Chapter 12

ASK Demodulator

12-1 : Curriculum Objectives

1. To understand the operation theory of ASK demodulation.
2. To understand the operation theory of ASK asynchronous detector.
3. To understand the operation theory of ASK synchronous detector.
4. To understand the methods of testing and adjusting the ASK demodulation circuit.

12-2 : Curriculum Theory

In chapter 11, we have mentioned that we need a modulator to modulate the data to a high carrier frequency, so that the signal can be transmitted effectively. Therefore, for receiver, we must convert the digital signal back to the modulating signal. Figure 12-1 shows the theoretical diagram of ASK demodulation. There are two methods to design the ASK demodulator, which are asynchronous detector and synchronous detector. We will discuss these two types of ASK demodulator in this chapter.

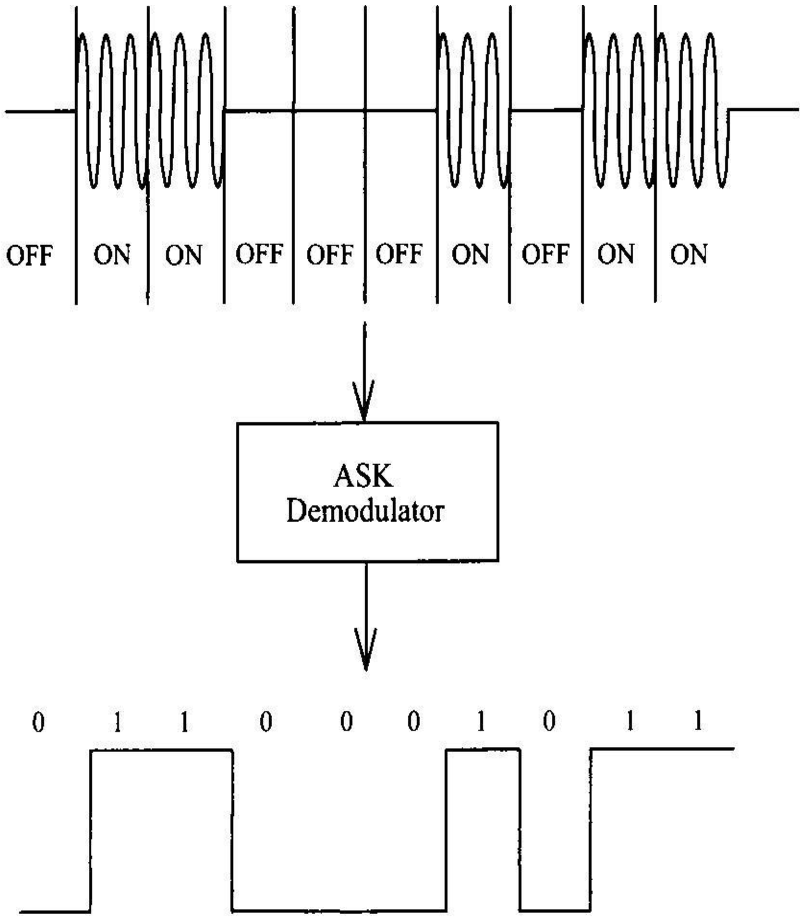

Figure 12-1 Theoretical diagram of ASK demodulation.

1. Asynchronous ASK Detector.

Figure 12-2 is the block diagram of asynchronous ASK detector. This structure is a typical asynchronous ASK detector. When the ASK signal pass through the rectifier, we can obtain the 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 digital signal will be recurred.

Figure 12-3 is the circuit diagram of asynchronous ASK detector, which R_1, R_2 and µA741 comprise an inverting amplifier to amplify the input signal. Then D_1 is the rectifying diode to make the modulation signal passes through D_1 half wave rectifier. R_3 and C_1 comprise a low-pass filter. µA741, VR_1 , D_2, R_4 and C_2 comprise a comparator, therefore, the output terminal can demodulate the digital demodulated signal.

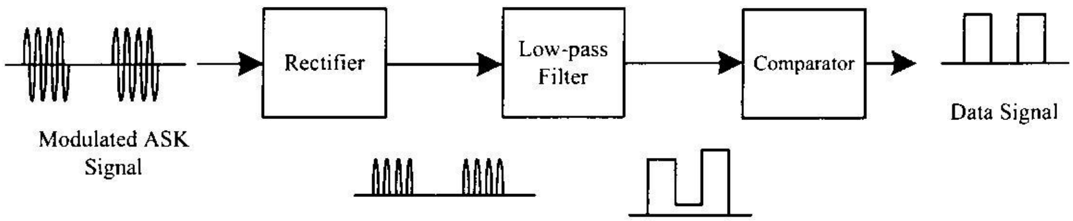

Figure 12-2 Block diagram of asynchronous ASK detector.

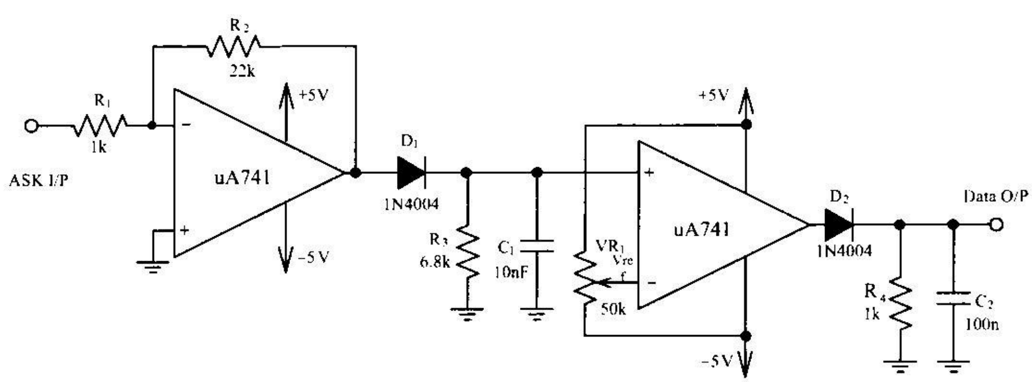

Figure 12-3 Circuit diagram of ASK asynchronous detector.

2. Synchronous ASK Detector

We have mentioned before that we can use synchronous detector to design the ASK demodulation. This experiment utilizes the structure of square-law detector and the block diagram is shown in figure 12-4. Let $X_{ASK}(t)$ be the ASK modulated signal, which is

$$x_{ASK}(t) = A_i \cos(\omega_c t + \phi_0); \quad 0 \le t \le T, \quad i = 1, 2, \cdots, M \qquad (12\text{-}1)$$

In equation (12-1), the values of amplitude A_i have M types of possible change, the ω_c and ϕ_0 denote the cutoff frequency and phase constant, respectively. When we input the ASK modulated signal to the two input terminals of balance modulator, then the output signal of balanced modulator can be expressed as

$$\begin{aligned} x_{out}(t) &= k x_{ASK}(t)\, x_{ASK}(t) \\ &= k A_i^2 \cos^2(\omega_C + \phi_0) \\ &= \frac{kA_i^2}{2} + \frac{kA_i^2}{2}\cos(2\omega_C t + 2\phi_0) \end{aligned} \qquad (12\text{-}2)$$

where $0 \le t \le T$, $i = 1, 2, \cdots, M$

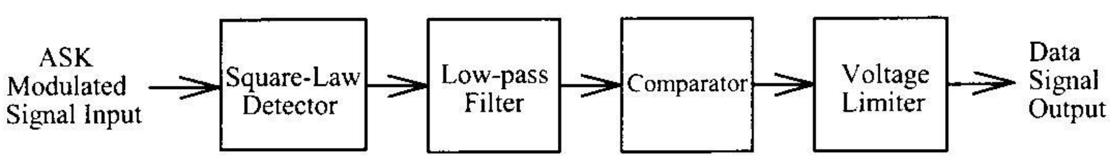

Figure 12-4 Basic block diagram of ASK demodulator.

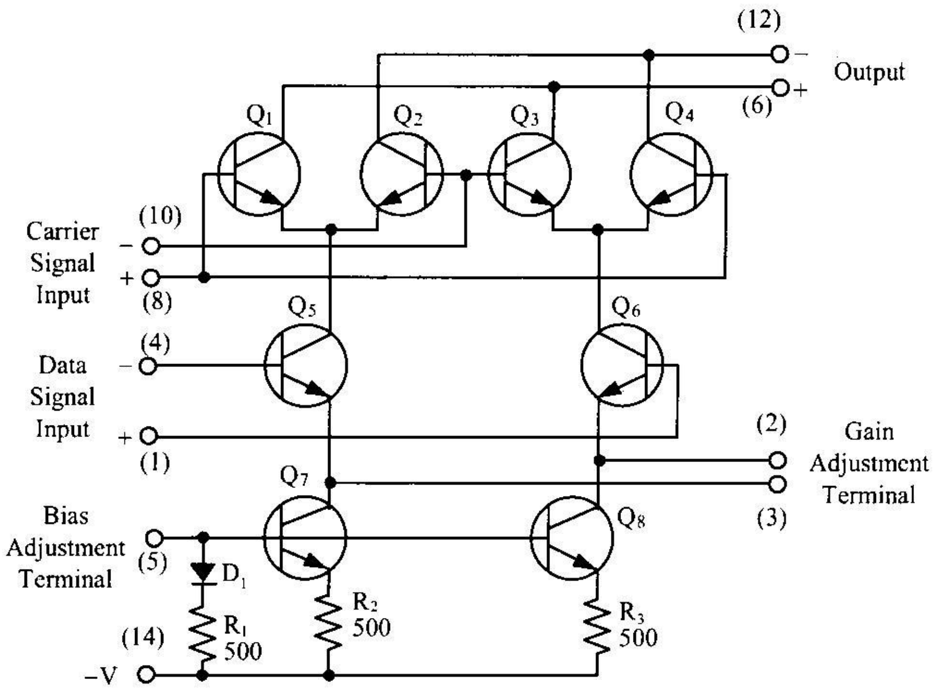

Figure 12-5 Internal circuit diagram of MC1496 balanced modulator.

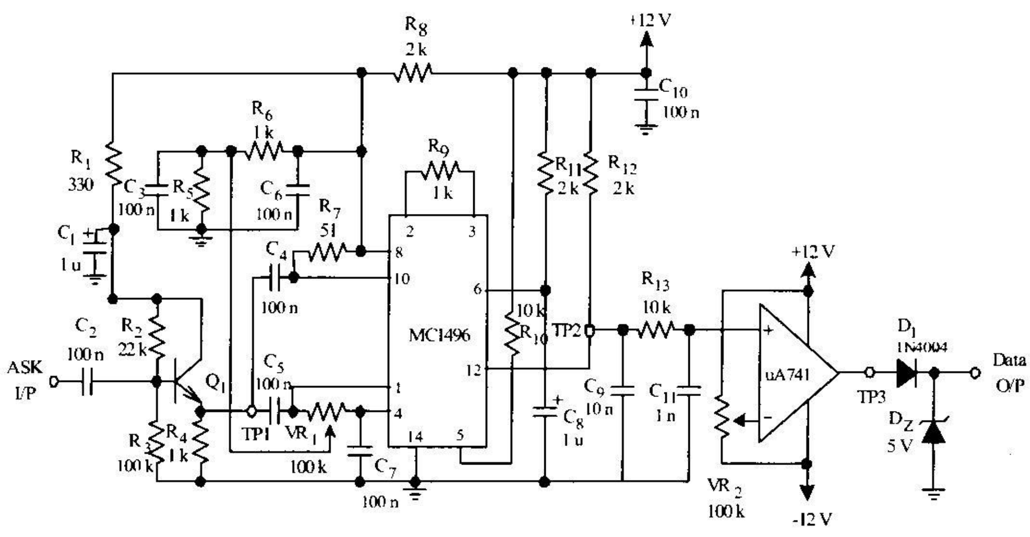

Figure 12-6 Circuit diagram of ASK synchronous detector.

where k represents the gain of balanced modulator. The first term of equation (12-2) is the data signal amplitude and the second term is the 2nd harmonic of the modulated signal. From the output signal $x_{out}(t)$if the first data signal amplitude receives the demodulated ASK signal, this means that the data signal can be recovered correctly.

In this chapter, we utilize MC1496 balanced modulator to design the square-law detector as shown in figure 12-5. Figure 12-5 is the internal circuit diagram of MC1496 balanced modulator (Readers may refer to the circuit diagram in chapter 11).

Figure 12-6 is the circuit diagram of synchronous ASK detector. In figure 12-6, Q_1, C_1, C_2, R_2, R_3 and R_4 comprise an emitter follower. VR_1controls the input ranges of modulated ASK signal and the output signal of MC1496 (pin 12) is shown in equation (12-2). The C_9, C_{11} and R_{13} comprise a low-pass filter, which the objective is to remove the 2nd harmonic of modulated ASK signal as shown in the second term in equation (12-2). The first term in the equation (12-2) is the data signal amplitude part, which can be recovered by using the comparator and voltage limiter comprised by µA741, VR_2, D_1 and D_2.

12-3 : Experiment Items

Experiment 1: Asynchronous ASK detector (XR 2206)

1. Use the ASK modulator in chapter 11 with R, = 1 M (as shown in figure 11-3) or refer to figure DCT 11-1 on GOTT DCT-6000-06 module to produce the amplitude modulated signal as the modulated ASK signal input. Let J2 be short circuit and J3 be open circuit.

2. At the data signal input terminal (Data I/P) in figure DCT11-1, input 5V amplitude and 100 Hz TTL signal.

3. Connect the ASK signal output terminal (ASK O/P) in figure DCT11-1 to the signal input terminal of the asynchronous ASK detector (ASK I/P) in figure DCT 12-1.

4. Adjust the variable resistor VR_1 in figure DCT12-1 to obtain the optimum reference level of the comparator. By using oscilloscope, observe on the output signal waveforms of the negative feedback amplifier (TP1), demodulated signal output port (TP2), comparator reference level (TP3) and the digital signal output port (Data O/P). Finally, record the measured results in table 12-1.

5. According to the input signal in table 12-1, repeat step 2 to step 4 and record the measured results in table 12-1.

6. Use the ASK modulator in chapter 11 with R, = 510 Ω (as shown in figure 11 -3) or refer to figure DCT 11-1 on GOTT DCT-6000-06 module to produce the amplitude modulated signal as the modulated ASK signal input. Let J2 be open circuit and J3 be short circuit.

7. According to the input signal in table 12-2, repeat step 2 to step 4 and record the measured results in table 12-2.

Experiment 2: Asynchronous ASK detector (MC 1496)

1. Use the ASK modulator in chapter 11 (as shown in figure 11 -6) or refer to figure DCT11-2 on GOTT DCT-6000-06 module to produce the amplitude modulated signal as the modulated ASK signal input.

2. At the data signal input terminal (Data I/P) in figure DCT11-2, input 5 V amplitude and 100 Hz TTL signal. At the carrier signal input terminal (Carrier I/P), input 400 mV amplitude and 20 kHz sine wave frequency.

3. Adjust VR_1 of ASK modulator in figure DCT11-2 and observe on the modulated ASK signal before the signal occurs distortion, then slightly adjust VR_2 to avoid the asymmetry of the signal to obtain the optimum output waveform of modulated ASK signal (ASK O/P).

4. Connect the ASK signal output terminal (ASK O/P) in figure DCT11-2 to the signal input terminal of the asynchronous ASK detector (ASK I/P) in figure DCT 12- 1.

5. Adjust the variable resistor VR_1 in figure DCT12-1 to obtain the optimum reference level of the comparator. By using oscilloscope, observe on the output signal waveforms of the negative feedback amplifier (TP1), demodulated signal output port (TP2), comparator reference level (TP3) and the digital signal output port (Data O/P). Finally, record the measured results in table 12-3.

6. According to the input signal in table 12-3, repeat step 3 to step 5 and record the measured results in table 12-3.

7. At the data signal input terminal (Data I/P) in figure DCT11-2, input 5V amplitude and 100 Hz TTL signal. At the carrier signal input terminal (Carrier I/P), input 400 mV amplitude and 100 kHz sine wave frequency.

8. According to the input signal in table 12-4, repeat step 3 to step 5 and record the measured results in table 12-4.

Experiment 3: Synchronous ASK detector

1. Use the ASK modulator in chapter 11 (as shown in figure 11 -6) or refer to figure DCT 11-2 on GOTT DCT-6000-06 module to produce the amplitude modulated signal as the modulated ASK signal input.

2. At the data signal input terminal (Data I/P) in figure DCT11-2, input 5V amplitude and 1 kHz TTL signal. At the carrier signal input terminal (Carrier I/P), input 400 mV amplitude and 100 kHz sine wave frequency.

3. Adjust VR_1 of ASK modulator in figure DCT11-2 and observe on the modulated ASK signal before the signal occurs distortion, then slightly adjust VR_2 to avoid the asymmetry of the signal to obtain the optimum output waveform of modulated ASK signal (ASK O/P).

4. Connect the ASK signal output terminal (ASK O/P) in figure DCT11-2 to the signal input terminal of the asynchronous ASK detector (ASK I/P) in figure DCT 12-2.

5. By using oscilloscope and switching to DC channel, then adjust VR_2 of figure DCT12-2 to obtain the optimum comparator reference voltage. Then observe on the output signal waveforms of the emitter follower (TP1), balanced modulator (TP2), comparator (TP3) and data signal output port (Data O/P). Finally, record the measured results in table 12-5. If the signal output waveform occurs distortion, then slightly adjust VR_1.

6. According to the input signal in table 12-5, repeat step 3 to step 5 and record the measured results in table 12-5.

7. At the data signal input terminal (Data I/P) in figure DCT11-2, input 5 V amplitude and 1 kHz TTL signal. At the carrier signal input terminal (Carrier I/P), input 400 mV amplitude and 40 kHz sine wave frequency.

8. According to the input signal in table 12-6, repeat step 3 to step 5 and record the measured results in table 12-6.

12-4 : Measured Results

Table 12-1 Measured results of ASK demodulator by using asynchronous detector. (2206 IC, J2 SC, J3 OC)

<table>
<tr><th>Data Signal Frequencies</th><th>Data I/P</th><th>ASK O/P</th></tr>
<tr><td rowspan="5">Vp = 5 V
fData = 100 Hz</td><td></td><td></td></tr>
<tr><td>TP1</td><td>TP2</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP3</td><td>Data O/P</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 12-1 Measured results of ASK demodulator by using asynchronous detector. (continue)
(2206 IC, J2 SC, J3 OC)

Data Signal Frequencies	Data I/P	ASK O/P
Vp = 5 V *f*Data = 500 Hz		
	TP1	TP2
	TP3	Data O/P

Table 12-2 Measured results of ASK demodulator by using asynchronous detector. (2206 IC, J2 OC, J3 SC)

Data Signal Frequencies	Data I/P	ASK O/P
Vp = 5 V *f*Data = 100 Hz		
	TP1	TP2
	TP3	Data O/P

Table 12-2 Measured results of ASK demodulator by using asynchronous detector. (continue) (2206 IC, J2 OC, J3 SC)

<table>
<tr><td>Data Signal Frequencies</td><td>Data I/P</td><td>ASK O/P</td></tr>
<tr><td rowspan="5">Vp = 5 V
*f*Data = 500 Hz</td><td></td><td></td></tr>
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<tr><td></td><td></td></tr>
<tr><td>TP3</td><td>Data O/P</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 12-3 Measured results of ASK demodulator by using asynchronous detector. (MC 1496, Vc = 400mV, fc = 20 kHz)

<table>
<tr><td>Data Signal Frequencies</td><td>Data I/P</td><td>ASK O/P</td></tr>
<tr><td rowspan="5">Vp = 5 V
fData = 100 Hz</td><td></td><td></td></tr>
<tr><td>TP1</td><td>TP2</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP3</td><td>Data O/P</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 12-3 Measured results of ASK demodulator by using asynchronous detector.(continue)
(MC 1496, Vc = 400mV, fc = 20 kHz)

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<tr><td>Data Signal Frequencies</td><td>Data I/P</td><td>ASK O/P</td></tr>
<tr><td rowspan="5">Vp = 5 V
*f*Data = 500 Hz</td><td></td><td></td></tr>
<tr><td>TP1</td><td>TP2</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP3</td><td>Data O/P</td></tr>
<tr><td></td><td></td></tr>
</table>

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<table>
<tr><th>Data Signal Frequencies</th><th>Data I/P</th><th>ASK O/P</th></tr>
<tr><td rowspan="5">Vp = 5 V
*f*Data = 100 Hz</td><td></td><td></td></tr>
<tr><td>TP1</td><td>TP2</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP3</td><td>Data O/P</td></tr>
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</table>

Table 12-4 Measured results of ASK demodulator by using asynchronous detector.(continue)
(MC 1496, Vc = 400mV, fc = 100 kHz)

<table>
<tr><th>Data Signal Frequencies</th><th>Data I/P</th><th>ASK O/P</th></tr>
<tr><td rowspan="5">Vp = 5 V
fData = 500 Hz</td><td></td><td></td></tr>
<tr><td>TP1</td><td>TP2</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP3</td><td>Data O/P</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 12-5 Measured results of ASK demodulator by using asynchronous detector. (MC 1496, Vc = 400mV, fc = 100 kHz)

Data Signal Frequencies	Data I/P	ASK O/P
Vp = 5 V *f*Data = 1kHz		
	TP1	TP2
	TP3	Data O/P

Table 12-5 Measured results of ASK demodulator by using asynchronous detector.(continue)
(MC 1496, Vc = 400mV, fc = 100 kHz)

Data Signal Frequencies	Data I/P	ASK O/P
Vp = 5 V *f*Data = 5 kHz		
	TP1	TP2
	TP3	Data O/P

Table 12-6 Measured results of ASK demodulator by using asynchronous detector. (MC 1496, Vc = 400mV, fdata = 1 kHz)

Data Signal Frequencies	Data I/P	ASK O/P
40 kHz		
	TP1	TP2
	TP3	Data O/P

Table 12-6 Measured results of ASK demodulator by using asynchronous detector. (continue)
(MC 1496, Vc = 400mV, fdata = 1 kHz)

<table>
<tr><td>Data Signal Frequencies</td><td>Data I/P</td><td>ASK O/P</td></tr>
<tr><td rowspan="5">70 kHz</td><td></td><td></td></tr>
<tr><td>TP1</td><td>TP2</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP3</td><td>Data O/P</td></tr>
<tr><td></td><td></td></tr>
</table>

12-5 : Problem Discussion

1. In figure 12-3, if we neglect the µA741 op-amp and connect the ASK modulator to the diode detector, then what are the results?

2. What are the purposes of the comparators in figure 12-3 and figure 12-6?

3. In figure 12-6, what are the objectives of R_{13}, C_9 and C_{11}?

4. In figure 12-6, what are the objectives of D_1 and Dz?