Trainer Module: ETEK ACS-3000-02

Chapter Three

AM Modulator

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3-1: Curriculum Objectives

1. To understand the basic theory of amplitude modulation (AM).
2. To understand the waveform and frequency spectrum of AM modulator, also calculate the percentage of modulation.
3. To design and implement the AM modulator by using transistor.
4. To design and implement the AM modulator by balanced modulator.
5. To understand the measurement and adjustment of AM modulator.

3-2: Curriculum Theory

In amplitude modulation (AM), we utilize the amplitude of audio signal to modulate the amplitude of carrier signal, which means that the amplitude of carrier signal will be varied with amplitude of audio signal. The waveform of AM modulation is shown in figure 3-1 and its block diagram is shown in figure 3-2. In figure 3-2, we know that in order to generate the AM signal, we just need to add a DC signal with the audio signal, and then multiply the added signal with the carrier signal.

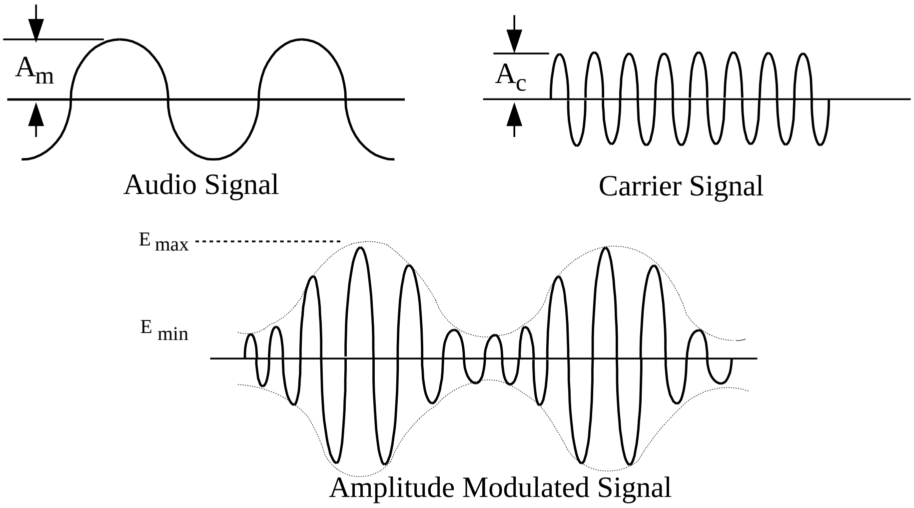


Figure 3-1 Signal waveform of amplitude modulation.

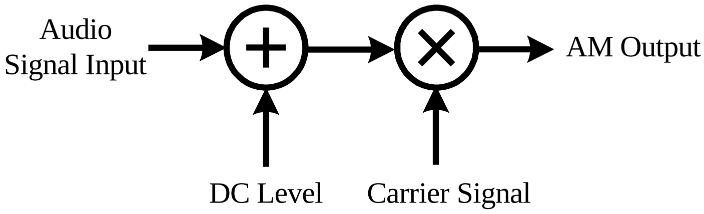


Figure 3-2 Block diagram of AM modulator.

Let the audio signal be $A_m \cos(2\pi f_m t)$ and carrier signal be $A_c \cos(2\pi f_c t)$, then the amplitude modulation can be expressed as

$$x_{AM}(t) = \left[A_{DC} + A_m \cos(2\pi f_m t)\right] A_c \cos(2\pi f_c t)$$

$$= A_{DC} A_c \left[1 + m\cos(2\pi f_m t)\right]\cos(2\pi f_c t) \qquad (3\text{-}1)$$

Where

$m = A_m / A_{DC}$.

A_{DC} : DC signal magnitude.

A_m : Audio signal amplitude.

A_C : Carrier signal amplitude.

f_m : Audio signal frequency.

f_C : Carrier signal frequency.

m: Modulation index or depth of modulation.

From equation (3-1), we notice that the variation of the magnitude $A_{DC} A_c [1 + m\cos(2\pi f_m t)]$ of the carrier signal can be controlled by parameter "m". This means that we can change the magnitude of the audio signal (A_m) or DC signal (A_{DC}) to control the level or depth of the carrier signal. Therefore, this parameter "m" is known as the modulation index.

Besides, we can also rewrite equation (3-1) as

$$x_{AM}(t) = \frac{1}{2} A_{DC} A_C m \{\cos[2\pi(f_c + f_m)t] + \cos[2\pi(f_c - f_m)t]\} + A_{DC} A_C \cos(2\pi f_c t) \tag{3-2}$$

The first term represents double sideband signals; the second term represents carrier signal. From equation (3-2), we can sketch the frequency spectrum of amplitude modulation as shown in figure 3-3. Since the audio signal is hidden in the double sidebands and the carrier signal does not contain any message, therefore the power is consumed in carrier during transmission of amplitude modulation signal. For this reason, the transmission efficiency of AM modulation is lower than double sidebands suppressed carrier (DSB-SC) modulation but its demodulation circuit is much simpler.

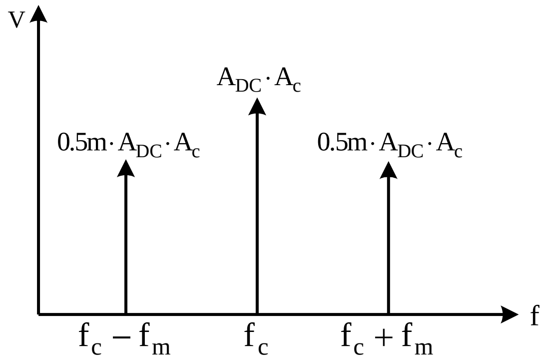


Figure 3-3 Frequency spectrum of amplitude modulation signal.

There is an important parameter "m" in equation (3-1) called modulation index or depth of modulation. Normally it is represented in percentage, so we also call modulation percentage. Modulation index is an important parameter in equation (3-1). The definition is as follow

$$m = \frac{\text{Audio signal amplitude}}{\text{DC signal magnitude}} \times 100\ \% = \frac{A_m}{A_{DC}} \times 100\ \% \qquad (3\text{-}3)$$

Generally, the magnitude of DC signal is not easy to measure; therefore, we express the modulation index in another form

$$m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \times 100\ \% \qquad (3\text{-}4)$$

Where E_{max} and E_{min} as shown in figure 3-1 are $E_{max} = A_C + A_m$ and $E_{min} = A_C - A_m$.

We know that at amplitude modulation, the audio signal is hidden in the double sidebands, so if the double sideband signals are getting stronger, the transmission efficiency is getting better. From equation (3-2), we know that the double sideband signals are proportional to the modulation index. Thus, the larger the modulation index, the better the transmission efficiency.

Normally modulation index is smaller or equal to 1. If greater than 1, we call it over modulation, as shown in figure 3-4. Figure 3-4 shows the waveforms of the over modulation. In figure 3-4, we can see that the variation of carrier signal is no longer a sinusoidal wave. It is rather a distorted sinusoidal wave, therefore, this kind of AM signal is unable to demodulate and recover to the original by using the envelop detection in next chapter.

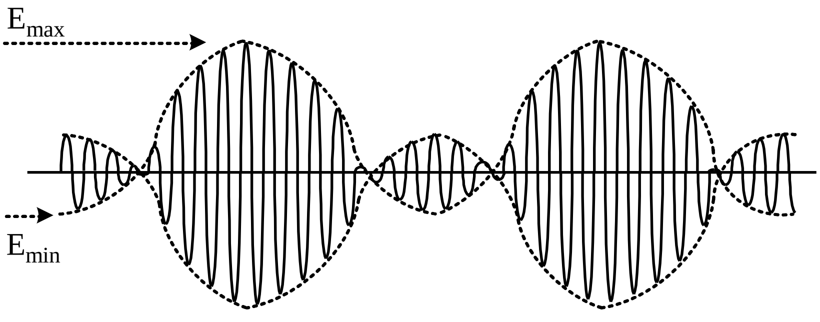


Figure 3-4 Waveforms of the over modulation.

As we know that the AM modulator can be implemented by using a multiplier. However, in electronics circuit, the multiplier is constructed by the nonlinear characteristics of active component. Therefore, in this chapter, we will discuss the design of AM modulator by using a single transistor and balanced modulator.

3-1 Transistor AM Modulator

The circuit diagram of transistor AM modulator is shown in figure 3-5. In figure 3-5, the audio signal ($A_m \cos(2\pi f_m t)$) will pass through a transformer and send into the base of the transistor. The carrier signal ($A_c \cos(2\pi f_c t)$) also passes through a transformer and sends into the emitter of the transistor. These two signals will form a small amount of small signal voltage difference at the base and emitter of the transistor. The small signal voltage difference is

$$V_{be} = V_b - V_e = A_m \cos(2\pi f_m t) - A_c \cos(2\pi f_c t) \quad (3\text{-}5)$$

Then at the collector of the transistor, this voltage difference will produce a small signal collector current as

$$I_c = I_s e^{V_{be}/V_T} \quad (3\text{-}6)$$

Expand equation (3-6) by Taylor's expansion, then we get

$$I_c = aV_{be} + bV_{be}^2 \quad (3\text{-}7)$$

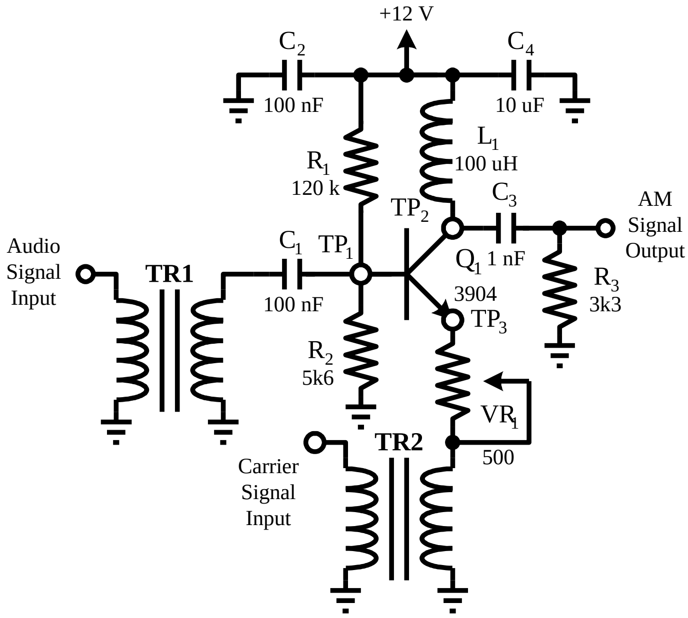


Figure 3-5 Circuit diagram of transistor AM modulator.

In equation (3-7), we notice that after the audio signal and the carrier signal input into the base and collector of the transistor, we can obtain $\cos^2(2\pi f_m t)$, $\cos^2(2\pi f_c t)$ and $\cos(2\pi f_m t)\times\cos(2\pi f_c t)$ signals at the collector. Then we utilize the filter to obtain the modulated AM signal $\cos(2\pi f_m t)\times\cos(2\pi f_c t)$. In figure 3-5, the inductor L_1, capacitor C_3 and resistor R_3 comprise a high-pass filter, which is used to obtain the modulated AM signal. Capacitor C_1 is the coupling capacitor. Capacitor C_2 and C_3 are the bypass capacitors. Resistors R_1 and R_2 are the bias resistors. Variable resistor VR_1 is used to change the operation point of the transistor and it also used to control the magnitude of the carrier, which inputs into the collector of the transistor. Therefore, it can adjust the output signal waveform of the modulator.

3-2 MC1496 AM Modulator

The main different between the design of AM modulator by using balanced modulator and the transistor is that we can use the theory of balanced modulator to cancel out the unwanted harmonics signals, which is produced by the nonlinear characteristic of the transistor, then the remain signal is the AM signal. In this chapter, we utilize the balanced modulator (MC1496) to implement the AM modulator.

Follow the variation of input signal frequency, the balanced modulator (MC1496) can become a frequency multiplier, AM modulator or double sidebands suppressed carrier modulator (DSB-SC Modulator). Its input signal, output signal and circuit characteristics are shown in table 3-1.

Table 3-1 Three different types of modulation signal produced by different signals frequency of balanced modulator.

Input Carrier Signal	Input Audio Signal	Output Balanced Modulator	Circuit Characteristics
f_c	f_c	$2f_c$	Frequency Multiplier
f_c	f_m	f_c, $f_c + f_m$, $f_c - f_m$	Amplitude Modulator
f_c	f_m	$f_c + f_m$, $f_c - f_m$	DSB-SC Modulator

Figure 3-6 is the internal circuit diagram of MC1496, where D_1, R_1, R_2, R_3, Q_7 and Q_8 comprise an electric current source, which can supply DC bias current for Q_5 and Q_6. Q_5 and Q_6 comprise a differential combination to drive the dual differential amplifiers constructed by Q_1, Q_2, Q_3 and Q_4. Pin 1 and 4 are the inputs of audio signal, after that this signal will be amplified by the differential amplifier, which is comprised by Q_5 and Q_6. Pin 8 and 10 are the inputs of carrier signal. Then the amplified audio signal will multiply by the carrier signal at the dual differential amplifiers constructed by Q_1, Q_2, Q_3 and Q_4. Finally, the output signals can be obtained at the collectors of Q_1, Q_2, Q_3 and Q_4, respectively. The resistor between pins 2 and 3 controls the gain of the balanced modulator; the resistor of pin 5 determines the magnitude of bias current for amplifier.

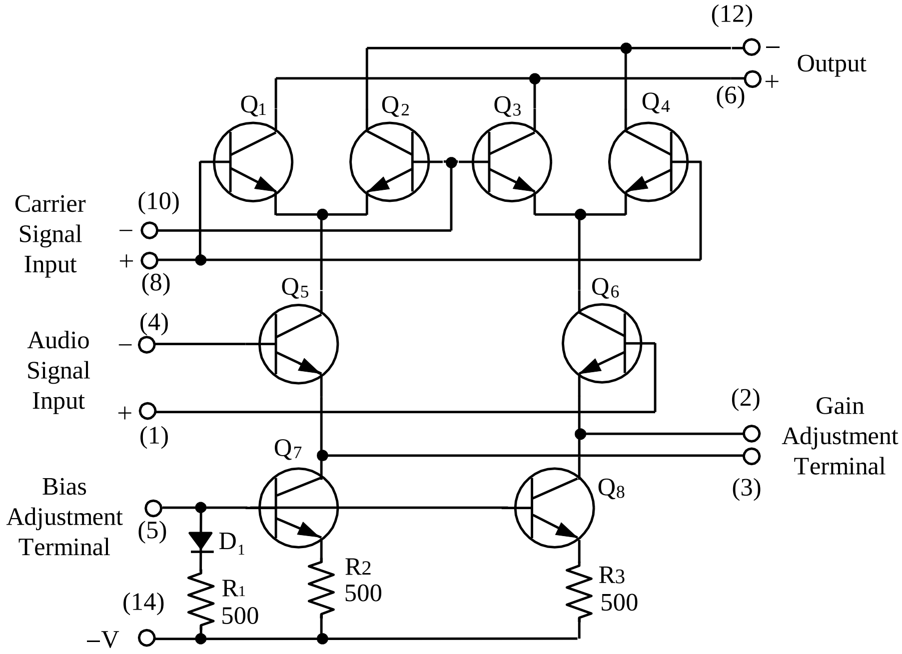


Figure 3-6 Internal circuit diagram of MC1496.

Figure 3-7 is the circuit diagram of AM modulator by utilizing MC1496. We can see that the carrier signal and audio signal belong to single ended input. The carrier signal input from pin 10 and the audio signal input from pin 1. Therefore, R_8 determine the gain of the whole circuit and R_9 determine the magnitude of bias current. If we adjust the variable resistor VR_1 or change the input amplitude of audio signal, then we can control the percentage modulation of AM modulator.

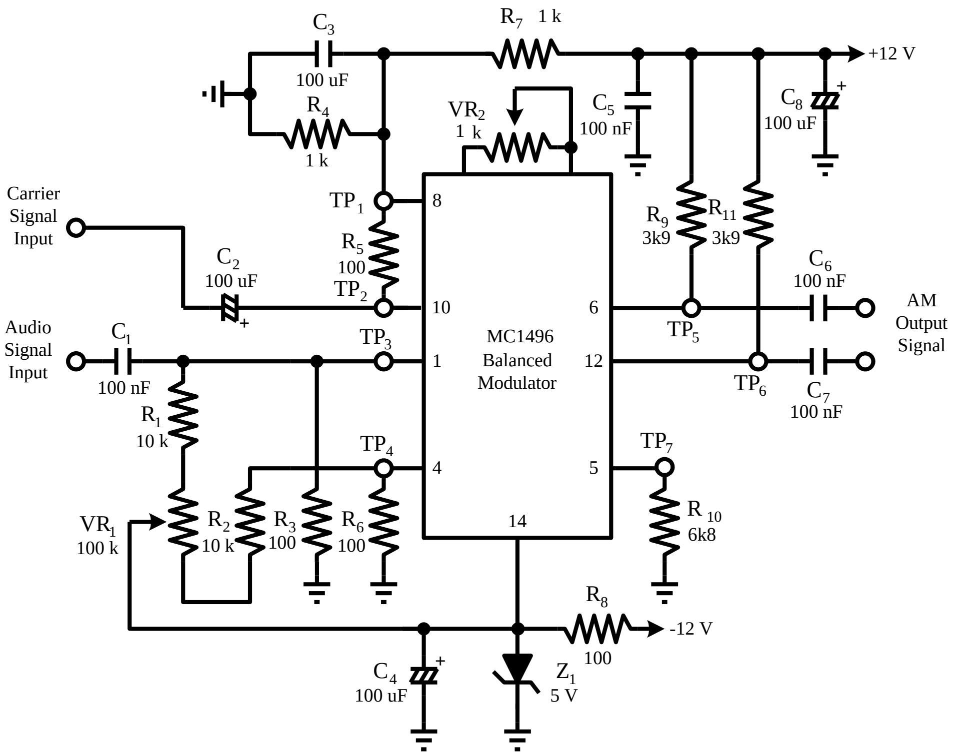


Figure 3-7 Circuit diagram of amplitude modulator by utilizing MC1496.

3-3: Experiment Items

Experiment 1: Transistor AM modulator

1. Refer to the circuit diagram in figure 3-5 or figure ACS3-1 on ETEK ACS-3000-02 module.

2. At audio signal input port (Audio I/P), input 150 mV_{pp} amplitude, 1 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 300 mV_{pp} amplitude, 500 kHz sine wave frequency.

3. By using oscilloscope, observe on output signal waveforms of AM output port (AM O/P). Adjust VR_1 so that the modulated AM signal is maximum without distortion. Then records the measured results in table 3-2.

4. By using oscilloscope, observe on output signal waveforms of the base (TP1) and collector (TP2) of the transistor. Then record the measured results in table 3-2.

5. By using oscilloscope, observe on output signal waveforms of the mixing (TP3) of the transistor. Then record the measured results in table 3-2.

6. By using spectrum analyzer, observe on the frequency spectrum of AM O/P and TP2. Then record the measured results in table 3-2.

7. Substitute the measured results into equation (3-4), find the modulation percentage and record in table 3-2.

8. According to the input signals in table 3-2, repeat step 4 to 7 and record the measured results in table 3-2.

9. According to the input signals in table 3-3, repeat step 2 to 7 and record the measured results in table 3-3.

Experiment 2: MC1496 AM modulator

Experiment 2-1: Observe on the variation of AM modulator by changing the amplitude and frequency of audio signal

1. Refer to the circuit diagram in figure 3-7 or figure ACS3-2 on ETEK ACS-3000-02 module. Let J1 be short circuit, J2 be open circuit; i.e. $R_{10} = 6.8\,k\Omega$.

2. At audio signal input port (Audio I/P), input 600 mV_{pp} amplitude, 1 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 300 mV_{pp} amplitude, 500 kHz sine wave frequency.

3. By using oscilloscope, observe on output signal waveforms of AM output ports (AM O/P1 and AM O/P2). Adjust VR_2 so that the signal at AM O/P1 is maximum without distortion. Adjust VR_1 so that the modulation index of the AM signal reach 50 %. Then records the measured results in table 3-4.

4. By using oscilloscope, observe on input signal waveforms of the pin 8 (TP1), pin 10 (TP2), pin 1 (TP3), and pin 4 (TP4) of the balanced modulator. Then record the measured results in table 3-4.

5. By using oscilloscope, observe on output signal waveforms of the mixing (TP5 and TP6) of the balanced modulator and the bias operation point (TP7). Then record the measured results in table 3-4.

6. By using spectrum analyzer, observe on the frequency spectrum of AM O/P1, AM O/P2, TP5 and TP6. Then record the measured results in table 3-4.

7. Substitute the measured results into equation (3-4), find the modulation percentage and record in table 3-4.

8. According to the input signals in table 3-4, repeat step 4 to 7 and record the measured results in table 3-4.

9. Let J1 be open circuit and J2 be short circuit, i.e. change the resistor R_{10} = 6.8 kΩ to R_{12} = 3.3 kΩ. Repeat step 2 to step 8 and record the measured results in table 3-5.

10. According to the input signals in table 3-6, repeat step 2 to 7 and record the measured results in table 3-6.

Experiment 2-2: Observe on the variation of AM modulator by changing the amplitude and frequency of carrier signal

1. Refer to the circuit diagram in figure 3-7 or figure ACS3-2 on ETEK ACS-3000-02 module. Let J1 be open circuit, J2 be short circuit; i.e. R_{12} = 3.3 kΩ.

2. At audio signal input port (Audio I/P), input 600 mV_{pp} amplitude, 1 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 200 mV_{pp} amplitude, 500 kHz sine wave frequency.

3. By using oscilloscope, observe on output signal waveforms of AM output ports (AM O/P1 and AM O/P2). Adjust VR_2 so that the signal at AM O/P1 is maximum without distortion. Adjust VR_1 so that the modulation index of the AM signal reach 50 %. Then records the measured results in table 3-7.

4. By using oscilloscope, observe on output signal waveforms of the pin 8 (TP1), pin 10 (TP2), pin 1 (TP3), and pin 4 (TP4) of the balanced modulator. Then record the measured results in table 3-7.

5. By using oscilloscope, observe on output signal waveforms of the mixing (TP5 and TP6) of the balanced modulator and the bias operation point (TP7). Then record the measured results in table 3-7.

6. By using spectrum analyzer, observe on the frequency spectrum of AM O/P1, AM O/P2, TP5 and TP6. Then record the measured results in table 3-7.

7. Substitute the measured results into equation (3-4), find the modulation percentage and record in table 3-7.

8. According to the input signals in table 3-7, repeat step 4 to 7 and record the measured results in table 3-7.

9. According to the input signals in table 3-8, repeat step 2 to 7 and record the measured results in table 3-8.

Experiment 2-3: Observe on the variation of AM modulator by changing the variable resistor VR_1

1. Refer to the circuit diagram in figure 3-7 or figure ACS3-2 on ETEK ACS-3000-02 module. Let J1 be open circuit, J2 be short circuit; i.e. R_{12} = 3.3 kΩ.

2. At audio signal input port (Audio I/P), input 600 mV_{pp} amplitude, 1 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 300 mV_{pp} amplitude, 500 kHz sine wave frequency.

3. By using oscilloscope, observe on output signal waveforms of AM output ports (AM O/P1 and AM O/P2). Adjust VR_1 so that the modulation index of the AM signal reach 30 %. Then records the measured results in table 3-9.

4. By using spectrum analyzer, observe on the frequency spectrum of AM O/P1 and AM O/P2. Then record the measured results in table 3-9.

5. Substitute the measured results into equation (3-4), find the modulation percentage and record in table 3-9.

6. According to the input signals in table 3-9, repeat step 2 to 5 and record the measured results in table 3-9.

Experiment 2-4: Observe on the variation of AM modulator by changing the variable resistor VR_2

1. Refer to the circuit diagram in figure 3-7 or figure ACS3-2 on ETEK ACS-3000-02 module. Let J1 be open circuit, J2 be short circuit; i.e. R_{12} = 3.3 kΩ.

2. At audio signal input port (Audio I/P), input 600 mV_{pp} amplitude, 1 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 300 mV_{pp} amplitude, 500 kHz sine wave frequency.

3. By using oscilloscope, observe on output signal waveforms of AM output ports (AM O/P1 and AM O/P2). Adjust VR_1 so that the modulation index of the AM signal reach 50 %.

4. Adjust VR_2 so that the resistance is 100 Ω, 300 Ω and 800 Ω, the others remain. Then record the measured results in table 3-10.

3-4: Experimental Results

Experiment 1: Transistor AM modulator

Table 3-2 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV).

Output Signal Ports	Audio Signal Amplitudes	
	100 mV_{pp}	150 mV_{pp}
AM O/P		
TP1		
TP2		
TP3		
AM O/P Output Signal Spectrums		
TP2 Output Signal Spectrums		
Modulation Index	E_{max} = ____ E_{min} = ____ m = _____%	E_{max} = ____ E_{min} = ____ m = _____%

Table 3-3 Observe on the variation of amplitude modulation by changing the frequency of audio signal (V_m = 200 mV_{pp}, f_c = 500 kHz, V_c = 300 mV_{pp}).

Output Signal Ports	Audio Signal Frequencies	
	100 Hz	400 Hz
AM O/P		
TP1		
TP2		
TP3		
AM O/P Output Signal Spectrums		
TP2 Output Signal Spectrums		
Modulation Index	E_{max} = ____ E_{min} = ____ m = ______%	E_{max} = ____ E_{min} = ____ m = ______%

Experiment 2: MC1496 AM modulator

Table 3-4 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{10} = 6.8 kΩ).

Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
AM O/P1		
AM O/P2		
TP1		
TP2		

Table 3-4 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (Continue) (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{10} = 6.8 kΩ).

Output Signal Ports	Audio Signal Amplitudes	
	$600\ mV_{pp}$	$300\ mV_{pp}$
TP3		
TP4		
TP5		
TP6		

Table 3-4 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (Continue) (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{10} = 6.8 kΩ).

Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
TP7		
AM O/P1 Output Signal Spectrums		
AM O/P2 Output Signal Spectrums		
TP5 Output Signal Spectrums		
TP6 Output Signal Spectrums		
Modulation Index	E_{max} = ____ E_{min} = ____ m = ______%	E_{max} = ____ E_{min} = ____ m = ______%

Table 3-5 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
AM O/P1		
AM O/P2		
TP1		
TP2		

Notice： The amplitude of measured signals on the test points of TP1, TP4 and TP5 would be very small, you may need a precision oscilloscope to measure those test points. Or you can ignore these steps of experiment item, and go to the next step.

Table 3-5 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (Continue) (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
TP3		
TP4		
TP5		
TP6		

Table 3-5 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (Continue) (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
TP7		
AM O/P1 Output Signal Spectrums		
AM O/P2 Output Signal Spectrums		
TP5 Output Signal Spectrums		
TP6 Output Signal Spectrums		
Modulation Index	E_{max} = ____ E_{min} = ____ m = ______%	E_{max} = ____ E_{min} = ____ m = ______%

Table 3-6 Observe on the variation of amplitude modulation by changing the frequency of audio signal (V_m = 600 mV_{pp}, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Audio Signal Frequencies	
	1 kHz	2 kHz
AM O/P1		
AM O/P2		
TP1		
TP2		

Notice： The amplitude of measured signals on the test points of TP1, TP4 and TP5 would be very small, you may need a precision oscilloscope to measure those test points. Or you can ignore these steps of experiment item, and go to the next step.

Table 3-6 Observe on the variation of amplitude modulation by changing the frequency of audio signal (Continue) (V_m = 600 mV_{pp}, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Audio Signal Frequencies	
	1 kHz	2 kHz
TP3		
TP4		
TP5		
TP6		

Table 3-6 Observe on the variation of amplitude modulation by changing the frequency of audio signal (Continue) (V_m = 600 mV_{pp}, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
TP7		
AM O/P1 Output Signal Spectrums		
AM O/P2 Output Signal Spectrums		
TP5 Output Signal Spectrums		
TP6 Output Signal Spectrums		
Modulation Index	E_{max} = ____ E_{min} = ____ m = ______%	E_{max} = ____ E_{min} = ____ m = ______%

Table 3-7 Observe on the variation of amplitude modulation by changing the amplitude of carrier signal (V_m = 600 mV_{pp}, f_m = 1 kHz, f_c = 500 kHz, R_{12} = 3.3 kΩ).

Output Signal Ports	Carrier Signal Amplitudes	
	200 mV_{pp}	300 mV_{pp}
AM O/P1		
AM O/P2		
TP3		
TP4		

Notice： The amplitude of measured signals on the test points of TP1, TP4 and TP5 would be very small, you may need a precision oscilloscope to measure those test points. Or you can ignore these steps of experiment item, and go to the next step.

Table 3-7 Observe on the variation of amplitude modulation by changing the amplitude of carrier signal (Continue) (V_m = 600 mV_{pp}, f_m = 1 kHz, f_c = 500 kHz, R_{12} = 3.3 kΩ).

Output Signal Ports	Carrier Signal Amplitudes	
	200 mV_{pp}	300 mV_{pp}
TP1		
TP2		
TP5		
TP6		

Table 3-7 Observe on the variation of amplitude modulation by changing the amplitude of carrier signal (Continue) (V_m = 600 mV_{pp}, f_m = 1 kHz, f_c = 500 kHz, R_{12} = 3.3 kΩ).

Output Signal Ports	Carrier Signal Amplitudes	
	200 mV_{pp}	300 mV_{pp}
TP7		
AM O/P1 Output Signal Spectrums		
AM O/P2 Output Signal Spectrums		
TP5 Output Signal Spectrums		
TP6 Output Signal Spectrums		
Modulation Index	E_{max} = _____ E_{min} = _____ m = _______%	E_{max} = _____ E_{min} = _____ m = _______%

Table 3-8 Observe on the variation of amplitude modulation by changing the frequency of carrier signal (V_m = 600 mV_{pp}, f_m = 1 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Carrier Signal Frequencies	
	500 kHz	1 MHz
AM O/P1		
AM O/P2		
TP3		
TP4		

Table 3-8 Observe on the variation of amplitude modulation by changing the frequency of carrier signal (Continue) (V_m = 600 mV_{pp}, f_m = 1 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Carrier Signal Frequencies	
	500 kHz	1 MHz
TP1		
TP2		
TP5		
TP6		

Table 3-8 Observe on the variation of amplitude modulation by changing the frequency of carrier signal (Continue) (V_m = 600 mV_{pp}, f_m = 1 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

Output Signal Ports	Carrier Signal Frequencies	
	500 kHz	1 MHz
TP7		
AM O/P1 Output Signal Spectrums		
AM O/P2 Output Signal Spectrums		
TP5 Output Signal Spectrums		
TP6 Output Signal Spectrums		
Modulation Index	E_{max} = ____ E_{min} = ____ m = ______%	E_{max} = ____ E_{min} = ____ m = ______%

Table 3-9 Observe on the variation of amplitude modulation by changing the variable resistor VR_1 (V_m = 600 mV_{pp}, f_m = 1 kHz, V_c = 300 mV_{pp}, f_c = 500 kHz, R_{12} = 3.3 kΩ).

Modulation Index		Output Signal Waveforms	Output Signal Spectrums	Modulation Percentages
30 %	AM O/P1			E_{max} = ____ E_{min} = ____ m =_____%
	AM O/P2			E_{max} = ____ E_{min} = ____ m =_____%
50 %	AM O/P1			E_{max} = ____ E_{min} = ____ m =_____%
	AM O/P2			E_{max} = ____ E_{min} = ____ m =_____%
110 %	AM O/P1			E_{max} = ____ E_{min} = ____ m =_____%
	AM O/P2			E_{max} = ____ E_{min} = ____ m =_____%

Table 3-10 Observe on the variation of amplitude modulation by changing the variable resistor VR_2 (V_m = 600 mV_{pp}, f_m = 1 kHz, V_c = 300 mV_{pp}, f_c = 500 kHz, R_{12} = 3.3 kΩ).

Magnitudes of Variable Resistor VR_2		Output Signal Waveforms	Output Signal Spectrums	Modulation Percentages
100 Ω	AM O/P1			E_{max} = ____ E_{min} = ____ m = ____%
	AM O/P2			E_{max} = ____ E_{min} = ____ m = ____%
300 Ω	AM O/P1			E_{max} = ____ E_{min} = ____ m = ____%
	AM O/P2			E_{max} = ____ E_{min} = ____ m = ____%
800 Ω	AM O/P1			E_{max} = ____ E_{min} = ____ m = ____%
	AM O/P2			E_{max} = ____ E_{min} = ____ m = ____%

3-5: Problems Discussion

1. Explain the objectives of the transistor Q_1 in figure 3-5.
2. Explain the objectives of the inductor L_1, capacitor C_3 and resistor R_3 in figure 3-5.
3. Explain the objectives of the variable resistor VR_1 in figure 3-7.
4. Refer to figure 3-7, if we let J2 be short circuit, J1 be open circuit, i.e. R_{10} changes to R_{12}, which its value is 6.8 kΩ changed to 3.3 kΩ. Then describe the variation of the DC bias current of MC1496.
5. Refer to figure 3-7, if we adjust the magnitude of the variable resistor VR_2 from small to large, then describe the variation of the output signal of AM modulator.
6. When modulation index, m = 50 % and 110 %, what are the ratio of E_{max} and E_{min}?

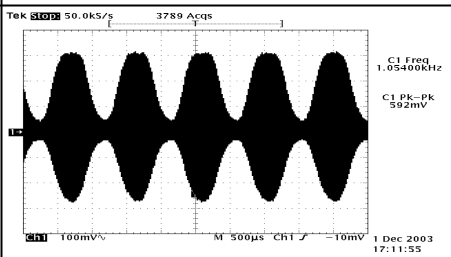
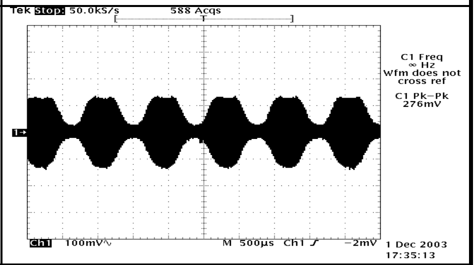
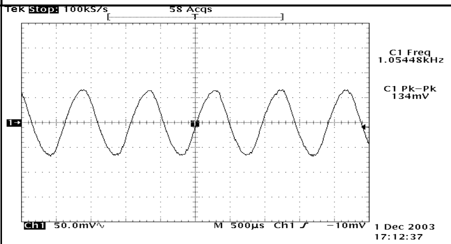
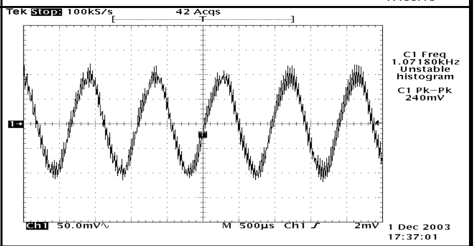
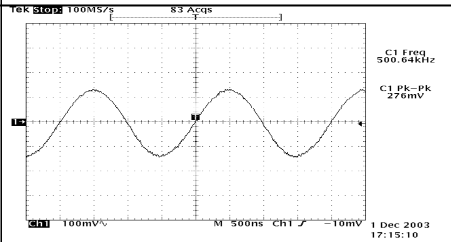
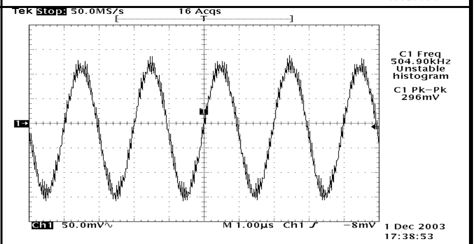
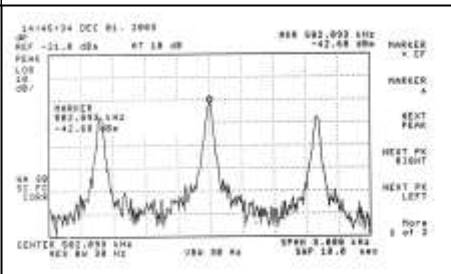
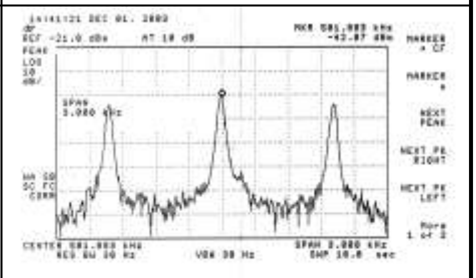
Appendix

Expected Experimental Results

Chapter 3: Expected Experimental Results

Experiment 1: Transistor AM modulator

Table 3-2 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}).

Output Signal Ports	Audio Signal Amplitudes	
	100 mV_{pp}	150 mV_{pp}
AM O/P		
TP1		
TP3		
AM O/P Output Signal Spectrums		
Modulation Index	E_{max} = 296 mV E_{min} = 50 mV m = 71 %	E_{max} = 138 mV E_{min} = 25 mV m = 69 %

Experiment 2: MC1496 AM modulator

Table 3-5 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{10} = 3.3 kΩ).

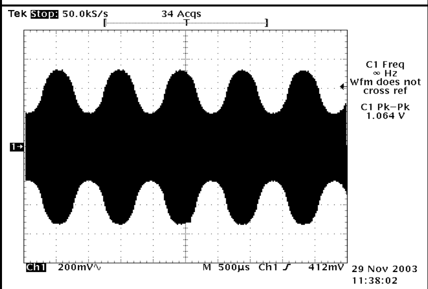
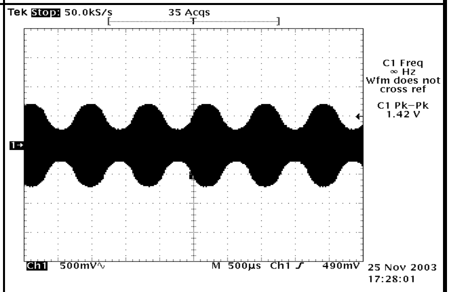
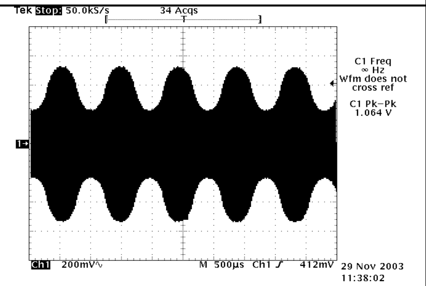
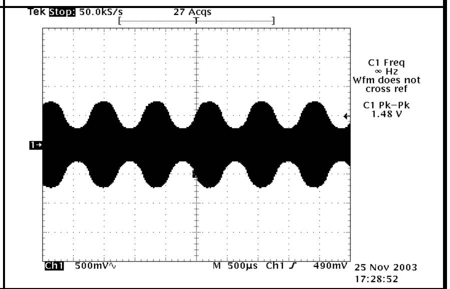
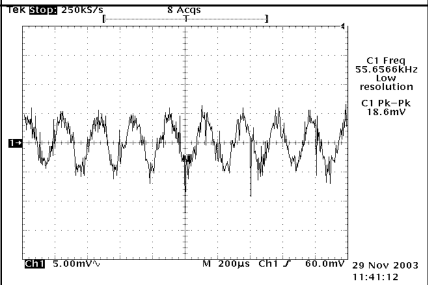
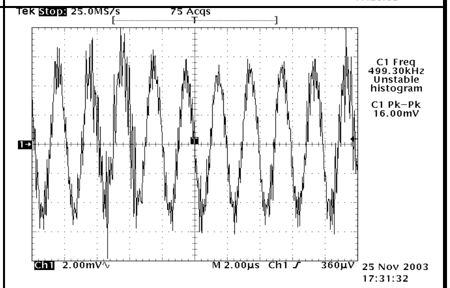
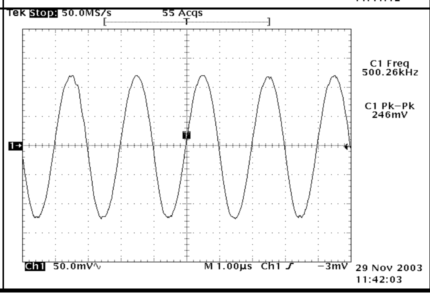
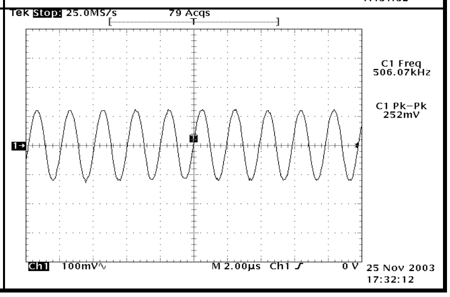
Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
AM O/P1		
AM O/P2		
TP1		
TP2		

Table 3-5 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (Continue) (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

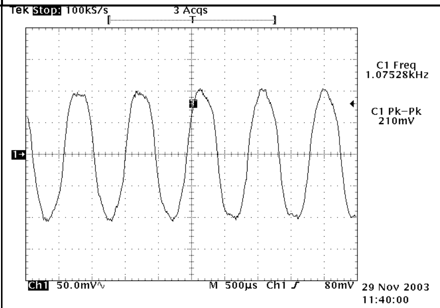
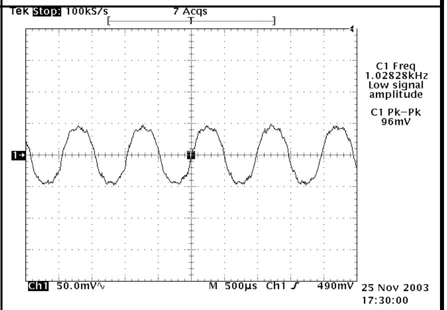
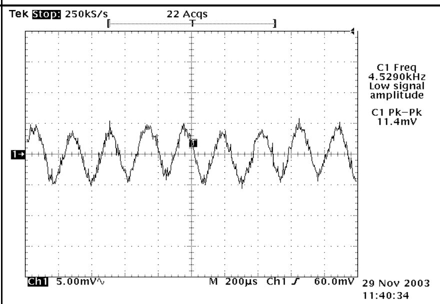
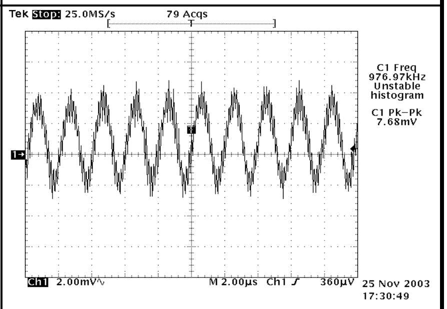
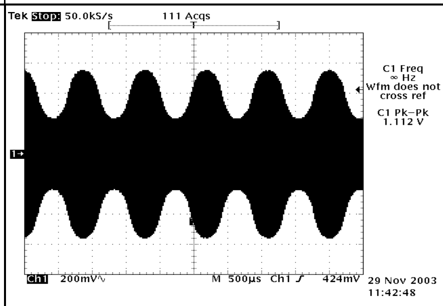
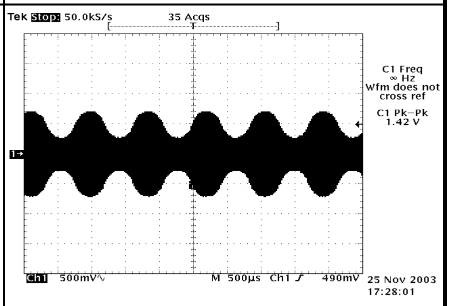
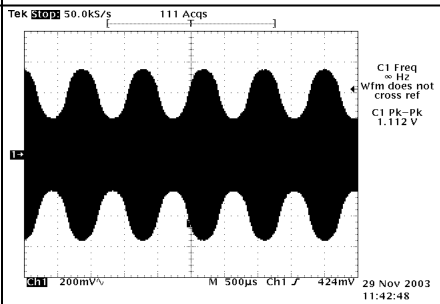
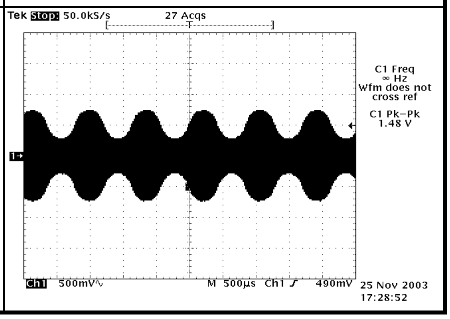
<table>
<tr><th rowspan="2">Output Signal Ports</th><th colspan="2">Audio Signal Amplitudes</th></tr>
<tr><th>600 mV_{pp}</th><th>300 mV_{pp}</th></tr>
<tr><td>TP3</td><td></td><td></td></tr>
<tr><td>TP4</td><td></td><td></td></tr>
<tr><td>TP5</td><td></td><td></td></tr>
<tr><td>TP6</td><td></td><td></td></tr>
</table>

Table 3-5 Observe on the variation of amplitude modulation by changing the amplitude of audio signal (Continue) (f_m = 1 kHz, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

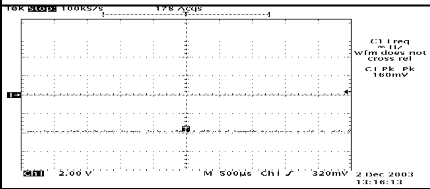
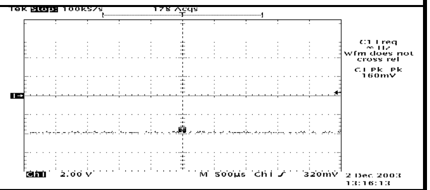
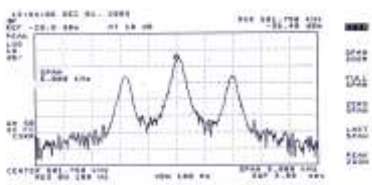
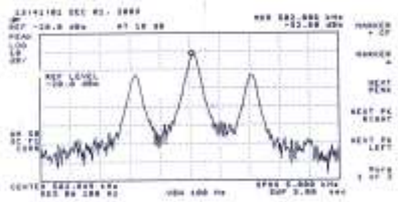
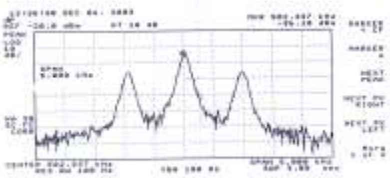
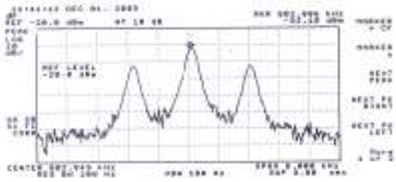
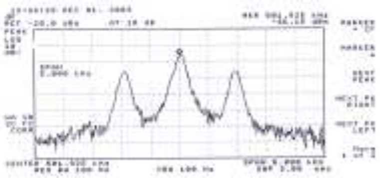
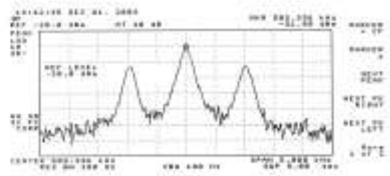
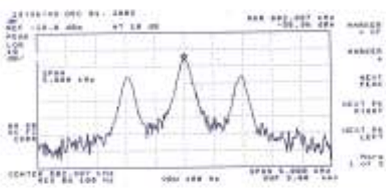
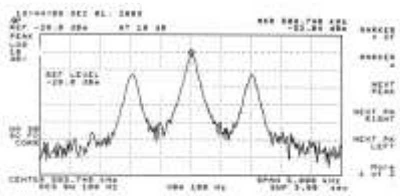
Output Signal Ports	Audio Signal Amplitudes	
	600 mV_{pp}	300 mV_{pp}
TP7		
AM O/P1 Output Signal Spectrums		
AM O/P2 Output Signal Spectrums		
TP5 Output Signal Spectrums		
TP6 Output Signal Spectrums		
Modulation Index	E_{max} = 500 mV E_{min} = 180 mV m = 47 %	E_{max} = 700 mV E_{min} = 250 mV m = 47.4 %

Table 3-6 Observe on the variation of amplitude modulation by changing the frequency of audio signal (V_m = 600 mV_{pp}, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

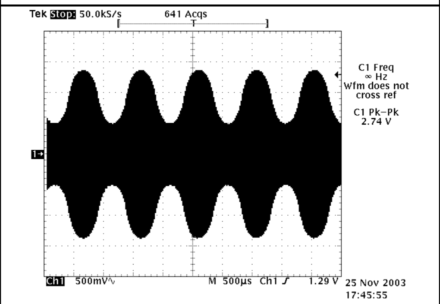
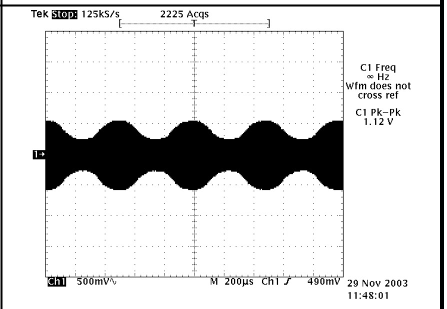
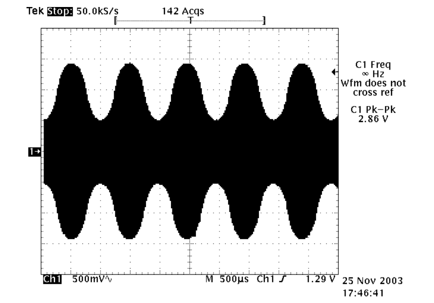
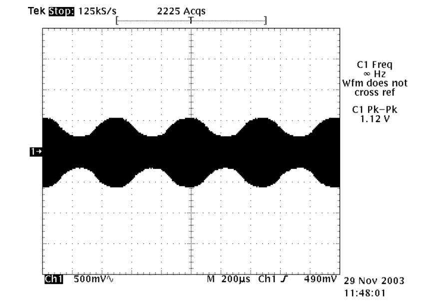
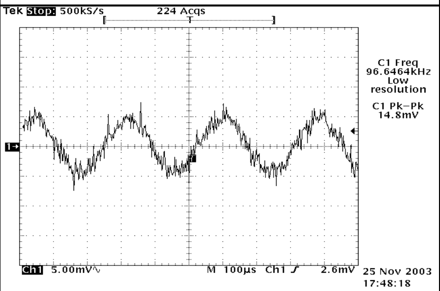
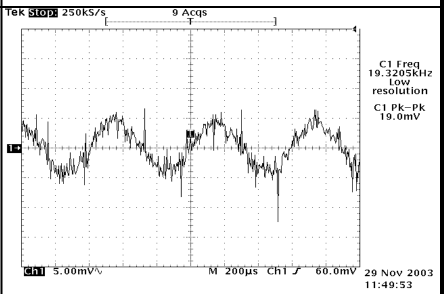
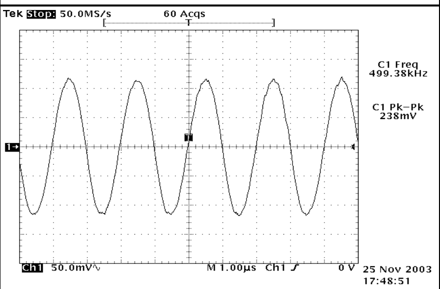
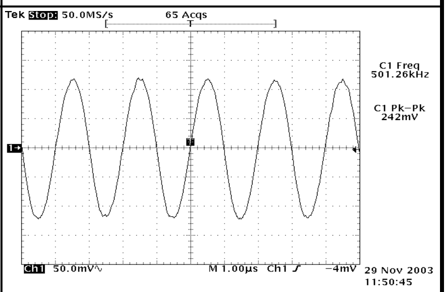
Output Signal Ports	Audio Signal Frequencies	
	1 kHz	2 kHz
AM O/P1		
AM O/P2		
TP1		
TP2		

Table 3-6 Observe on the variation of amplitude modulation by changing the frequency of audio signal (Continue) (V_m = 600 mV_{pp}, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

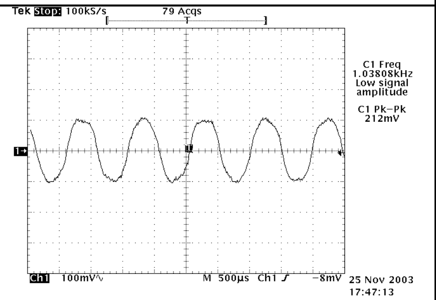
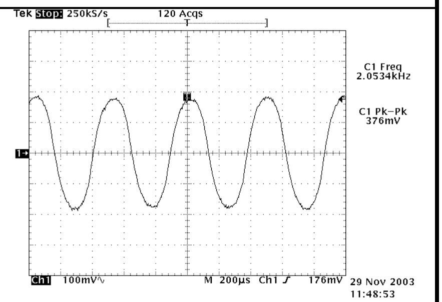
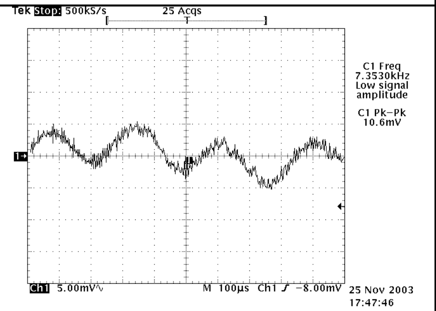
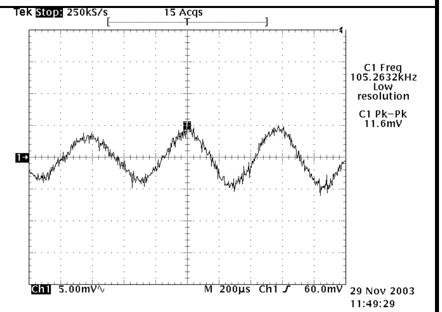
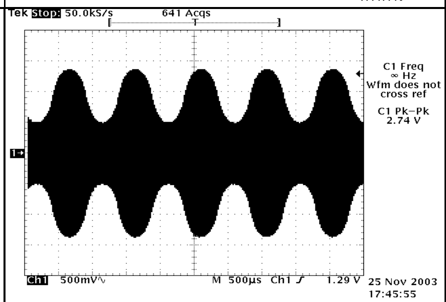
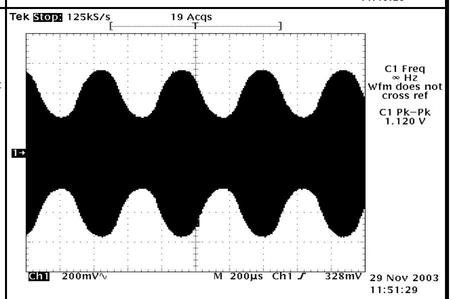
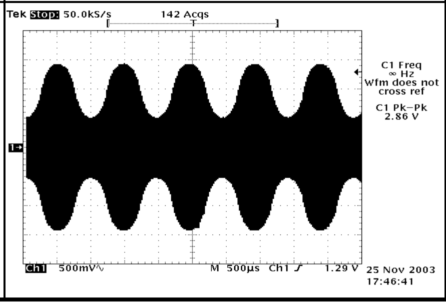
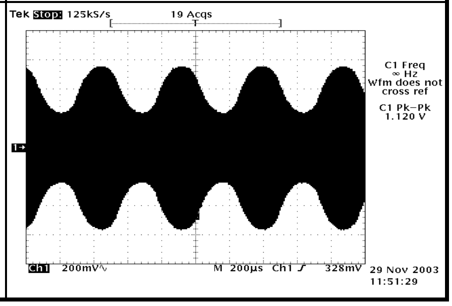
<table>
<tr><th rowspan="2">Output Signal Ports</th><th colspan="2">Audio Signal Frequencies</th></tr>
<tr><th>1 kHz</th><th>2 kHz</th></tr>
<tr><td>TP3</td><td>
</td><td>
</td></tr>
<tr><td>TP4</td><td>
</td><td>
</td></tr>
<tr><td>TP5</td><td>
</td><td>
</td></tr>
<tr><td>TP6</td><td>
</td><td>
</td></tr>
</table>

Table 3-6 Observe on the variation of amplitude modulation by changing the frequency of audio signal (Continue) (V_m = 600 mV_{pp}, f_c = 500 kHz, V_c = 300 mV_{pp}, R_{12} = 3.3 kΩ).

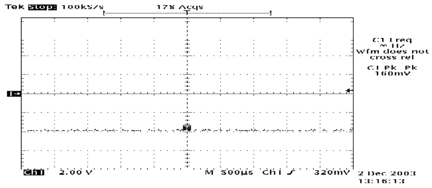
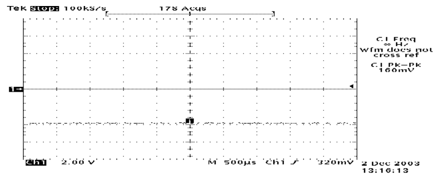
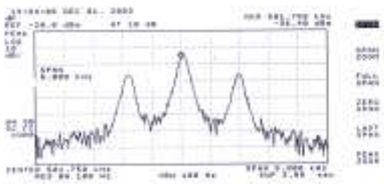
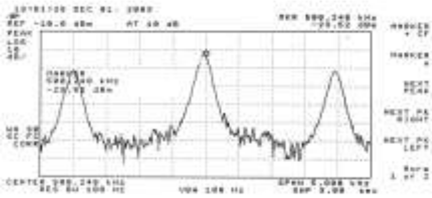
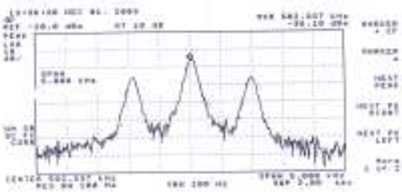
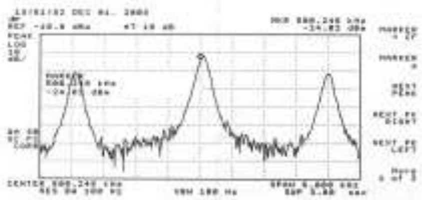
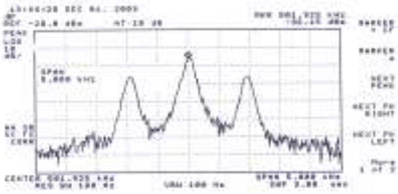
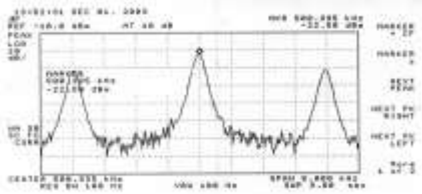
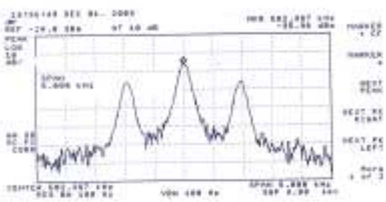
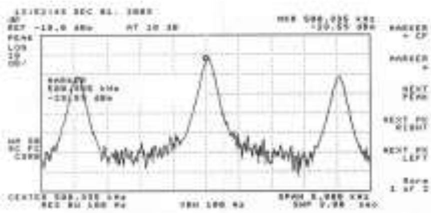
Output Signal Ports	Audio Signal Amplitudes	
	1 kHz	2 kHz
TP7		
AM O/P1 Output Signal Spectrums		
AM O/P2 Output Signal Spectrums		
TP5 Output Signal Spectrums		
TP6 Output Signal Spectrums		
Modulation Index	E_{max} = 1.37 V E_{min} = 500 mV m = 46.5 %	E_{max} = 560 mV E_{min} = 200 mV m = 47.4 %

Table 3-9 Observe on the variation of amplitude modulation by changing the variable resistor VR_1 (V_m = 600 mV_{pp}, f_m = 1 kHz, V_c = 300 mV_{pp}, f_c = 500 kHz, R_{12} = 3.3 kΩ).

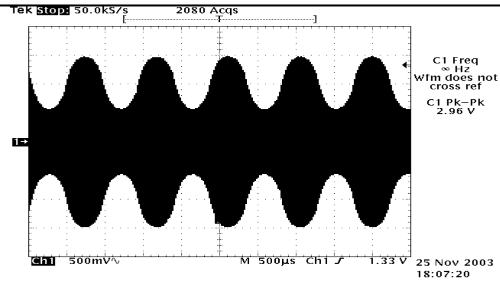
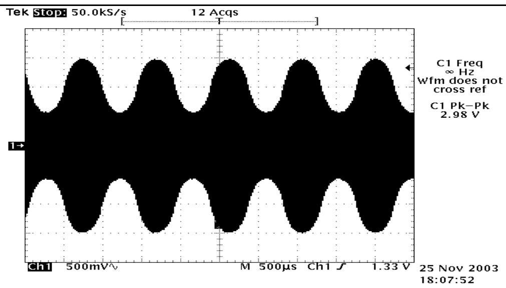
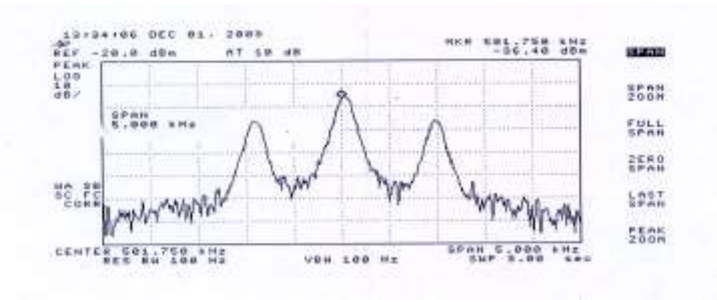
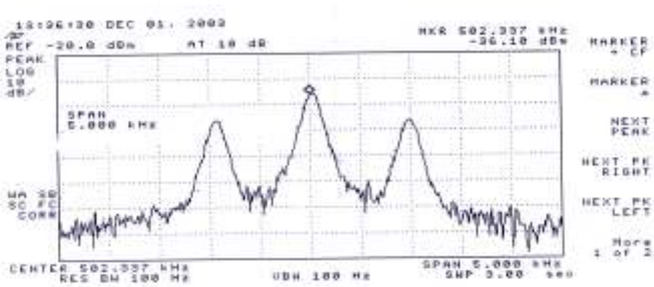
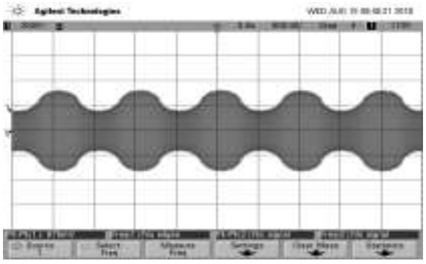
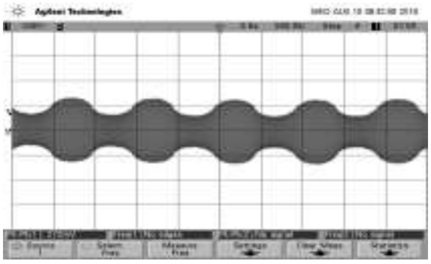
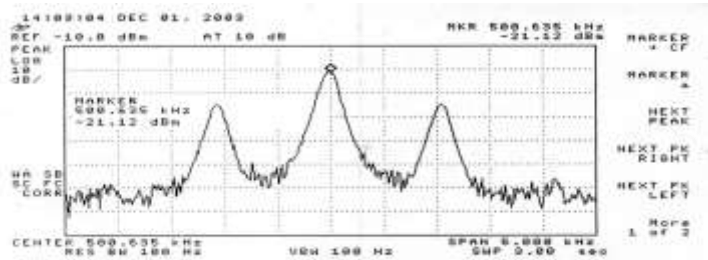
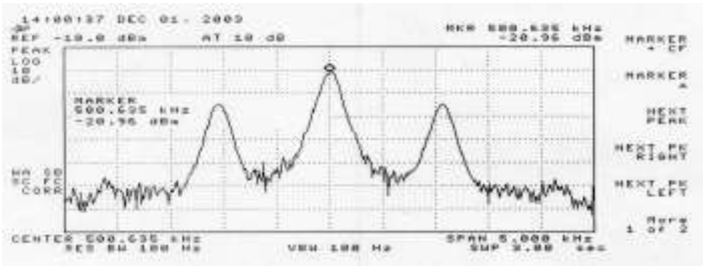
<table>
<tr><th colspan="2">Modulation Index</th><th>Output Signal Waveforms</th><th>Modulation Percentages</th></tr>
<tr><td rowspan="2">50 %</td><td>AM O/P1</td><td>
</td><td>E_{max} = 1.48 V
E_{min} = 550 mV
m = 49.4 %</td></tr>
<tr><td>AM O/P2</td><td>
</td><td>E_{max} = 1.48 V
E_{min} = 550 mV
m = 49.4 %</td></tr>
<tr><td rowspan="3">50 %</td><td></td><td colspan="2">Output Signal Spectrums</td></tr>
<tr><td>AM O/P1</td><td colspan="2"></td></tr>
<tr><td>AM O/P2</td><td colspan="2"></td></tr>
</table>

Table 3-10 Observe on the variation of amplitude modulation by changing the variable resistor VR_2 (V_m = 600 mV_{pp}, f_m = 1 kHz, V_c = 300 mV_{pp}, f_c = 500 kHz, R_{12} = 3.3 kΩ).

<table>
<tr><th colspan="2">Magnitudes of Variable Resistor VR_2</th><th>Output Signal Waveforms</th><th>Modulation Percentages</th></tr>
<tr><td rowspan="2">300 Ω</td><td>AM O/P1</td><td></td><td>E_{max} = 337.5 mV
E_{min} = 173 mV
m = 32.2 %</td></tr>
<tr><td>AM O/P2</td><td></td><td>E_{max} = 136 mV
E_{min} = 67.5 mV
m = 33.7 %</td></tr>
<tr><td rowspan="3">300 Ω</td><td rowspan="2">AM O/P1</td><td colspan="2">Output Signal Spectrums</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>AM O/P2</td><td colspan="2"></td></tr>
</table>