1=1KΩ

Vin with no distortion at output = V(p-p).

Freq(KHz)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V_{out} (V_{p-p})														

R_F =10 KΩ and R_1=1kΩ

Vin with no distortion at output = V(p-p).

Freq(KHz)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V_{out} (V_{p-p})														

RF =9 KΩ and R1=1kΩ

Amplifier gain	
Amplifier phase shift	

R_F =9 KΩ and R_1=1kΩ

Vin with no distortion at output = V(p-p).

Freq(KHz)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V_{out} (V_{p-p})														

Active Filters
(LPF, HPF and BPF)

Introduction:

Filter is a circuit capable of passing signals from input to output that have frequencies within a specified band and attenuation all others outside the band. This property is called selectivity.

There are four basic types of filters: low-pass, high-pass, band-pass, and band-stop. Basic filter action is accomplished with various combinations of resisters, capacitors, and sometimes inductors. These are called passive filters. Active filters use transistors or op-amps to provide desired voltage gains or impedance characteristics.

All filters have term called order of the filter which is mean how much the roll- off rate of the filter, it depend on the number of poles at the filter circuit, and the roll-off rate increases with the increase of filter order.

Procedure:

1- Connect circuit of figure (1). This will construct low-pass filter 1st order. Calculate the cutoff frequency, and measure the frequency response of the filter at input signal 4 vp_p.

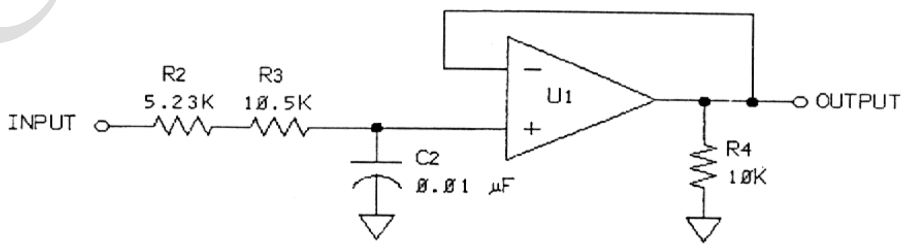


Figure (1): Circuit of LPF 1st order

2- Connect the circuit in figure (2) to get 2nd order filter. Then measure the frequency response of the filter. Calculate the cutoff frequency of the filter using this equation:

$$f_c = \frac{1}{2\pi\sqrt{R_1 R_3 C_1 C_2}} \qquad \ldots (1)$$

Order =														
V_{in} = 4vpp	*f* cutoff (calculate)=							*f* cutoff(measure) =						
Freq=(KHz)														
V_{out} =														

Note: Using this table in all state

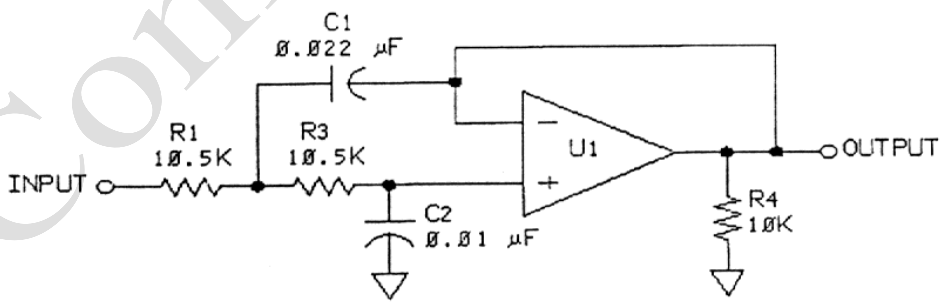
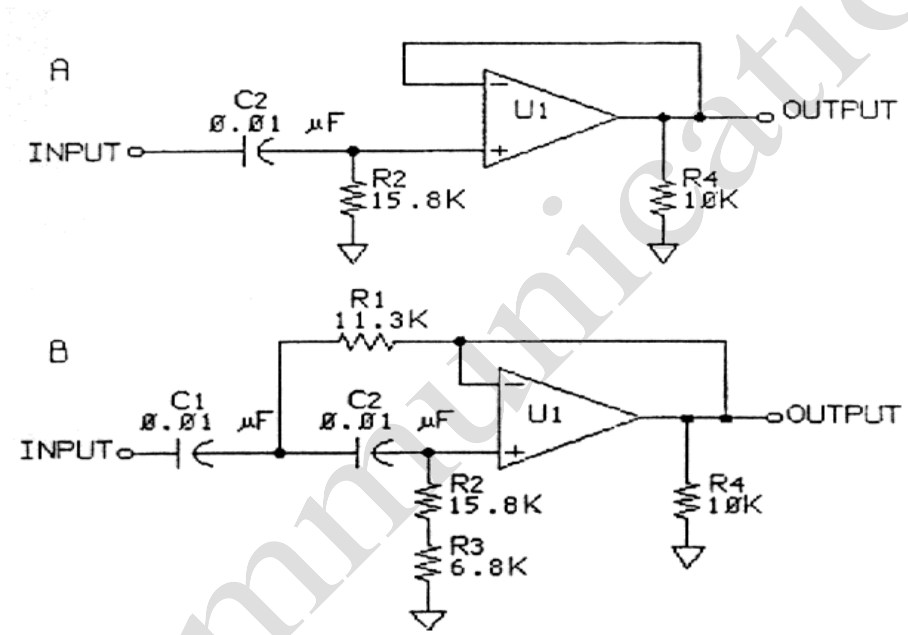


Figure (2): Circuit of LPF 2nd order

3- Connect circuit shown in figure(3-A). That represented high pass filter 1st order (first order). Measure and calculate the cutoff frequency and measure its frequency response.

4- To increase the order of the high-pass filter to the 2nd order (second order) connect the circuit in figure(3-B). Measure and calculate the cutoff frequency and measure its frequency response.



Figure(3-A&B): Circuit of HPF 1st order and 2nd order

5- Connect circuit on figure (4). This circuit work as band-pass filter. Also, measure the frequency response of the filter. To calculate the **center frequency** from this equation:

$$f_r = \frac{1}{2\pi\sqrt{(R_1 \| R_2) R_3 C_1 C_2}} \quad \dots (2)$$

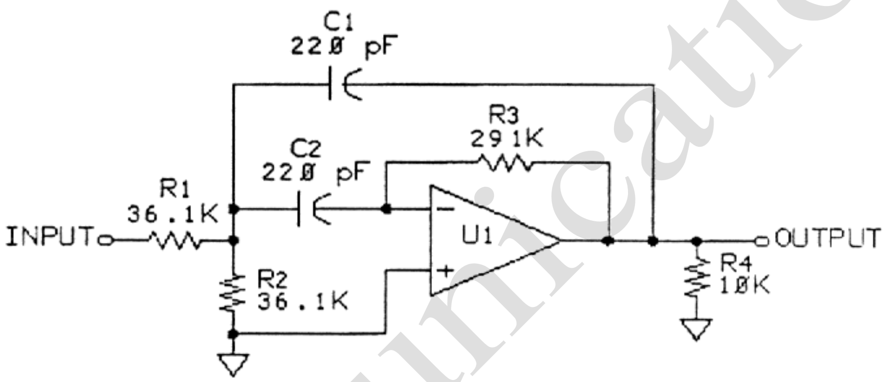


Figure (4): Circuit of Band pass filter BPF

Report:

1- Draw the frequency response for all filters arrangements.

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2- What is function of **OP amplifier** in LPF, HPF and BPF.

3- Calculate the **Quality factor (**Q) for the band pass filter.

4- What determines the high frequency cutoff of an amp high-pass filter? Why?

5- What is advantage increase **Order** for filter?

6- Why cutoff frequency selects at **-3dB** from frequency response?

7- What is difference between **passive** and **active** filter

The Results of Expermint:

Order =														
V_{in} = 4vpp	*f* cutoff (calculate)=							*f* cutoff(measure) =						
Freq=(KHz)														
V_{out} =														

Order =														
V_{in} = 4vpp	*f* cutoff (calculate)=							*f* cutoff(measure) =						
Freq=(KHz)														
V_{out} =														

Order =														
V_{in} = 4vpp	*f* cutoff (calculate)=							*f* cutoff(measure) =						
Freq=(KHz)														
V_{out} =														

Order =														
V_{in} = 4vpp	*f* cutoff (calculate)=							*f* cutoff(measure) =						
Freq=(KHz)														
V_{out} =														

BPF	*f* *center=*													
V_{in} = 4vpp	*f* 1cutoff (measure)=							*f* 2cutoff(measure) =						
Freq=(KHz)														
V_{out} =														
Freq=(KHz)														
V_{out} =														

Transducer Fundamentals

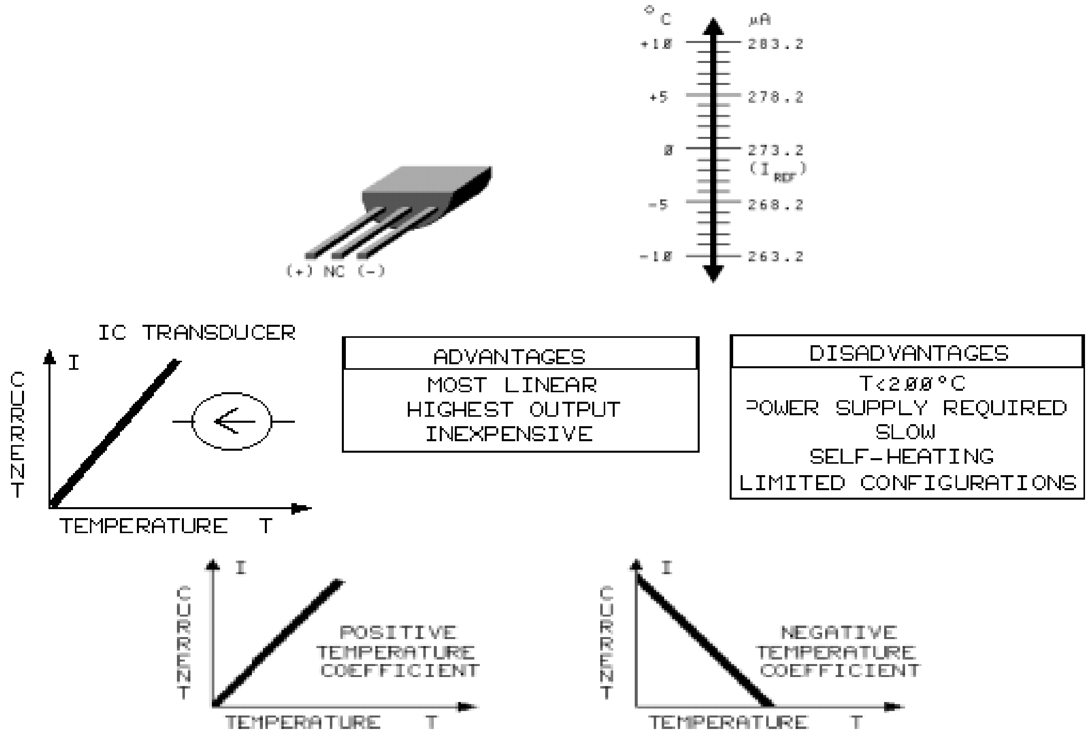
Introduction:

_**IC TEMPERATURE TRANSDUCER:** The IC temperature transducer used as a current source whose output current is a function of temperature. At a reference point of 0°C (the freezing point of water), the output current (I_{REF}) is 273.2 µA. Every temperature transducer has a temperature coefficient that describes the way the transducer's characteristics change as temperature changes. The temperature coefficient α (the Greek letter alpha) of the IC transducer on your circuit board is one micro amp. per degree Celsius (α = 1 µA/°C). A positive or negative temperature change from the 0°C reference point causes a positive or negative current change of 1 µA/°C.

For any temperature T, the current at that temperature (I_T) may be expressed as follows:

$I_T = (\alpha \times T) + 273.2\ \mu A$

(where I_T is in µA, T is in °C, and α= 1 µA/°C).



This is a simplified block diagram of the IC TRANSDUCER circuit block. The transducer's current output [I(T)] drives an op amp that is configured as a current-to-voltage converter. The resulting output is a voltage [V(T)] that is a function of the transducer's temperature. The remaining circuitry allows the block to operate as a temperature controller that regulates the temperature inside the oven.

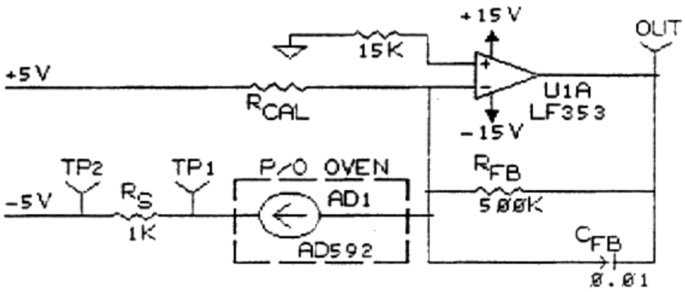
Resistor R_{SP} is used to select a **set point**, or the temperature at which the oven is to be regulated. A second op amp, configured as a comparator, determines whether the oven temperature is above or below the set point. The comparator's output drives a transistor that switches a heater resistor on if the temperature is below the set point, or off if the temperature is above the set point.

Procedures:

1- Use circuit configuration shown below to do the followings steps set the Oven Temperature at 35°C.

2- Determine the transducer current by using Ohm law across Rs resistor between Tp1&Tp2and calculate this current by equation

$I_T = (\alpha \times T) + 273.2\ \mu A$



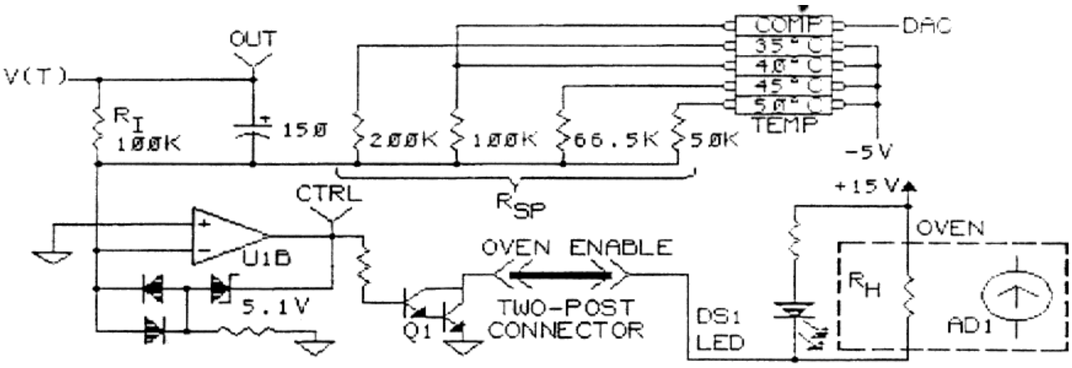
3- Measure the output voltage of **op-amp**, at at same degree and determined by the following equation:

$V_{OUT} = (T - 30\ °C) \times 0.5V/°C$

4- Tabulate in the transducer current for temperatures (40- 45- 50).

Temperature	I(T)عملي	V(T)عملي	I(T)نظري	V(T)نظري	The error
At room					
35°					
40°					
45°					
50°					

5- Use circuit configuration shown below to do the followings steps.



6- Set the temperature to 50˚. Measure (V_{OUT}) of op-amp with the time each step **20 Sec.**

Time sec	V(T=50 ˚)	Time sec	V(T=50 ˚)
0		140	
20		160	
40		180	
60		200	
80		220	
100		240	
120		260	

7- Measure the maximum and minimum $_{VOUT}$ and calculate the temperature by using this equation $T = (V_{OUT} / 0.5) + 30˚$.

8- Measure the voltage control at LED **(ON, OFF)**

Report:

1- Draw the characteristics for the transducers used in this experiment (current versus temperature and voltage versus temperature).
2- Draw the output of the comparator and temperature with time for the oven control circuit in step 6.
3- What's the purpose of the diodes in the comparator circuit of the oven?
4- What's the purpose of the transistors in the circuit of the oven?

Paper of The Results.

Temperature	I(T)عملي	V(T)عملي	I(T)نظري	V(T)نظري	The error
At room					
35°					
40°					
45°					
50°					

Time sec	V(T=50 ˚)	Time sec	V(T=50 ˚)
0		140	
20		160	
40		180	
60		200	
80		220	
100		240	
120		260	

G: -
Date: -
Name of the Group:

1-
2-
3-
4-
5-