كتاب تجارب

معمل الاتصالات

<u>أولا: بيانات المعمل الأساسية</u>

- **اسم المعمل**: معمل الاتصالات
- **القسم العلمي**: قسم هندسه الاتصالات والالكترونيات
- **المشرف**: ا.د/شريف السيد كشك
- **مهندس المعمل:** د/ مجدي فاضل
- **أمين المعمل**: أ/ سارة محمود
- **تليفون:** 1277
- **الموقع:** الدور الثالث، المعامل البحرية أمام صالات عمارة
- **مساحة: 124.75 م^2**

ثانيا: قائمه بالأجهزة والمعدات الموجودة بالمعمل:

Serial number	العدد	الجهاز
1042	2	40 HZ oscilloscope CDS
Model TP8102	7	Function generator
5052	3	Function generator
1232	7	Digital multimeter
300223	1	3/8 logic analog model
-	1	Universal counter
-	10	Micro electronic kit
2012	2	Function generator
-	1	Micro trainer model
2597	1	Transmitter model
MC188	1	Field meter model
-	1	جهاز قياس هرموني متغير
2090	1	Power supply
1230	1	Digital storage oscilloscope
3xBue	1	Analog digital communication computing
1008	1	جهاز توليد ذبذبات
1082	1	Ac power supply
3230	1	Function generator
-	1	Feedback communication system

ثالثا: قائمه بالتجارب التي تؤدي داخل المعمل:

الغرض منها	التجربة	م
Understanding the principle of amplitude modulation(AM). Designing an amplitude modulator usingMC1496. 2. Measuring and adjusting an amplitude modulator circuit	**AM Modulators**	1
1. Understanding the principle of amplitude demodulation. 2. Implementing an amplitude demodulator with diode. 3. Implementing an amplitude demodulator with a product detect	**AM Demodulators**	2
1. Studying the operation and characteristics of varactor diode. 2. Understanding the operation of voltage controlled oscillator. 3. Implementing a frequency modulator with voltage-controlled oscillator.	**FM Modulators**	3
1. Studying the principle of phase-locked loop. 2. Understanding the characteristics of the PLLLM565. 3. Demodulating FM signal using PLL. 4. Demodulating FM signal using FM to AM conversion discriminator	**FM Demodulators**	4
To construct a two stage R-C Coupled amplifier, to study the frequency response of the amplifier and to determine the bandwidth.	**RC-Coupled Amplifier**	5
The ability to diagnose and cure problems in a systematic manner is an exceptionally valuable skill. In PHY2028 students are given a heap of components, a breadboard, and measuring equipment. This virtually guarantees that nothing will work first time, and students are forced to develop troubleshooting skills.	**Troubleshooting Amplifier**	6
1. To construct a series-fed transistor Hartley oscillator. 2. To change frequency determining components and observe variations infrequency. 3. To measure any harmonic frequencies present. Hart- ley oscillator is used for varying frequencies over large ranges, as in local oscillators of radio receivers.	**oscillators-and-multi-viberators**	7

رابعا الخدمات المجتمعية التي يؤديها المعمل:

1. **عدد المستفيدين من المعمل**: طلاب قسم هندسه الاتصالات والالكترونيات (4 دفعات)، طلاب قسم برنامج هندسة الاتصالات (4 دفعات)، طلاب الدراسات العليا
2. **الجهات التي تتعامل مع المعمل:** قسم هندسه الاتصالات والالكترونيات
3. **الدخل السنوي: لا يوجد**
4. **الجهات الممولة لأنشطه المعمل: قسم** هندسه الاتصالات والإلكترونيات والبرامج الخاصة
5. **المشاريع التنافسية التي يشارك فيها المعمل:** مشاريع تخرج لطلاب قسم هندسه الاتصالات والالكترونيات دفعة سنه رابعة

خامسا الخدمات الطلابية:

1. **عدد المستفيدين من المعمل**: طلاب قسم هندسه الاتصالات والالكترونيات (4 دفعات)، طلاب قسم برنامج الهندسة الاتصالات (4 دفعات)، طلاب الدراسات العليا
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3. **الفرق الدراسية التي تستخدم المعمل:** طلاب قسم هندسه الاتصالات والالكترونيات (4 دفعات)، قسم برنامج الهندسة الاتصالات (4 دفعات)
4. **الرسائل العلمية:** رسائل علميه خاصة بالهندسة الاتصالات
5. **الدورات:** لا يوجد
6. **الدراسات العليا:** يوجد محاضرات خاصة بتدريس مواد تمهيدي ماجستير بقسم هندسه الاتصالات والالكترونيات خاصة بتصميم الشبكات
7. **المسابقات:** لا يوجد
8. **الأنشطة:** مشاريع تخرج خاصة بطلاب قسم هندسه الاتصالات والالكترونيات

Experiment 1

AM Modulators

1.1 Educational Objectives:

- ❖ Understanding the principle of amplitude modulation(AM).
- ❖ Understanding the waveform and frequency spectrum of AM signal and calculating the percent of modulation.
- ❖ Designing an amplitude modulator using MC1496.
- ❖ Measuring and adjusting an amplitude modulator circuit

1.2 Reference Readings:

- ❖ Kennedy G., **Electronic Communication Systems**, McGraw-Hill, Third Edition, 1994,
- ❖ D. Roddy and J. Coolen, **Electronic Communications**, Prentice Hall of India, 1995.
- ❖ Young Paul H., **Electronic Communication Techniques**, Merrill Publishing Company, Third Edition 1990.
- ❖ Haykin Simon, **Communication Systems**, John Wiley, 4th Edition, 2001.

1.3 Background Information:

Modulation is the process of impressing a low-frequency intelligence signal onto a high-frequency carrier signal. Amplitude Modulation (AM) is a process that a high-frequency carrier signal is modulated by a low- frequency modulating signal (usually an audio). In amplitude modulation the carrier amplitude varies with the modulating amplitude, as shown in Fig.1-1.

If the audio signal is $Am\cos(2\pi f_m t)$ and the carrier signal is $Ac\cos(2\pi f_c t)$, the amplitude-modulated signal can be expressed by

$$\begin{aligned} x_{AM}(t) &= \left[A_{DC} + A_m \cos(2\pi f_m t)\right] A_c \cos(2\pi f_c t) \\ &= A_{DC}\left[1 + m\cos(2\pi f_m t)\right] A_c \cos(2\pi f_c t) \\ &= A_{DC} A_c \left[1 + m\cos(2\pi f_m t)\right] \cos(2\pi f_c t) \end{aligned} \quad (1\text{-}1)$$

Where

A_{DC} = dc level

Am = audio amplitude

Ac = carrier amplitude

fm = audio frequency

fc = carrier frequency

m = modulation Index or depth of modulation = Am / ADC

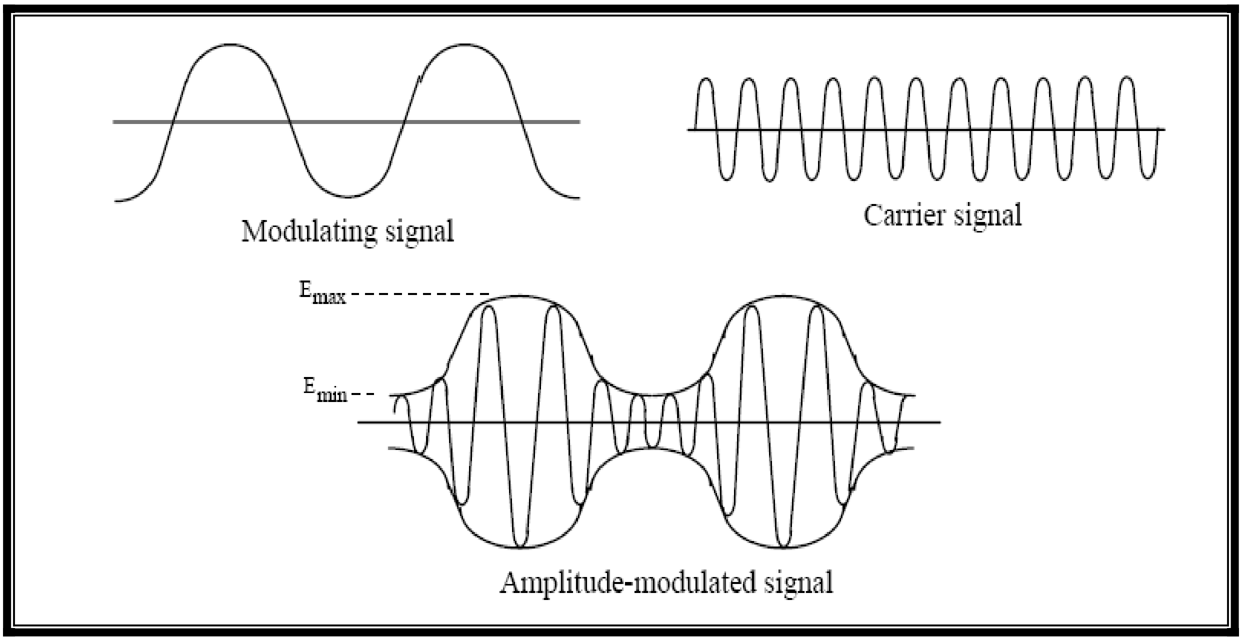


Fig.1-1 Amplitude modulation waveforms

Rewriting Eq. (1-1), we obtain

$$x_{AM}(f) = \frac{1}{2} A_{DC} A_C m \{\cos[2\pi(f_c + f_m)t] + \cos[2\pi(f_c - f_m)t]\}$$
$$+ A_{DC} A_c \cos(2\pi f_c t)$$

(1-2)

The first term on the right side of Eq. (1-2) represents double sideband signal and the second term is the carrier signal. According to Eq. (1-2), we can plot the spectrum of AM modulated signal as shown in Fig. 3-2. In an AM transmission the carrier frequency and amplitude always remain constant, while the side bands are constantly varying in frequency and amplitude. Thus, the carrier contains no message or information since it never changes. This means that the carrier power is a pure dissipation when transmitting an AM signal. Thus, the transmitting efficiency of amplitude modulation is lower than that of double-sideband suppressed carrier (DSB-SC) modulation, but the amplitude demodulator circuit is simpler.

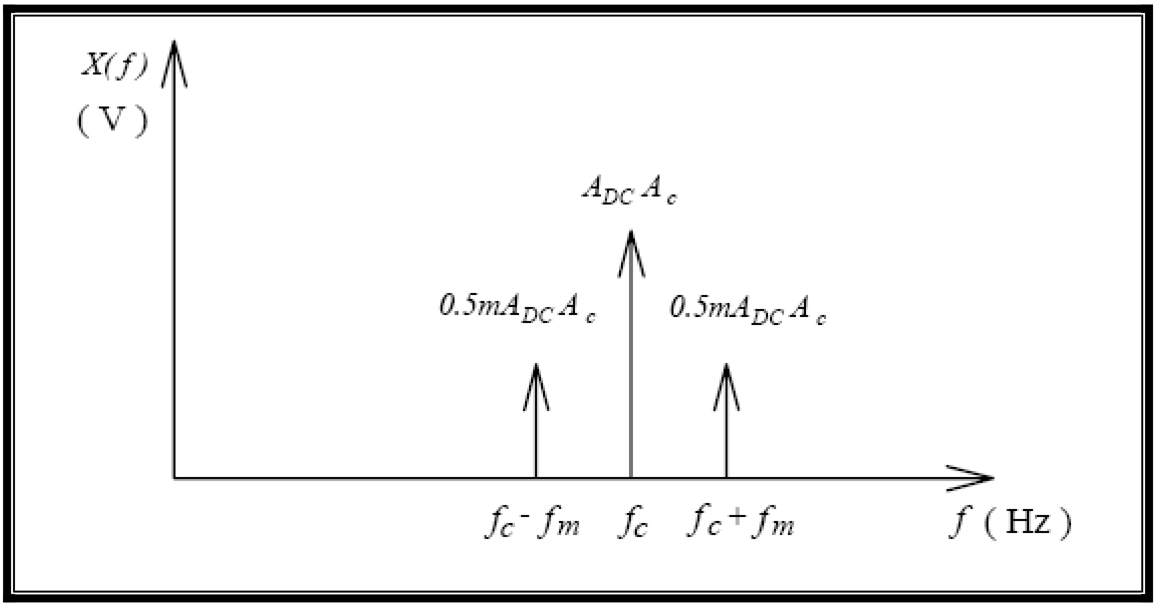


Fig.3-2 Spectrum of AM signal

The m in Eq. (3-1), called modulation index or depth of modulation, is an important parameter. When m is a percentage, it is usually called percentage modulation. It is defined as:

$$m = \frac{Modulating\ Amplitude}{DC\ Level} \times 100\% = \frac{A_m}{A_{DC}} \times 100\% \qquad (1\text{-}3)$$

It is difficult to measure the A*DC* in a practical circuit so that the modulation index is generally calculated by

$$m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \times 100\% \qquad (1\text{-}4)$$

Where $E_{max}=A_c+A_m$ and $E_{min}=A_c-A_m$, *as* indicated in Fig. 1-1.

As mentioned above, audio signal is contained in the side bands so that the greater the sideband signals the better the transmitting efficiency. From Eq. (1-2), we can also find that the greater the modulation index, the greater the sideband signals and the better the transmitting efficiency. In practice, the modulation index is usually less or equal to 1; if m > 1, it is called over modulation.

A comparison between various balanced modulator outputs under various input frequency conditions

Carrier Input	Audio Input	Balanced Modulator Output	Circuit Characteristic
f_c	f_c	$2f_c$	Freq. Doubler
f_c	f_m	f_c, f_c+f_m, f_c-f_m	AM
f_c	f_m	f_c+f_m, f_c-f_m	DSB-SC

In the following experiments we will implement an AM modulator using a monolithic balanced modulator MC1496. According to different input signal frequencies, the MC1496 may be used as a frequency multiplier, an AM modulator, or a double sideband suppressed carrier (DSB-SC) modulator. Table 1-1 shows the summary of different input, output signals and circuit characteristics.

Fig. 1-3 shows the internal configuration of MC1496. The differential amplifier Q5 and Q6 is used to drive the differential amplifiers Q1Q2 andQ3Q4. The constant-current source generator Q7 and Q8 provides the differential amplifier Q5 and Q6 with a constant current. Overall gain of MC1496 can be controlled by externally connecting a resistor between pins 2 and 3. For AM modulation, the modulating signal should be applied to pins 1 and 4, and the carrier to pins 8 and 10. The bias current to pin 5 is commonly provided by connecting a series resistor from this pin to the power supply.

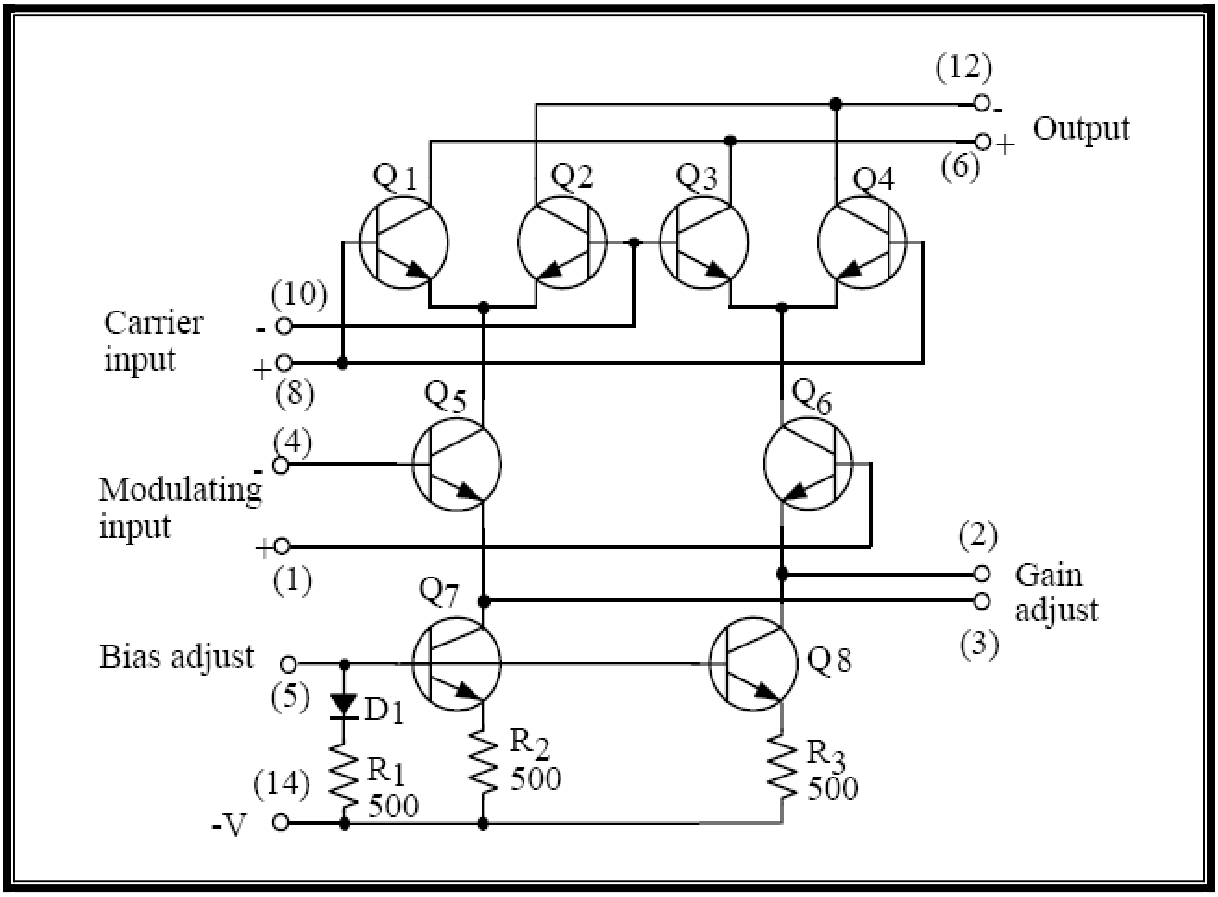


Fig.3-3 MC1496 internal circuit

Fig. 1-4 shows an AM modulator circuit, whose carrier and audio signals are single-ended inputs, carrier to pin 10 and audio to pin 1. The gain of entire circuit is determined by the R8 value. The R9 determines the amount of bias current. Adjusting the amount of VR1 or the audio amplitude can change the percentage modulation.

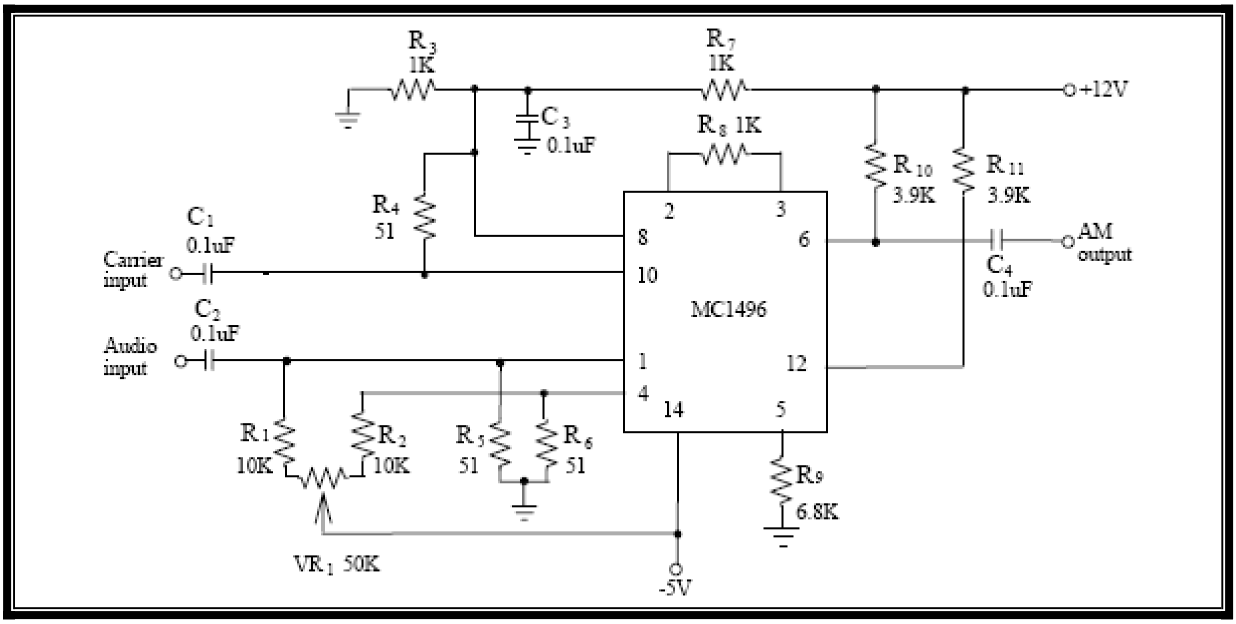


Fig.3-4 Amplitude modulator using MC1496

1.4 EQUIPMENTREQUIRED

1. ModuleKL-92001
2. ModuleKL-93002
3. Oscilloscope
4. Spectrum Analyzer
5. RF Generator

EXPERIMENT2

AM DEMODULATORS

2.1 EDUCATIONAL OBJECTIVES:

- Understanding the principle of amplitude demodulation.
- Implementing an amplitude demodulator with diode.
- Implementing an amplitude demodulator with a product detector.

2.2 REFERENCE READINGS:

- Kennedy G., **Electronic Communication Systems**, Mc GRW-Hill, Third Edition, 1994,
- D. Roddy and J. Coolen, **Electronic Communications**, Prentice Hall of India,1995.
- Young Paul H., **Electronic Communication Techniques**, Merrill Publishing Company, Third Edition 1990.
- Haykin Simon, **Communication Systems**, John Wiley, 4^{th} Edition, 2001.

2.3 BACKGROUND INFORMATION:

A demodulation process is just the opposition of a modulation process. As noticed in Chapter 3, an AM signal is a modulated signal that is high- frequency carrier amplitude varied with low-frequency audio amplitude for transmission. To recover the audio signal in receiver, it is necessary to extract the audio signal from an AM signal. The process of extracting a modulating signal from a modulated signal is called demodulation or detection. It is shown in Fig.2-1.

In general, detectors can be categorized into two types: synchronous and asynchronous detectors. We will discuss these two types of AM detectors in the rest of this chapter.

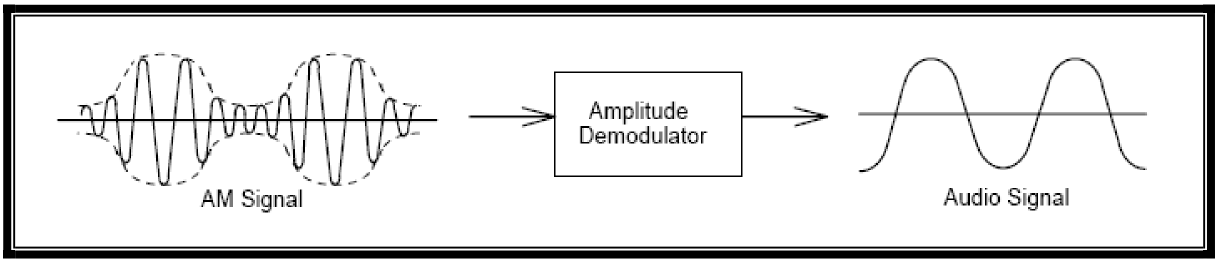


Fig.2-1 illustration of an amplitude demodulation

- **Diode Detector**

Since an AM modulated signal is the signal that the carrier amplitude varies with the modulating amplitude, a demodulator is used to extract the original modulating signal from the AM signal.

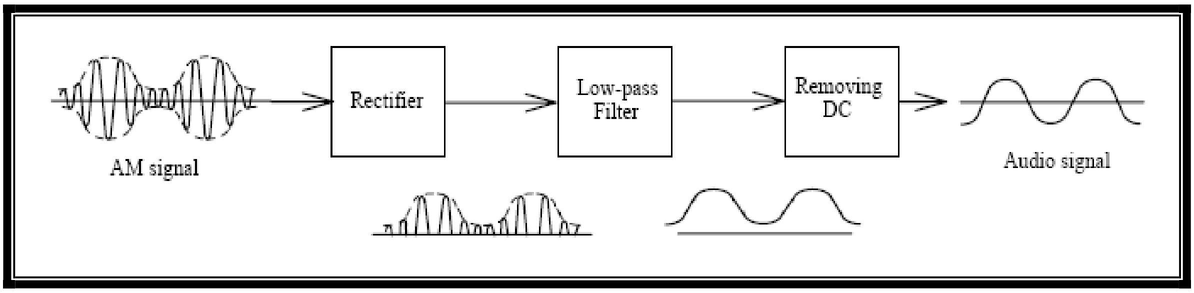


Fig.2-2 Block diagram of a rectified demodulator

The block diagram of diode detector, shown in Fig. 2-2, is a typical asynchronous detector. The AM modulated signal including both positive- half and negative-half envelope waves is applied to the input of the rectifier. The rectified output signal is the positive half envelope plus a dc level and is fed into a low-pass filter whose output is the original modulating signal with dc level. Then the modulating signal will be recovered by removing the dc voltage.

Fig. 2-3 shows a practical diode detector circuit. The components R1, R2, R3, R4, U1 and U2 constitute two inverting amplifiers connected in cascading to offer a proper gain for the AM signal. The amplified AM signal is rectified by D1 diode and then fed into the input of the low-pass filter constructed by C2, C3 and R5. The output signal of low-pass filter is the positive-half envelope with a dc level. The capacitor C4 is used to pass the ac components while blocking the dc component.

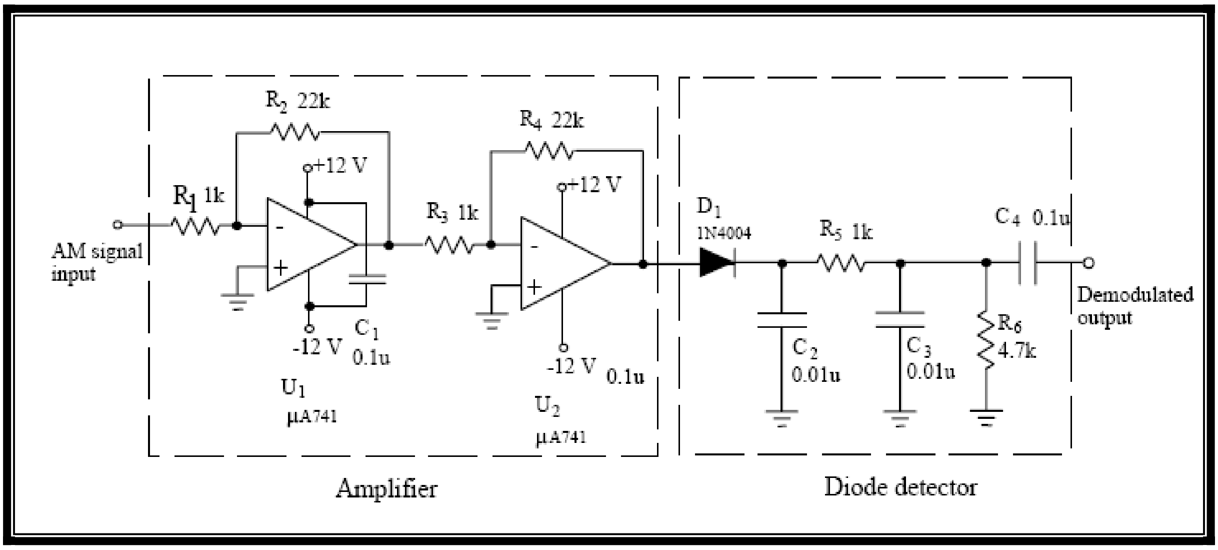


Fig.2-3 Diode detector circuit

• Product Detector

Demodulation for AM signal can be also accomplished with the balanced modulator discussed before. Such demodulator is called synchronous detector or product detector. Fig. 2-4 provides the internal circuit of MC1496 balanced modulator. See the discussion in Chapter 3 for details. If $x_{AM}(t)$ represents the AM signal and $x_C(t)$ is the carrier, and are expressed by

$$x_{AM}(t) = V_{DC}\left[1 + m\cos(2\pi f_m t)\right]\left[V_c \cos(2\pi f_c t)\right] \tag{2-1}$$

$$\boxed{x_c(t) = V_c \cos(2\pi f_c t)} \qquad (2\text{-}2)$$

If these two signals are connected to the inputs of balance demodulator, then the output of balance demodulator will be

$$\boxed{\begin{aligned} x_{out}(t) &= kx_c(t) \times x_{AM}(t) \\ &= kV_{DC}V_c^{\,2}\left[1 + m\cos(2\pi f_m t)\right]\cos^2(2\pi f_c t) \\ &= \frac{kV_{DC}V_c^{\,2}}{2} + \frac{kV_{DC}V_c^{\,2}}{2} m\cos(2\pi f_m t) \\ &\quad + \frac{kV_{DC}V_c^{\,2}}{2}\left[1 + m\cos(2\pi f_m t)\right]\cos\left[2(2\pi f_c t)\right] \end{aligned}} \qquad (2\text{-}3)$$

Where *k* is the gain of balanced modulator. The first term on the right side of Eq. (2-3) represents dc level, the second term is the modulating signal, and the third term is the second-order harmonic signal. To recover the modulating signal, the intelligence must be extracted from the AM signal *xout*(*t*).

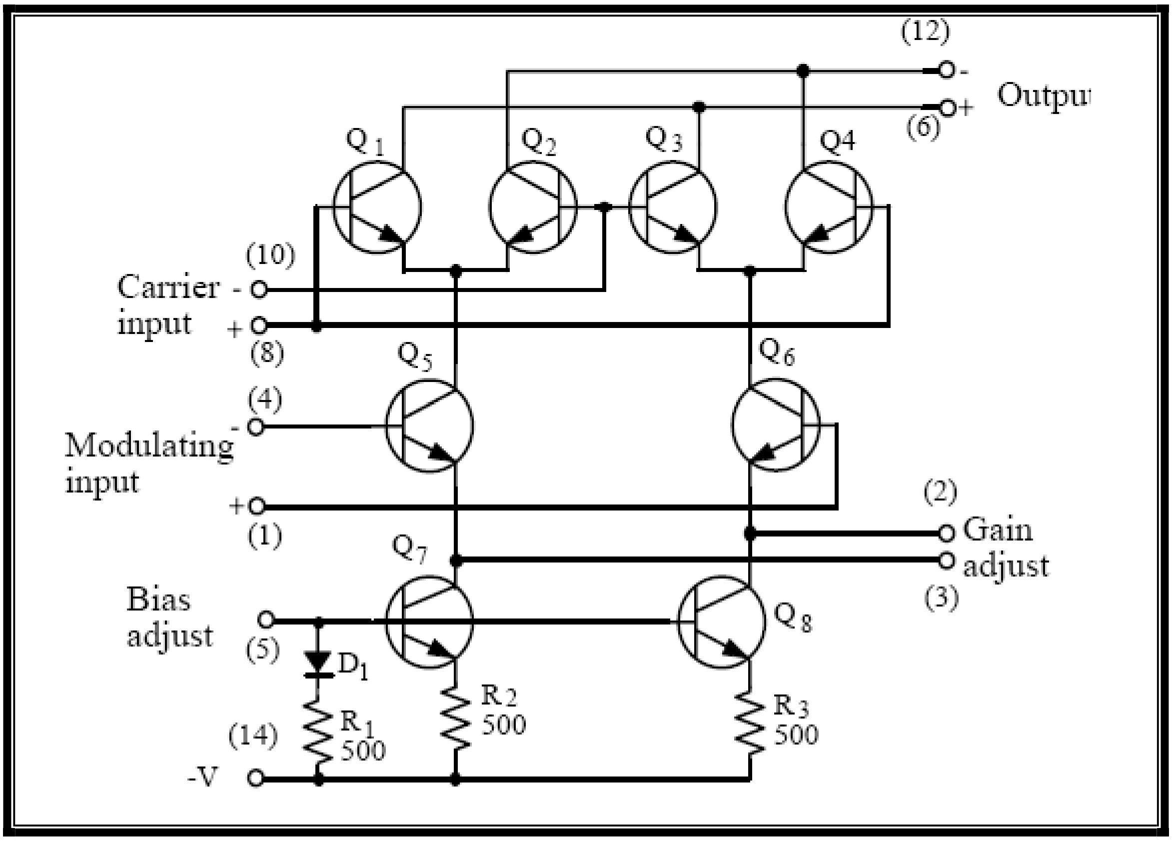


Fig. 2-4 MC 1496 internal circuit

Fig. 2-5 shows the product detector circuit. The VR1 controls the input level of the carrier signal. The output signal from the MC1496 pin 12 is expressed by Eq. (2-3). The low-pass filter constructed by C7, C9 and R9 is used to remove the third term, which is the second-order harmonic signal in the AM modulated signal. The first term of Eq. (2-3) is the dc level that can be blocked by the capacitor C10. The amplitude demodulated output signal can be given by

$$\boxed{x_{out}(t) = \frac{kV_{DC}V_c^{\,2}}{2} m\cos(2\pi f_m t)} \tag{2-4}$$

Eq. (2-4) represents the audio signal. In other words, the product detector has extracted the audio signal from the AM signal.

From the discussion above, we can conclude that the diode detector is an asynchronous detector whose circuit is simple but quality is bad. The product detector is a synchronous detector whose quality is excellent but the circuit is more complicated and the carrier signal must exactly synchronize with the AM signal.

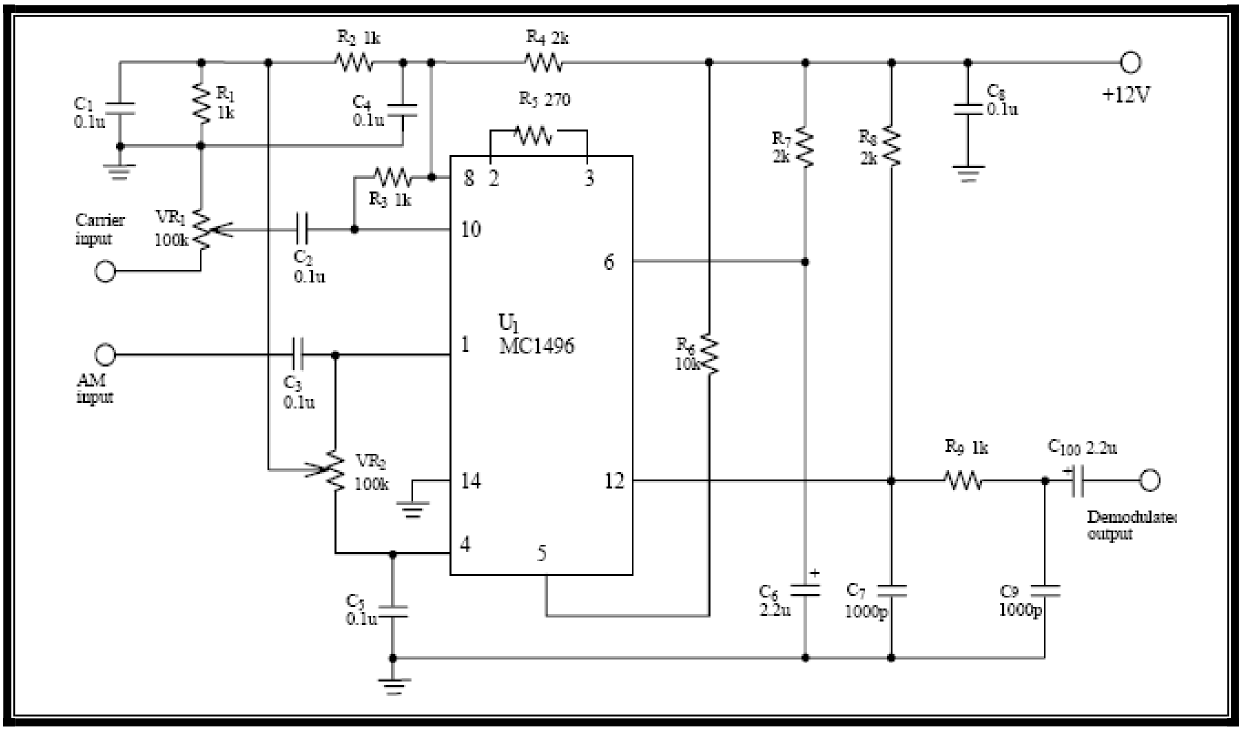


Fig. 2-5 Product detector circuit

2.4 EQUIPMENT REQUIRED

1. Module KL-92001
2. Module KL-93002
3. Oscilloscope
4. RF Generator

EXPERIMENT3

FM MODULATORS

3.1 EDUCATIONAL OBJECTIVES:

- ❖ Studying the operation and characteristics of varactor diode.
- ❖ Understanding the operation of voltage controlled oscillator.
- ❖ Implementing a frequency modulator with voltage-controlled oscillator.

REFERENCE READINGS:

- ❖ Kennedy G., **Electronic Communication Systems**, McGRW-Hill, Third Edition,1994,
- ❖ D. Roddy and J. Coolen, **Electronic Communications**, Prentice Hall of India,1995.
- ❖ Young Paul H., **Electronic Communication Techniques**, Merrill Publishing Company, Third Edition1990.
- ❖ Haykin Simon, **Communication Systems**, John Wiley, 4th Edition, 2001.

3.2 BACKGROUND INFORMATION:

- **Principle of Frequency Modulation Operation:**

Frequency modulation (FM) is a process in which the carrier frequency is varied by the amplitude of the modulating signal (i.e., intelligence signal). The FM signal can be expressed by the following equation:

$$x_{FM}(t) = A_c \cos\theta(t) = A_c \cos\left[2\pi f_c t + 2\pi f_\Delta \int x(\lambda)d\lambda\right]$$

(3-1)

If $x(\lambda)=A_m\cos(2\pi f_m\lambda)$, then

$$\boxed{\begin{aligned} x_{FM}(t) &= A_c \cos\left[2\pi f_c t + \frac{f_\Delta A_m}{f_m}\sin(2\pi f_m t)\right] \\ &= A_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)] \end{aligned}}$$

(3-2)

Where

$\theta(t)$ = instantaneous modulated frequency

fc = carrier frequency

FM = modulating frequency

β = modulation index = $Am\,(f_\Delta / FM)$

The frequency of FM signal $x_{FM}(t)$ may be expressed as

$$\boxed{\begin{aligned} f &= \frac{1}{2\pi}\frac{d}{dt}\theta(t) = \frac{1}{2\pi}\frac{d}{dt}[2\pi f_c t + \beta \ \sin(2\pi f_m t)] \\ &= f_c - f_m\beta \ \cos(2\pi f_m t) \end{aligned}}$$

(3-3)

From Eq. (3-3) we can find that the frequency of frequency modulated signal occurs frequency deviation from the center frequency of the carrier when the intelligence amplitude is variation.

- <u>**Varactor Diode:**</u>

The varactor diode, sometimes called tuning diode, is the diode whose capacitance is proportional to the amount of the reverse bias voltage across p-n junction. Increasing the reverse bias voltage applied across the diode decreases the capacitance due to the depletion region width becomes wider.

Conversely, when the reverse bias voltage decreased, the depletion region width becomes narrower and the capacitance increased. When an ac voltage is applied across the diode, the capacitance varies with the change of the amplitude.

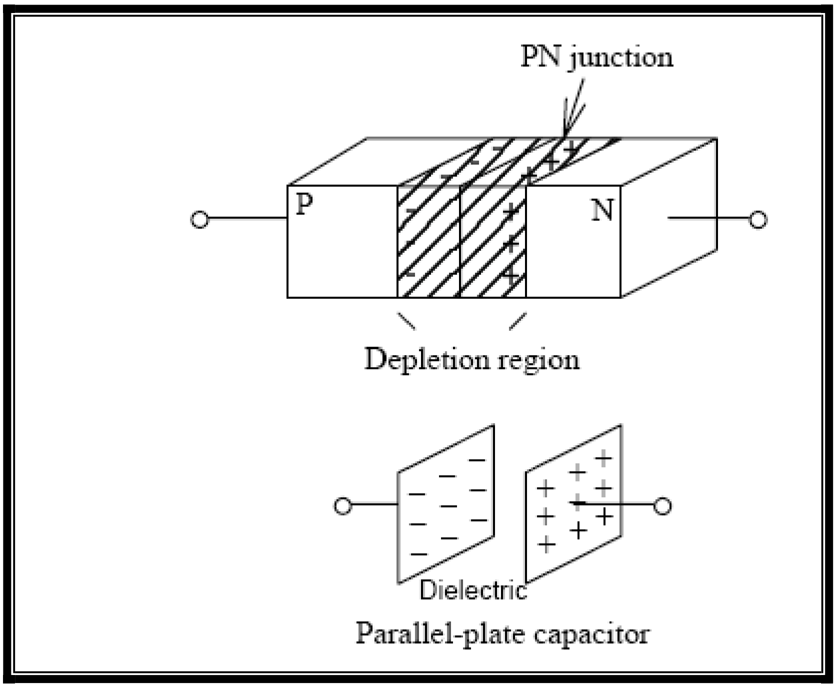


Fig. 3-1 Relationship between reactor diode and capacitor

A relationship between a varactor diode and a conventional capacitor is shown in Fig. 3-1. In fact, a reverse-biased varactor diode is similar to a capacitor. When a p and n semiconductors combined together, a small depletion region is formed because of the diffusion of minority carriers. The positive and negative charges occupy n and p sides of junction, respectively. This just likes a capacitor. The amount of internal junction capacitance can be calculated by the capacitance formula

$$\boxed{C = \frac{\varepsilon A}{d}} \qquad (3\text{-}4)$$

Where

$\varepsilon = 11.8\ \varepsilon_0$ = dielectric constant

$\varepsilon_o = 8.85 \times 10^{-12}$

A= cross area of capacitor

d = width of depletion region

From the formula above, we know that the varactor capacitance is inversely proportional to the width of depletion region (or the distance between plates) if the area *A* is constant. Therefore, a small reverse voltage will produce a small depletion region and a large capacitance. In other words, an increase in reverse bias will result in a large depletion region and a small capacitance.

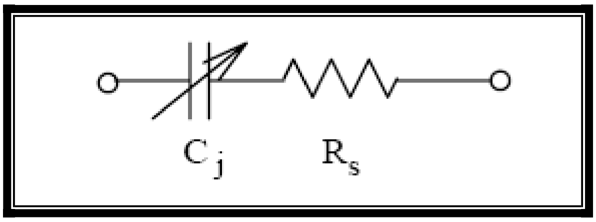


Fig.3-2 the equivalent circuit of varactor diode

A varactor diode can be considered as a capacitor and resistor connected in series as shown in Fig. 3-2. The CJ is the junction capacitance between p and n junctions. The Rs is the sum of bulk resistance and contact resistance, approximately several ohms, and it is an important parameter determining the quality of varactor diode.

Tuning ratio (TR) is defined as the ratio of the capacitance of varactor diode at the reverse voltage V2 to that at another reverse voltage V1, and can be expressed by

$$\boxed{TR = \frac{C_{V2}}{C_{V1}}} \qquad (3\text{-}5)$$

Where

TR = tuning ratio

C_{V1} = capacitance of varactor diode at $V1$

C_{V2} = capacitance of varactor diode at $V2$

The 1SV55 varactor diode is used in our experiments and its major characteristics are

C_{3V} = 42 pF (capacitance of varactor diode at 3V)

TR = 2.65 (at 3V →30V)

- **<u>Frequency Modulator Based on MC1648VCO:</u>**

In our experiments we will implement the frequency modulator with MC1648 VCO chip shown in Fig. 3-3. Basically, this circuit is an oscillator and the tuning circuit at input end determines its oscillating frequency. In this circuit, capacitors C2 and C3 are the bypass capacitors for filtering noise. When operating at a high frequency (for example 2.4 MHz), the capacitive reactance of these two capacitors are very small and can be neglected for practical purposes.

Therefore, an ac equivalent circuit of tuning tank, shown in Fig. 3-4, is a parallel LC resonant circuit. The C can be considered as the capacitance of 1SV55 (Cd) and the input capacitance of MC1648 (Cin) connected in parallel. The value of Cin is approximately 6 pF. If we neglect the spray capacitance, the oscillating frequency can be calculated by the formula

$$\boxed{f_O = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{L(C_d + 6\times10^{-12})}} \quad (\text{Hz})} \tag{3-6}$$

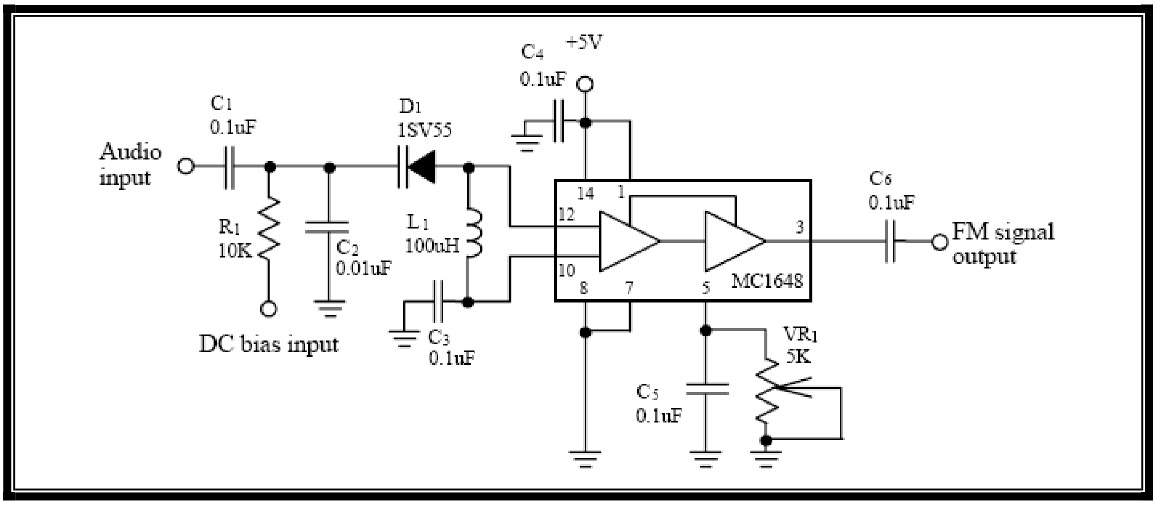


Fig.3-3 MC1648 FM modulator circuit

As mentioned above, the capacitance Cd of varactor diode D1 varies with the amount of its reverse bias voltage. According to Eq. (3-6), we know that the change of Cd value will cause the change of oscillating frequency. In the circuit of Fig. 3-3, a small dc bias will produce a large Cd value and a low frequency output. On the other hand, an increase in dc bias will result in a small Cd value and a high frequency output. Therefore, if the dc bias is fixed and an audio signal is applied to this input, the VCO output signal will be a frequency- modulated signal.

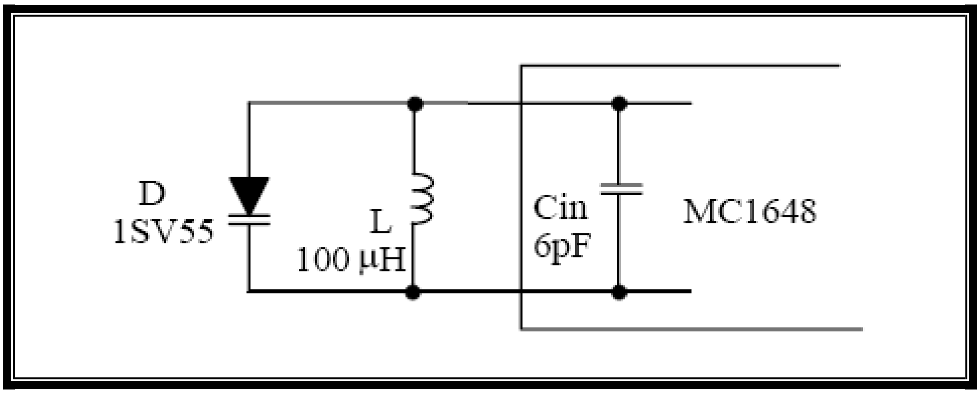


Fig.3-4 AC equivalent circuit of tuning tank

- **<u>Frequency Modulator Based on LM566VCO:</u>**

The circuit of Fig. 3-5 is a frequency modulator based on voltage-controlled oscillator (VCO) IC, LM566. If the SW1 is open, this circuit is a typical VCO whose output frequency is determined by the values of C3 and VR1, and the audio input voltage. If the values of C3 and VR1 are fixed, the output frequency is directly proportional to the voltage difference between pins 8 and 5, (V8-V5). In other words, an increase in audio input voltage (V5) causes a decrease in the value of (V8-V5) and a decrease in the output frequency. Conversely, decreasing the audio input voltage (V5) will cause the output frequency to increase. As discussed above, the values of C3 and VR1 can also determine the output frequency, which is inversely proportional to the product of VR1 and C3. That is, the greater the VR1×C3 value the lower the output frequency.

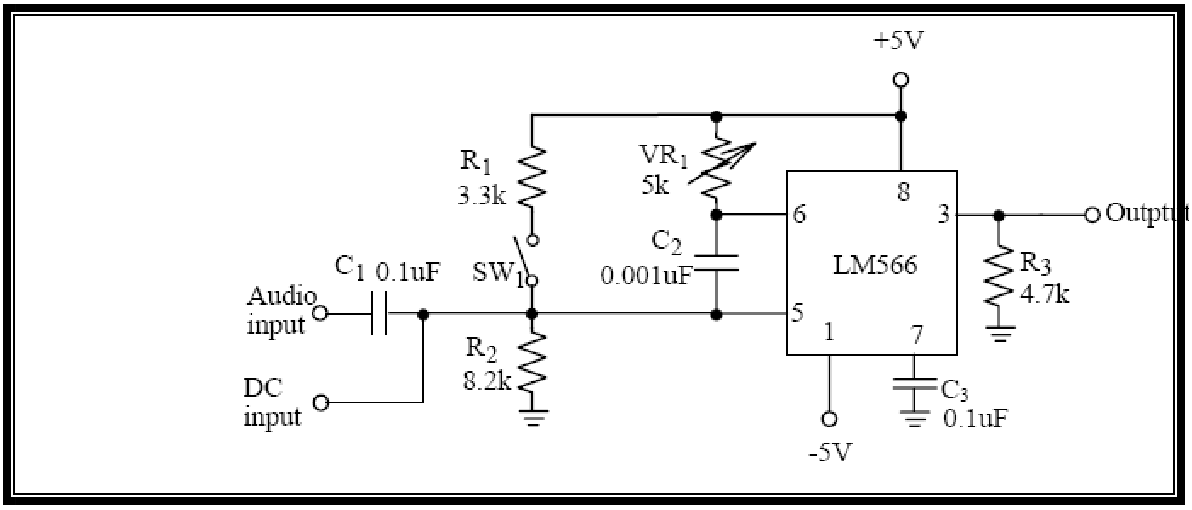


Fig.3-5 LM566 frequency modulator circuit

If the SW1 is closed, the voltage divider constructed by R1 and R2 provides a dc level to the audio input (pin 5). By adjusting the VR1, we can easily tune the VCO center frequency *fo*. When an audio signal is applied to the audio input, the output frequency will generate frequency deviations around *fo* in the variations of audio amplitude. Thus, a frequency-modulated signal is obtained.

3.3 EQUIPMENTREQUIRED

1. ModuleKL-92001
2. ModuleKL-93004
3. Oscilloscope
4. Spectrum Analyzer

Experiment4

FM Demodulators

4.1 Educational Objectives:

- Studying the principle of phase-locked loop.
- Understanding the characteristics of the PLLLM565.
- Demodulating FM signal using PLL.
- Demodulating FM signal using FM to AM conversion discriminator

4.1 Reference Readings:

- Kennedy G., **Electronic Communication Systems**, McGRW-Hill, Third Edition,1994,
- D. Roddy and J. Coolen, **Electronic Communications**, Prentice Hall of India,1995.
- Young Paul H., **Electronic Communication Techniques**, Merrill Publishing Company, Third Edition1990.
- Haykin Simon, **Communication Systems**, John Wiley, 4th Edition, 2001.

4.2 Background Information:

Frequency demodulator, also called frequency discriminator, is a circuit, which converts instantaneous frequency variations to linear voltage changes. There are many types of circuit used in communication system such as FM to AM conversion, balanced, and phase-shift discriminators and phase-locked loop (PLL) frequency demodulator. In this experiment we will introduce the operations of PLL frequency demodulator and FM to AM conversion discriminator.

- **Phase-Locked Loop (PLL)operation**

The PLL is an electronic feedback control system, as illustrated by the block diagram in Fig. 4-1, of locking the output and input signals in good agreements in both frequency and phase. In radio communication, if a carrier frequency drifts due to transmission, the PLL in receiver circuit will track the carrier frequency automatically.

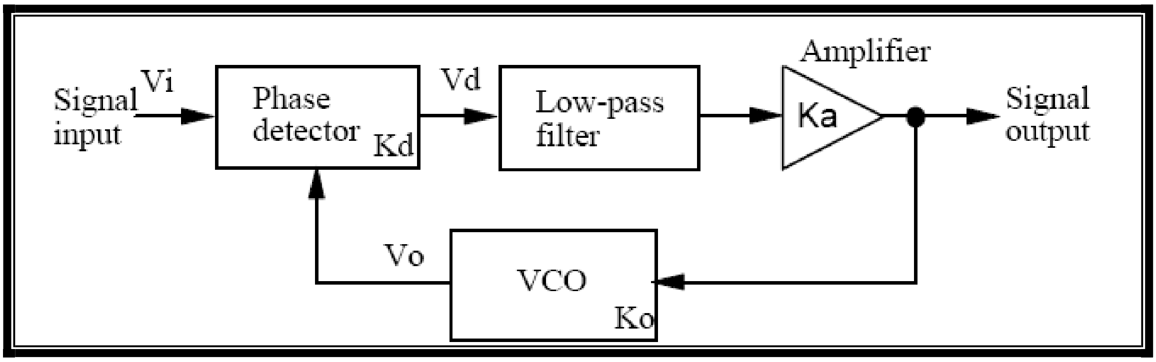


Fig.4-1 PLL block diagram

The PLL in the following experiments is used in two different ways: (1) as a demodulator, where it is used to follow phase or frequency modulation and (2) to track a carrier signal which may vary in frequency with time. In general, a PLL circuit includes the following sections:

1. Phase Detector(PD)
2. Low Pass Filter(LPF)
3. Voltage Controlled Oscillator(VCO)

The phase detector within the PLL locks at its two inputs and develops an output that is zero if these two input frequencies are identical. If the two input frequencies are not identical, then the output of detector, when passed through the low-pass filter removing the ac components, is a dc level applied to the VCO input. This action closes the feedback loop since the dc level applied to the VCO input changes the VCO output frequency in an attempt to make it exactly match the input frequency. If the VCO output frequency equals the

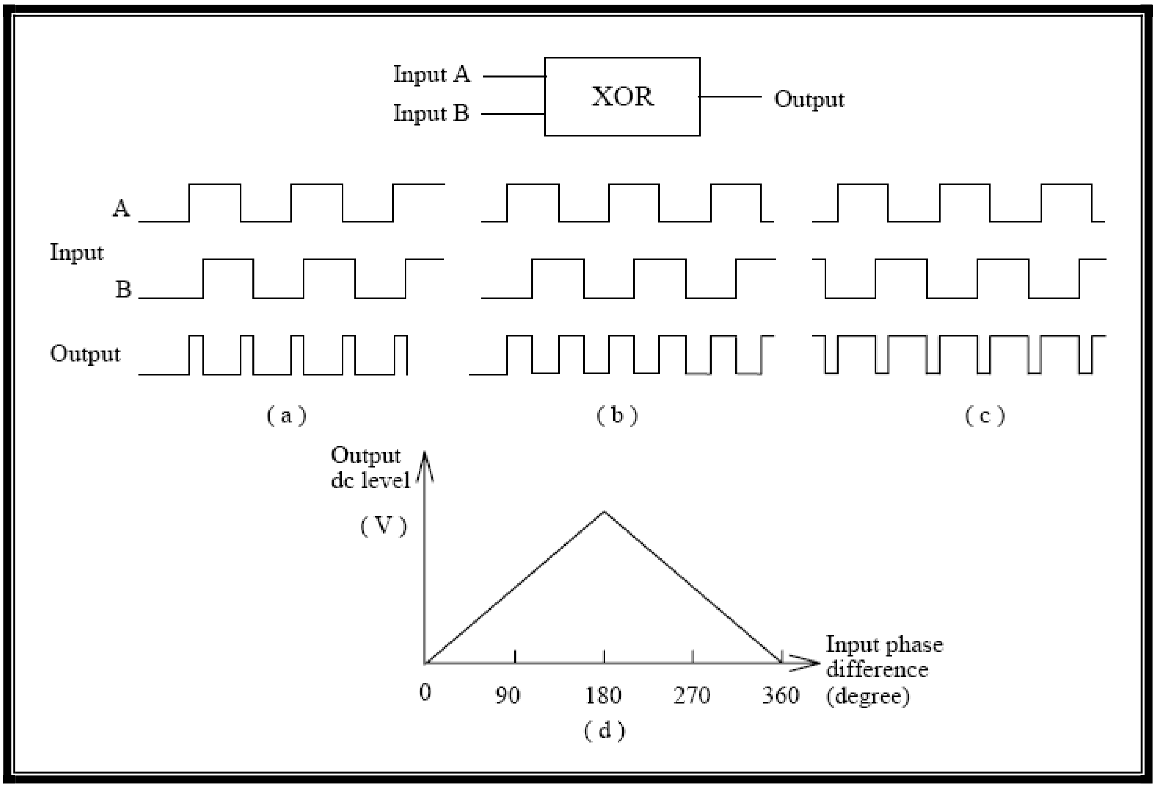


Fig.4-2 Phase detection

A better understanding of the operation of phase detector may be obtained by considering that the simple EXCULSIVE-OR (XOR) gate is used as a phase detector. The XOR gate can be thought of as an inequality detector which compares the inputs and produces a pulse output when these inputs are unequal. The width of the output pulse is proportional to the phase error of the input signals. As shown in Fig. 4-2, the width of the output pulse of (b) is larger than that of (a) and is smaller than that of (c). When the output of phase detector is applied to the input of low-pass filter, the output of low-pass filter should be a dc level that is directly proportional to the pulse width. In other words, the output dc level is proportional to the phase error of input signals. Fig. 4-2(d) shows the relationship between the input phase error and the output dc level.

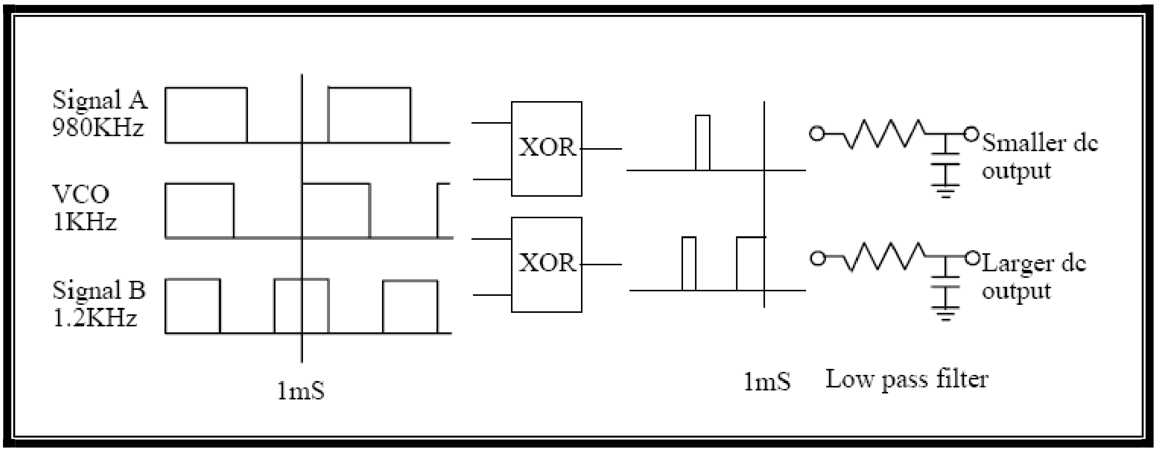


Fig.4-3 Operation of frequency locking

For a further understanding of the operation of the PLL can be obtained by considering that initially the PLL is not in lock. The VCO has an input voltage of 2V and is running at its free-running frequency, say 1 kHz. Consider the signals shown in Fig. 4-3. If the VCO frequency and the signal A with the lower frequency 980Hz are applied to the inputs of the phase detector XOR, the narrower width of output pulse will cause the low-pass filter obtaining the smaller output voltage of 1V. This smaller voltage decreases the VCO frequency close to the input frequency. If the VCO output frequency equals the input frequency, lock will result. On the contrary, the higher frequency 1.2 KHz of input signal B causes the larger filter output of 3V that increases the VCO frequency output to lock at the input frequency.

- **<u>LM565 PLL Basic Characteristics</u>**

The LM565 is a general-purpose phase-locked loop and is widely used in frequency demodulation. In designing with the LM565, the important parameters of interest are as follows:

1. Free-running Frequency

Fig. 4-4 shows a PLL circuit with LM565. In the absence of the input signal, the output frequency of the VCO is called the free-running frequency fo. In the PLL circuit of Fig. 4-4, the free-running frequency of LM565 is determined by the timing components C2 and VR1, and can be found by

Free running frequency
$$\boxed{f_o = \frac{1}{3.7 VR_1 C_2}}$$

Closed loop gain
$$\boxed{K_L = K_d K_a K_o = \frac{33.6 f_o}{V_c}}$$

where Vc = total supply voltage to the circuit = Vcc-(-Vcc) =5V-(-5V) = 10V

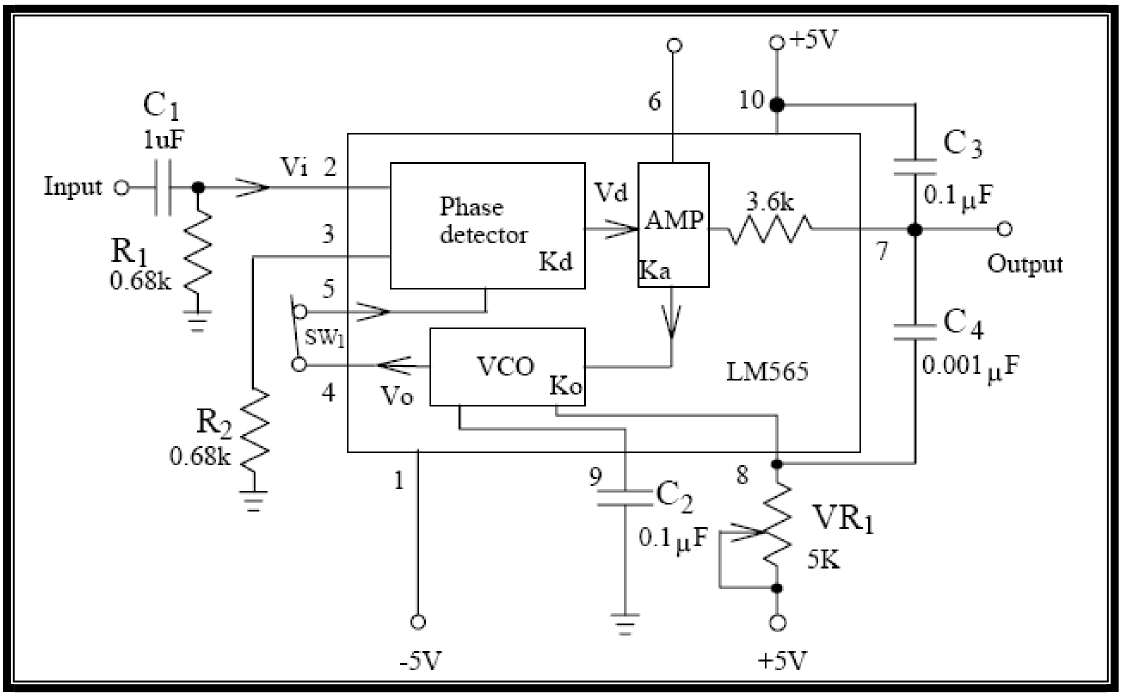


Fig.4-4 LM565 PLL

2. Lock Range:

Initially, the PLL is in already-locked state and the VCO is running at some frequency. If the input frequency *fi* is away from the VCO frequency *fo*, locking may still occur. When the input frequency reaches a specific frequency where the PLL loses lock, the frequency difference of *fi* and *fo* is called the lock range of the loop. The lock range of LM565 can be found by

$$\boxed{f_L = \frac{8f_O}{V_C}} \qquad (4\text{-}3)$$

3. Capture Range:

Initially, the loop is unlocked and the VCO is running at some frequency. If the input frequency *fi* is close to the VCO frequency *fo*, unlocking may maintain.

When the input frequency reaches a specific frequency where the PLL locks, the frequency difference of *fi* and *fo* is called the capture range of the loop. The capture range of LM565 can be found by

$$\boxed{f_c = \left(\frac{1}{2\pi}\right)\sqrt{\frac{2\pi \times f_L}{3.6 \times 10^3 \times C_2}}} \qquad (4\text{-}4)$$

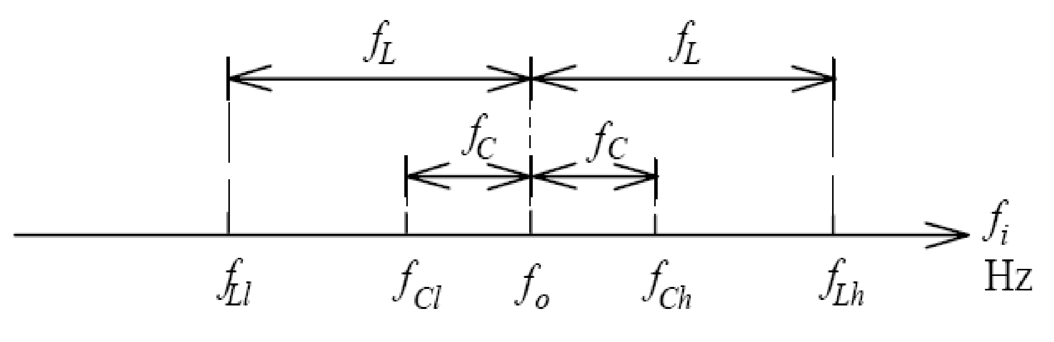


Fig.4-5 Illustration of lock and capture ranges

- **Frequency Demodulator Based on LM565PLL**

The PLL circuit of Fig. 4-4 can be used as a frequency demodulator. When the input signal increases in frequency, the output signal decreases in voltage.

Inversely, if the input signal decreases in frequency, the output signal will increase in voltage.

The VCO circuit of the LM565 is equivalent to that of the LM566. The free-running frequency *fo* of the VCO is determined by the values of external components C2 and VR1. The internal resistor 3.6 kΩ (pin7) and the external capacitor C3 form a low-pass filter. The capacitor C4 connected between pins 7 and 8 is a frequency compensation capacitor.

- **FM-to-AM Conversion Discriminator:**

Fig. 4-6 shows the blocks of FM to AM discriminator. The inputs FM signal is first converted into the AM signal by the differentiator, and then the output AM signal is demodulated by the envelope detector to recover the original audio signal.

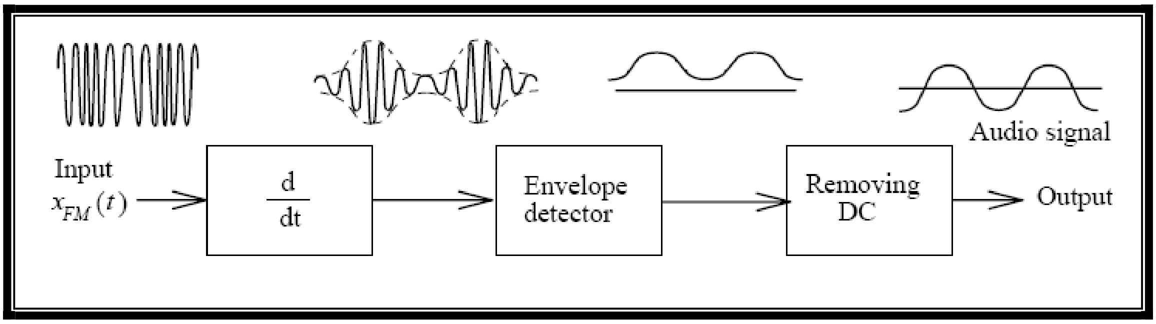


Fig.4-6 Block diagram of FM-to-AM conversion discriminator

in Fig. 4-6, if input signal *xFM* (*t*) is

$$x_{FM}(t) = A_c \cos\theta(t) = A_c \cos\left[2\pi f_c t + 2\pi f_\Delta \int^t x(\lambda)d\lambda\right]$$

Then the differentiator output will be

$$\boxed{\begin{aligned} x'_{FM} &= -A_c\theta'(t)\sin\theta(t) \\ &= -2\pi A_c\left[f_c + f_\Delta x(t)\right]\sin\left[\theta(t)+180^\circ\right] \end{aligned}} \quad (4\text{-}6)$$

From Eq. (4-6) above, the amplitude of $x'_{FM}(t)$ signal vary with the variation of $x(t)$ amplitude. Thus the $x'_{FM}(t)$ signal is an amplitude modulated signal. If this AM signal passes through an envelope detector, the audio signal will be recovered.

The circuit of Fig.4-7 is a frequency discriminator with FM-to-AM conversion technique. The components U1, C1, C2, R1 and R2, operate as a differentiator. The inverting amplifier U2 with a gain of - R4 /R3, and the AM peak detector including D1, R5, R6, C4 and C5. The coupling capacitor C6 is used to block the dc level.

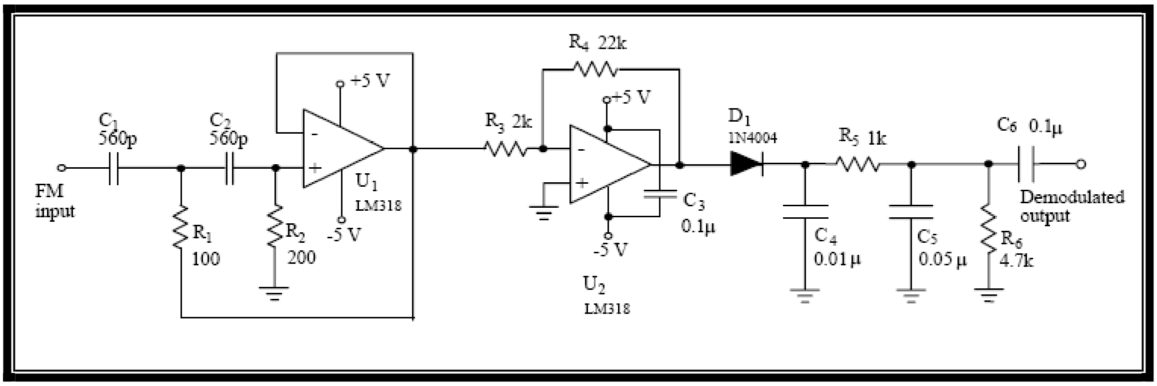


Fig.4-7 FM to AM conversion discriminator circuit

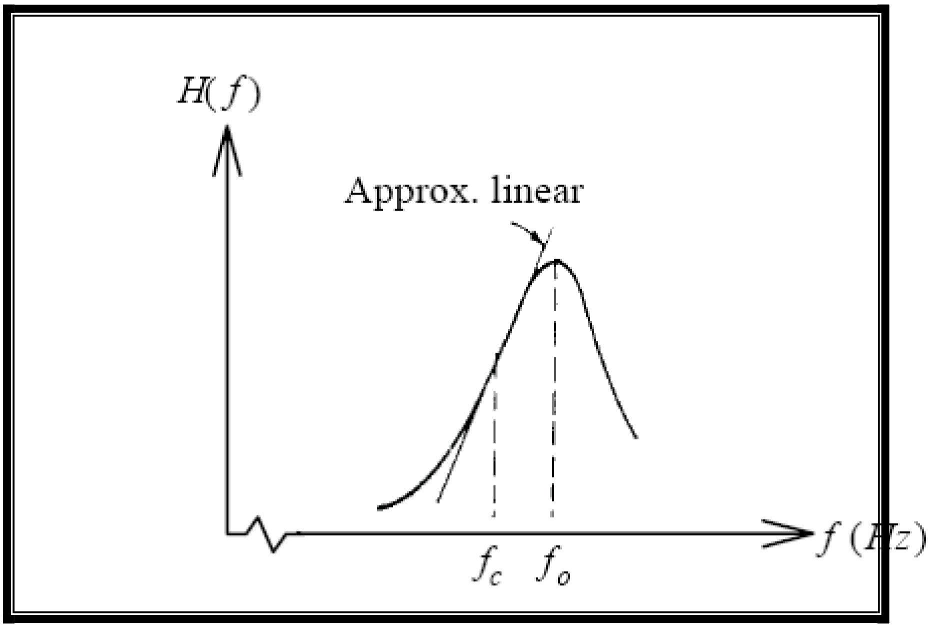


Fig.4-8 Frequency response of band pass filter

Excepting various frequency demodulators mentioned above, LC band pass filters are popularly available in the use of frequency demodulation in ultrahigh and microwave frequency ranges. Fig. 4-8 shows the response of band pass filter. The linear portion on the curve where the voltage variation is proportional to the frequency variation meets the requirement of a discriminator.

4.3 EQUIPMENT REQUIRED

1. ModuleKL-92001
2. ModuleKL-93004
3. Oscilloscope

Experiment5

R-C Couple Amplifier

Aim: To construct a two stage R-C Coupled amplifier, to study the frequency response of the amplifier and to determine the bandwidth.

Apparatus: Two identical n-p-n transistors, power supply (0-15V), signal generator (0 – l MHz), Carbon resistors, Capacitors, a.c. milli-voltmeter and connecting terminals.

Formula: $Voltage\ Gain(G) = \frac{V_0}{V_i}$

Where V_o = Output voltage V_i = Input voltage

Bandwidth of the amplifier = f_2 - f_1KHz

where f_1 = lower half-power (cut-off) frequency f_2 = upper half-power (cut-off)frequency

Description: - D.C. power supply, the resistances R_1, R_2 and R_E provides potential divider biasing and stabilization network. i.e. It establishes a proper operating point to get faithful amplification. R_E reduces the variation of collector current with temperature. The potential divider bias provides forward bias to the emitter junction and reverse bias to the collector junction. Since the emitter is grounded, it is common to both input and output signals. Therefore, the amplifier is common-emitter amplifier. Capacitor C_{in} (= 10 uF) isolates the d.c. component and the internal resistance of the signal generator and couples the a.c. signal voltage to the base of the transistor. The capacitor C_E connected across the emitter resistor $R_E$is of large value (= 100 uF) offers a low reactance path to the alternating component of emitter current and thus bypasses resistor R_E at audio frequencies. Consequently, the potential difference across $R_E$is due to the d.c. component of the current only.

The coupling capacitor C_c (= 10 μF) couples the output of the first stage of amplifier to the input of the second stage. It blocks the d.c. voltage of the first stage from reaching the base of the second stage. The output voltage is measured between the collector and emitter terminals.

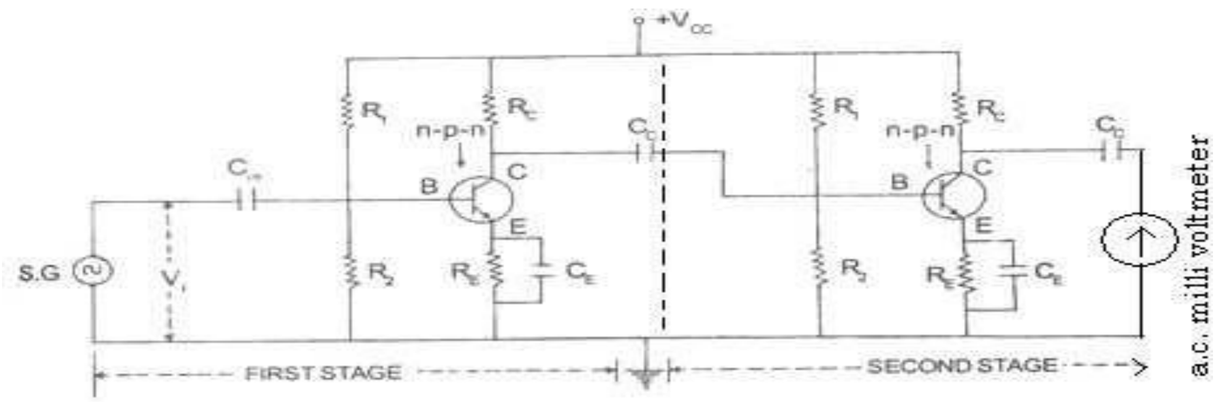


Fig. 1

<u>THEORY</u>: - When a.c. signal is applied to the base of the first transistor, it is amplified and developed across the out of the 1st stage. This amplified voltage is applied to the base of next stage through the coupling capacitor C_c where it is further amplified and reappears across the output of the second stage. Thus the successive stages amplify the signal and the overall gain is raised to the desired level. Much higher gains can be obtained by connecting a number of amplifier stages in succession (one after the other). Resistance-capacitance (RC) coupling is most widely used to connect the output of first stage to the input (base) of the second stage and so on. It is the most popular type of coupling because it is cheap and provides a constant amplification over a wide range of frequencies. **Fig. 1** shows the circuit arrangement of a two stage RC coupled CE mode transistor amplifier where resistor R is used as a load and the capacitor C is used as a coupling element between the two stages of the amplifier.

Frequency response curve

The curve representing the variation of gain of an amplifier with frequency is known as frequency response curve. It is shown in **Fig. 2**. The voltage gains of the amplifier increases with the frequency, f and attains a maximum value. The maximum value of the gain remains constant over a certain frequency range and afterwards the gain starts decreasing with the increase of the frequency. It may be seen to be divided into three regions. 1) Low frequency range (<50 Hz) 2) Mid frequency range (50 Hz to 20 KHz) and 3) High frequency range (> 20 kHz).

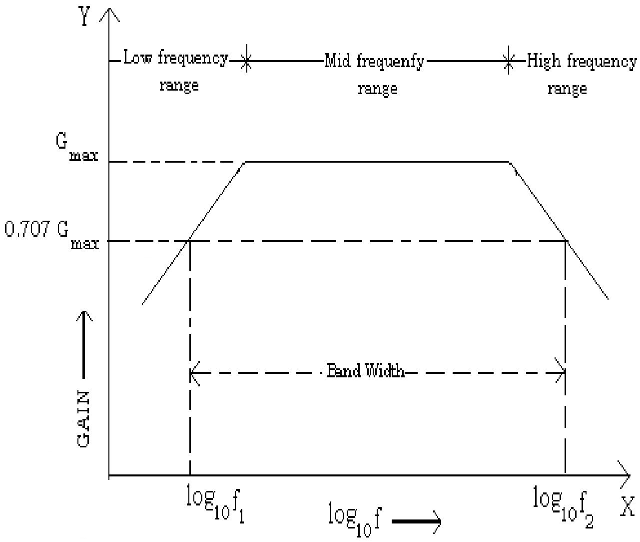


Fig. 2

Procedure: - The circuit connections are made as shown in the Fig.1. First the signal generator is connected directly to the a.c. milli-voltmeter by keeping signal frequency at about 500 Hz. The amplitude (voltage) of the input signal is adjusted to 0.1V or 0.05V. This is the amplifier input (Vi). Now the signal generator is disconnected from the a.c. milli-voltmeter and connected to the input of the of the amplifier and the a.c. milli- voltmeter is connected to the output of the amplifier.

Set the input frequency at 10 Hz, note the output voltage (Vo) from the a.c. milli-voltmeter keeping the input voltage, V_i constant. Vary the input frequency 'f' and note the output voltage. The frequency of the input signal is varied in convenient steps

i.e. at least 5 values with equal intervals, in each range of frequency in the signal generator, the output voltage V_o is noted in the table for each frequency. Calculate the voltage gain, G of the amplifier for each value of the frequency, f of the input signal, using the relation, Voltage gain, $G = V_o / V_i$.

To determine the bandwidth (BW) of the amplifier

Draw the frequency response curve as said above, by taking the frequency f (or $\log_{10}f$) on X-axis and voltage gain on Y-axis. Note the maximum gain, G_{max} and mark the value of $0.707G_{max}$onthey-axis. From that value draw a line (dashed line) parallel to x-axis. This line cuts the curve at two points, called the half-power points. From those two points draw two perpendicular lines on to x - axis, the feet of two perpendiculars corresponding to two frequencies f_1 and f_2. These are called as lower half- power frequency and the upper half-power frequency (or cut-off frequency). The difference between these two frequencies f_1 and f_2 is the bandwidth (BW) of the amplifier.

$\therefore$ Bandwidth of the amplifier = $f_2 - f_1$

<u>Precautions</u>: - 1) Before going to the experiment the input voltage V_i should be measured.

2) The input voltage should be less than 0.1V.

3) The input voltage should be maintained at constant value throughout the experiment.

4) The connections should be tight.

Experiment 6

Trouble shooting Amplifier

Introduction

The ability to diagnose and cure problems in a systematic manner is an exceptionally valuable skill. In PHY2028 students are given a heap of components, a breadboard, and measuring equipment. This virtually guarantees that nothing will work first time, and students are forced to develop troubleshooting skills.

Students: please ensure that you can answer 'yes' to the relevant questions below before asking a demonstrator for help.

The Method

Carry out quick and easy checks first: start with a visual inspection, then use a multi-meter, finally an oscilloscope.

Before You Start

1. Is the circuit diagram open on the bench?
2. Do you understand how it is supposed to work?
3. Are you sure of the pin-outs and polarity of each device?

Power and Grounds

1. Is the power supply is working? Check for stable outputs with a digital multimeter (DMM)
2. Are op-amps connected to both supply rails? Check voltages with respect to ground at pins of each device. Do not cause short-circuits with the DMM probes
3. Is the ground rail continuous? Check voltage between power supply rail and points on circuit that should be at ground.

Passive Components

1. Are the resistor and capacitor values correct? Check them with a DMM/capacitance meter. If you are not confident that you can estimate the

effects of other components for in situ measurements, carefully disconnect one end of the component from the board. Don't simultaneously touch both probes with your hands when making the measurement or you will get misleading results.

2. Are potentiometers being used correctly? Check that the wiper voltage varies in a reasonable manner as the potentiometer is adjusted. Avoid using potentiometers as variable resistors.
3. Are switches of the correct type? Have you checked your assumptions about which terminal is which with a DMM?

Op-Amps

If you suspect an op-amp is faulty, check it by substitution but first:

1. Is each pin of the op-amp connected?
   Check visually that none of its pins have become wrapped under its body instead of being inserted into the board.
2. Is the output finite?
   If the output is within a volt or so of either power rail then either it has failed, or there is an excessive voltage at its inputs.
3. Is the input consistent with the output?
   Measure the voltage between the inverting and non-inverting inputs, it should be within millivolts of zero.

Offset Voltages

A few millivolts of offset at the input of a system with a high DC gain can be amplified to the point that it saturates the final stage. Many op-amps have offset adjust facilities which can reduce the offset by something like a factor of 10. Offsets are temperature dependent.

Instability

Instability typically appears as high-frequency 'fuzz' on the output signal oscilloscope trace. Breadboard circuits are very prone to it because of inter-track capacitance and long components leads. Try the following:

1. Organize the physical layout of the circuit to keep the input and output stages separate.

2. Decouple the breadboard power supply rails with a *circa* 0.1µF capacitors to ground.
3. Work out the loop-gain (see worksheet 1) and study the op-amp manufacturer's data-sheet.
4. Don't use op-amps with an unnecessarily good frequency response, *e.g.* use a LM741 instead of an LF411 where possible.

Divide and Conquer

If you have a complex system involving several stages:

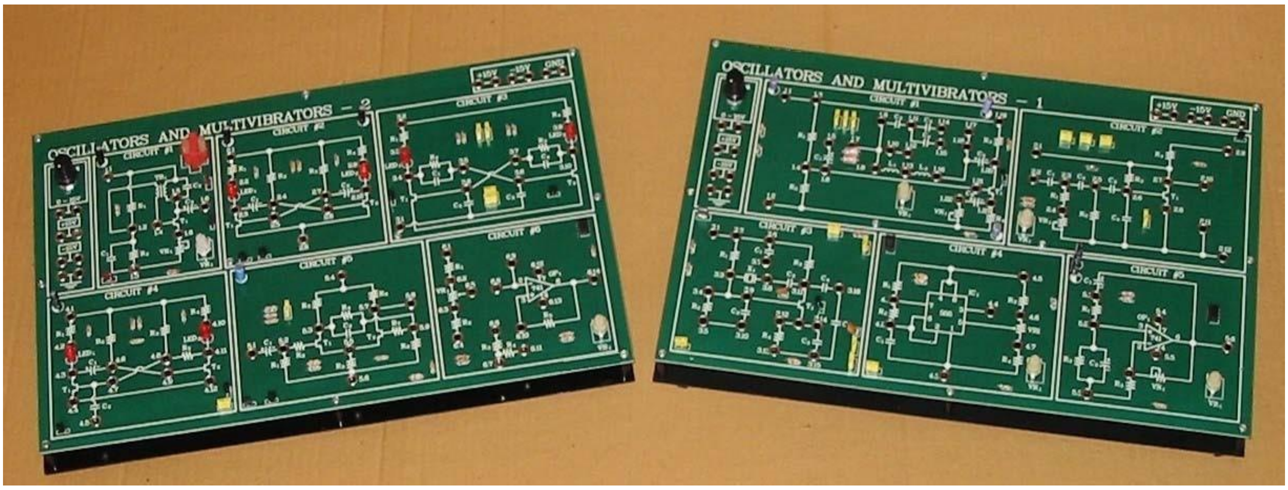
1. Divide the system into sub-circuits that can be tested individually.
   If you want to do an open-loop test on a closed-loop system use a signal generator or voltage source to inject a simulation of the closed-loop signal at the point where you open the loop.
2. Check the signal at the input and output of each section, using an oscilloscope if appropriate.
   It is possible for a faulty section to load its predecessor in the chain.

How to Kill a Working Circuit

1. Short-circuit a supply rail to something sensitive with the DMM probes when checking the PSU or by dropping something (*e.g.* a screwdriver) onto the working circuit.
2. Apply power for an instant to only one rail of a circuit that requires two rails.
3. Make changes to the circuit without switching off the PSU first.

Experiment7

OSCILLATORS-AND-MULTI-VIBERATORS



THE OSCILLATORS AND MULTIVIBRATORS TRAINER PROVIDE THE STUDY OF VARIOUS TYPES OF OSCILLATORS AND MULTIVIBRATORS CIRCUITS. THE CIRCUITS ARE SCREEN-PRINTED ON THE PRINTED CIRCUIT BOARD. THE STU- DENT'S WORKBOOK ARE WELL ORGANISED WHERE THE STUDENTS ARE ABLE TO FOLLOW AND UNDERSTAND EASILY.

The Oscillators and Multivibrators Trainer is designed to figure out the oscillators and multivibrators concept of every method study in theory. This trainer is a system with three different modules. On the panel of each module, a circuit diagram, input and output ports and test points which necessary in monitoring waveforms and signal levels.

The trainer offers training and experiment capabilities in two main areas: functional tests on individual circuits and experiments on the characteristics of the circuits.

Topics covered:

HARTLEY Oscillator

Objectives of this experiment:

- To construct a series-fed transistor Hartley oscillator.
- To change frequency determining components and observe variations infrequency.
- To measure any harmonic frequencies present. Hartley oscillator is used for varying frequencies over large ranges, as in local oscillators of radio receivers. COLPITTS' OSCILLATOR

Objectives of this experiment:

- To construct a basic COLPITTS oscillator, using a transistor.
- To determine the frequency of oscillation.
- To measure any harmonic frequencies generated by it. Colpitts oscillator is used for fixed frequency of oscillation.

CRYSTALOSCILLATOR

Objectives of this experiment:

- To construct a crystal oscillator.
- To determine the frequency of oscillator.
- To measure any harmonic frequency generated in the crystal oscillator called

PIERCE oscillator the frequency determining L-C network is provided by a piezo electric-quartz crystal. Inductance L is represented by the inertia of the mass of the crystal plate when R is vibrating, capacitance C is represented by the reciprocal of the stiffness of the crystal plate.

PHASE SHIFT OSCILLATOR

Objectives of this experiment:

- To determine the range frequency of an R-C phase shift oscillator.
- To construct RC phase shift oscillator & to compare the phase shift networks and feedback voltages in this oscillator. R-C oscillator uses resistors and capacitors as the frequency determining components. Each element of R-C network shifts the phase by 60 degrees. Three such elements shift the phase by 180 degrees. A transistor amplifier, associated with this network shifts the phase by another 180 degrees. Thus the R-C network and the transistor shifts the phase by 360 degrees in positive feedback circuit, throwing it into oscillation. This type of oscillator is used as a fixed frequency oscillator

WIEN-BRIDGE OSCILLATOR

Objectives of this experiment:

- To construct a wien-bridge oscillator and determine the resistor ratio required to develop the correct de- generative feedback.
- To insert a simple automatic gain-control and ob- serve the effect on oscillator operation.
- To vary the values of resistance and capacitance in the lead-lag network and to observe the resultant frequency changes.
- To construct wein-bridge oscillator using RC combination, usually preferred for low frequency application. A lead lag R-C network determines the oscillator frequency and controls the amount of regenerative.

VOLTAGE CONTROLLED OSCILLATOR

Objectives of this experiment:

- To construct voltage controlled oscillator circuit and verify the frequency variations in accordance with input voltage.

- ARMSTRONG OSCILLATOR

Objectives of this experiment:

- To construct Armstrong oscillator circuit and study the characteristics of the circuit.

MULTIVIBRATORS

Objectives of this experiment:

- The purpose of this experiment is to investigate the operation and characteristics of the as table multivi-brator, the mono-stable multi-vibrator and bistable multi-vibrator. A stable multi-vibrator is free running rectangular wave generator. It has two outputs, which are 180 degrees out of phase. Monostable is a one- shot multi-vibrator and R is triggered by sharp pulse, obtained by differentiating a square-wave. It produces one output pulse for each input pulse. A bistable is a flip-flop and it is stable either in ‘1’ or ‘0’ state, till it is triggered into their other state. Output changes for every two Input triggers. It can also be used as divide-by-two counter.

SCHMITT TRIGGER

Objectives of this experiment:

- To construct an emitter-coupled Schmitt trigger using transistors.
- To observe that this produces a rectangular wave output from a sine wave input. To construct Schmitt trigger using op-amp.
- To observe that any increase in amplitude of input sine wave has an effect on the width of the output waveform.
- To verify these facts, usingIC-7413.

Standard Accessories:

- Variable ±15VDC Power Supply with 240V, 50Hz input.
- 4 mm Patch Cables.
- Experiments Manual.

- Instructor’s Workbook.
- Operation Manual.