AM Demodulator

Experiment Objectives:

- To understand the theory of amplitude demodulation.
- To design and implement the diode detection amplitude demodulator.
- To design and implement the product detection amplitude demodulator.
- To understand the measurement and adjustment of AM demodulator.

Experiment theory:

From experiment 3, we know that the amplitude modulation signal utilizes the amplitude of audio signal to modulate high frequency carrier signal. Therefore, when we receive the amplitude modulation signal, we need to restore the audio signal. Figure 4.1 is the theory diagram of amplitude modulation. Normally detector can be classified as synchronous detector and asynchronous detector. We will discuss these two types of detectors in this experiment.

4.1: Diode detector for amplitude demodulation:

Since amplitude modulation signal utilizes audio signal to modulate carrier signal, which means the variation of carrier signal amplitude is followed by the change of audio signal amplitude. Hence the objective of amplitude demodulator is to take out the variation envelop detection from modulated AM signal. Figure 4.2 is the block diagram of diode detector. This circuit is a typical asynchronous detector. It rectifies the modulated AM signal and obtains a positive half wave signal. After that, the signal will pass through a low-pass filter and obtain an envelop detection. Then get rid of the DC signal, the audio signal will be recovered. If the input signal of the diode detector is the over modulated AM signal, as shown in figure 4.2. Then we are unable to recover the distorted signal to the audio signal by the diode detector. As for the over modulated AM signal, we need to use the product detector to demodulate this kind of signal, which will be discussed in next section.

![Figure 4-1 Theory diagram of amplitude demodulator](image-url)
Figure 4.3 is the circuit diagram of diode detector, in which resistors $R_1$, $R_2$, $R_3$, $R_4$, and $U_1$ and $U_2$ form two groups of inverting amplifiers to amplify the input signal, the amplified rate is 10 times of the original signal. Diode $D_1$ is the rectifier diode which can make the amplitude modulation signal become a positive half wave signal. Capacitors $C_1$, $C_2$ and resistors $R_5$ and $R_6$ comprise a low-pass filter to remove the envelop detection signal of audio signal which includes the DC level, then finally the objective of $C_3$ is to block the DC level and we can obtain a pure audio signal at output port.

### 4.2: Product detector for amplitude demodulation:

The AM demodulator can be implemented by utilizing a balanced modulator. We call this type of modulator as synchronous detector or product detector. Figure 4.4 is the block diagram of product detector. In figure 4.4, we notice that the design of product detector is to multiply the modulated AM signal by the synchronized carrier signal in AM modulator.

Let $x_{AM}(t)$ be the modulated AM signal, $x_c(t)$ be the carrier signal, i.e.:

\[
x_{AM}(t) = A_{DC}[1 + m \cos(2\pi f_m t)][A_c \cos(2\pi f_c t)] \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots
When these two signals input into two different ports of balanced modulator, then the output signal of the balanced modulator is as follow:

\[ x_{\text{out}}(t) = kx_c(t) \times x_{\text{AM}}(t) \]

\[ x_{\text{out}}(t) = kA_{\text{DC}}A_c^2[1 + m\cos(2\pi f_m t)]\cos^2(2\pi f_c t) \]

\[ x_{\text{out}}(t) = \frac{kA_{\text{DC}}A_c^2}{2} + \frac{kA_{\text{DC}}A_c^2}{2}m\cos(2\pi f_m t) + \frac{kA_{\text{DC}}A_c^2}{2}[1 + m\cos(2\pi f_m t)]\cos(4\pi f_c t) \quad \ldots \ldots 4.3 \]

Where (k) represents the gain of the balanced modulator. In equation 4.3, the first term is the DC signal, the second term is the audio signal and the third term is the second harmonic of modulated AM signal. If we can take out the second term from \( x_{\text{out}}(t) \) by using low-pass filter as shown in figure 4.4, then we can obtain the exact demodulated AM signal or audio signal.

![Figure 4.4](image)

Figure 4.4 is the block diagram of product detector. Variable resistor VR1 controls the input magnitude of carrier signal. Variable resistor VR2 controls the input magnitude of modulated AM signal, and then the output signal of MC1496 is located at pin 12. \( C_7, C_9 \) and \( R_8 \) comprise a low-pass filter which can remove the unwanted third term of equation 4.3, i.e. second harmonic of amplitude modulated signal. The DC signal, which is the first term of equation 4.3, can be blocked by \( C_{10} \). Therefore the signal that we obtain at output port will be:

\[ x_{\text{out}}(t) = \frac{kA_{\text{DC}}A_c^2}{2}m\cos(2\pi f_m t) \quad \ldots \ldots \ldots \ldots 4.4 \]

Equation 4.4 represents the audio signal or in other words the original modulating AM signal can be taken out via product detector.

These two types of detectors have its own advantages and disadvantages. As for diode detector, which is asynchronous detector, its circuit is simple but the performances are not as better as product detector. However, for product detector, which is synchronous detector, it has good performances but the circuit is more complicated that diode detector. Furthermore it also requires synchronous for both carrier signal (same frequency and same phase) for both modulator and demodulator, otherwise it will affect the quality of the output signal.
Experiment items:

Experiment 1: Diode detector

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 and J2 be open circuit to produce the modulated AM signal as the signal source in this experiment.

2. At audio signal input port (Audio I/P), input 600 mV amplitude, 3 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 300 mV amplitude, 300 kHz sine wave frequency.

3. Adjust VR1 so that the modulation index of the AM signal is maximum. Adjust VR2 so that the signal at AM O/P1 is 250 mV<sub>p-p</sub>.

4. Connect the output signal of the AM modulator (AM O/P1) to the input port (AM I/P) of diode detector in figure 4.3 or figure ACS4-1 on ETEK ACS-3000-02 module.

5. By using Oscilloscope, observe on the first stage (TP1) and second stage (TP2) which is amplified signal waveform. The rectifier's output (TP3), the output of the low-pass filter (TP4) and the demodulated AM output port (Audio O/P) then record the measured results in table 4.1.

6. According to the input signals in table 4.1, repeat steps 4 to 7 and record the measured results in table 4.1.

7. According to the input signals in table 4.2, repeat steps 3 to 7 and record the measured results in table 4.2.
Experiment 2: Product detector

Experiment 2.1: Observe on the variation of AM demodulator 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 and J2 be open circuit to produce the modulated AM signal as the signal source in this experiment.
2. At audio signal input port (Audio I/P), input 600 mV amplitude, 3 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 300 mV amplitude, 500 kHz sine wave frequency.
3. Adjust VR1 so that the modulation index of the AM signal is 50%.
4. Connect the output signal of the AM modulator (AM O/P1) to the input port (AM I/P) of product detector in figure 4.5 or figure ACS4-2 on ETEK ACS-30000-02 module. At the same time, also connect the carrier signal input port (Carrier I/P) of the product detector with the same carrier signal in AM modulator.
5. By using Oscilloscope, observe on output signal waveforms of product detector (Audio O/P), adjust VR1 and VR2 so that the signal at audio output is optimum without distortion. Adjust VR3 so that the signal at audio O/P is maximum without distortion.
6. By using oscilloscope, observe on the output signal waveforms of AM I/P, carrier I/P and audio O/P, then record the measured results in table 4.3.
7. By using oscilloscope, observe on output signal waveforms of the pin 1 (TP3), Pin 4 (TP4), pin 8 (TP1), and pin 10 (TP2) of the balanced modulator. Then record the measured results in table 4.3.
8. By using oscilloscope, observe on output signal waveforms of the multiplier (TP5 and TP6) of the balanced modulator and the low-pass filter (TP7), then record the measured results in table 4.3.
9. According to the input signals in table 4.3, repeat step 6 to step 9 and record the measured results in table 4.3.
10. According to the input signals in table 4.4, repeat step 3 to step 9 and record the measured results in table 4.4.

Experiment 2.2: Observe on the variation of AM demodulator 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 short circuit and J2 be open circuit to produce the modulated AM signal as the signal source in this experiment.
2. At audio signal input port (Audio I/P), input 600 mV amplitude, 3 kHz sine wave frequency; at carrier signal input port (Carrier I/P), input 300 mV amplitude, 500 kHz sine wave frequency.
3. Adjust VR1 so that the modulation index of the AM signal is 50%.
4. Connect the output signal of the AM modulator (AM O/P1) to the input port (AM I/P) of product detector in figure 4.5 or figure ACS4-2 on ETEK ACS-30000-02 module. At the same time, also connect the carrier signal input port (Carrier I/P) of the product detector with the same carrier signal in AM modulator.
5. By using Oscilloscope, observe on output signal waveforms of product detector (Audio O/P). Adjust VR1 and VR2 so that the signal at audio output is optimum without distortion. Adjust VR3 so that the signal at audio O/P is maximum without distortion.
6. By using oscilloscope, observe on the output signal waveforms of AM I/P, carrier I/P and audio O/P. Then record the measured results in Table 4.3.
7. By using oscilloscope, observe on output signal waveforms of the pin 1 (TP3), Pin 4 (TP4), pin 8 (TP1), and pin 10 (TP2) of the balanced modulator. Then record the measured results in Table 4.5.
8. By using oscilloscope, observe on output signal waveforms of the multiplier (TP5 and TP6) of the balanced modulator and the low-pass filter (TP7), then record the measured results in Table 4.5.
9. According to the input signals in Table 4.5, repeat step 6 to step 9 and record the measured results in Table 4.5.
10. According to the input signals in Table 4.6, repeat step 3 to step 9 and record the measured results in Table 4.6.
Measured results:

**Table 4-1:** Observe on the variation of AM modulation by changing the amplitude of audio signal. \((f_m=3 \text{ kHz}, f_c=300 \text{ kHz}, V_c=300 \text{ mV})\)

<table>
<thead>
<tr>
<th>Output signals ports</th>
<th>Audio signal amplitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM I/P</td>
<td>600 mV</td>
</tr>
<tr>
<td>TP1</td>
<td>300 mV</td>
</tr>
<tr>
<td>TP2</td>
<td>300 mV</td>
</tr>
<tr>
<td>TP3</td>
<td>300 mV</td>
</tr>
<tr>
<td>TP4</td>
<td>300 mV</td>
</tr>
<tr>
<td>Audio O/P</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4-2:** Observe on the variation of AM modulation by changing the frequency of audio signal. \((V_m=600 \text{ mV}, f_c=300 \text{ kHz}, V_c=300 \text{ mV})\)

<table>
<thead>
<tr>
<th>Output signals ports</th>
<th>Audio signal frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM I/P</td>
<td>3 KHz</td>
</tr>
<tr>
<td>TP1</td>
<td>6 KHz</td>
</tr>
<tr>
<td>TP2</td>
<td></td>
</tr>
<tr>
<td>TP3</td>
<td></td>
</tr>
<tr>
<td>TP4</td>
<td></td>
</tr>
<tr>
<td>Audio O/P</td>
<td></td>
</tr>
</tbody>
</table>
Table 4-3: Observe on the variation of AM modulation by changing the amplitude of audio signal.  \((f_m=3 \text{ kHz, } f_c=500 \text{ kHz, } V_c=300 \text{ mV})\)

<table>
<thead>
<tr>
<th>Output signals ports</th>
<th>Audio signal Amplitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600 mV</td>
</tr>
<tr>
<td>AM I/P</td>
<td></td>
</tr>
<tr>
<td>Carrier I/P</td>
<td></td>
</tr>
<tr>
<td>Audio O/P</td>
<td></td>
</tr>
<tr>
<td>TP1</td>
<td></td>
</tr>
<tr>
<td>TP2</td>
<td></td>
</tr>
<tr>
<td>TP3</td>
<td></td>
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<tr>
<td>TP4</td>
<td></td>
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<tr>
<td>TP5</td>
<td></td>
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<tr>
<td>TP6</td>
<td></td>
</tr>
<tr>
<td>TP7</td>
<td></td>
</tr>
</tbody>
</table>

Table 4-4: Observe on the variation of AM modulation by changing the frequency of audio signal.  \((V_m=600 \text{ mV, } f_c=500 \text{ kHz, } V_c=300 \text{ mV})\)

<table>
<thead>
<tr>
<th>Output signals ports</th>
<th>Audio signal frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 kHz</td>
</tr>
<tr>
<td>AM I/P</td>
<td></td>
</tr>
<tr>
<td>Carrier I/P</td>
<td></td>
</tr>
<tr>
<td>Audio O/P</td>
<td></td>
</tr>
<tr>
<td>TP1</td>
<td></td>
</tr>
<tr>
<td>TP2</td>
<td></td>
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<tr>
<td>TP3</td>
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<tr>
<td>TP4</td>
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</tr>
<tr>
<td>TP5</td>
<td></td>
</tr>
<tr>
<td>TP6</td>
<td></td>
</tr>
<tr>
<td>TP7</td>
<td></td>
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</tbody>
</table>
Table 4-5: Observe on the variation of AM modulation by changing the amplitude of carrier signal. 
\( V_m=600 \text{ mV}, \ f_m=3 \text{ kHz}, \ f_c=500 \text{ kHz} \)

<table>
<thead>
<tr>
<th>Output signals ports</th>
<th>Carrier signal amplitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600 mV</td>
</tr>
<tr>
<td>AM I/P</td>
<td></td>
</tr>
<tr>
<td>Carrier I/P</td>
<td></td>
</tr>
<tr>
<td>Audio O/P</td>
<td></td>
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<tr>
<td>TP1</td>
<td></td>
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<tr>
<td>TP2</td>
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<tr>
<td>TP3</td>
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<tr>
<td>TP4</td>
<td></td>
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<tr>
<td>TP5</td>
<td></td>
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<tr>
<td>TP6</td>
<td></td>
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<tr>
<td>TP7</td>
<td></td>
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</tbody>
</table>

Table 4-6: Observe on the variation of AM modulation by changing the frequency of carrier signal. 
\( V_m=600 \text{ mV}, \ f_m=3 \text{ kHz}, \ V_c=300 \text{ mV} \)

<table>
<thead>
<tr>
<th>Output signals ports</th>
<th>Carrier signal frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500 kHz</td>
</tr>
<tr>
<td>AM I/P</td>
<td></td>
</tr>
<tr>
<td>Carrier I/P</td>
<td></td>
</tr>
<tr>
<td>Audio O/P</td>
<td></td>
</tr>
<tr>
<td>TP1</td>
<td></td>
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<tr>
<td>TP2</td>
<td></td>
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<tr>
<td>TP3</td>
<td></td>
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<tr>
<td>TP4</td>
<td></td>
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<tr>
<td>TP5</td>
<td></td>
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<tr>
<td>TP6</td>
<td></td>
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<tr>
<td>TP7</td>
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