

Chapter 6

DSB-SC AND SSB DEMODULATORS

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6.1 OBJECTIVES

1. Demodulating DSB-SC and SSB signals using product detector.
2. Learning how to use product detector in communication receivers.

6.2 DISCUSSION OF FUNDAMENTALS

Fig. 6-1 shows the internal configuration of MC1496. The differential amplifier, Q_5 and Q_6 , is used to drive the differential amplifiers Q_1Q_2 and Q_3Q_4 . The constant-current source generator, Q_7 and Q_8 , provides the differential amplifier Q_5 and Q_6 with a constant current. Overall gain of MC1496 can be controlled by externally connecting a resistor between pins 2 and 3. For DSB-SC or SSB demodulation, the DSB-SC or SSB 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. Since the detector has two outputs (pins 6 and 12), one of the outputs can be used as the detector output and the other used for the use of automatic gain control (AGC).

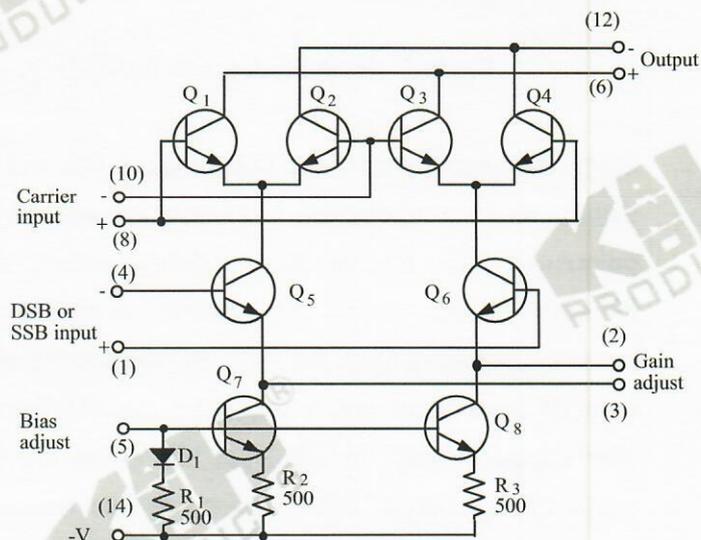


Fig.6-1 LM1496 internal circuit

Fig. 6-2 shows the product detector circuit with the MC1496 for DSB-SC or SSB demodulation. With some proper modifications, this circuit can also be used as an AM, FM, or PWM demodulator. The local carrier is applied to the inputs (pins 10 and 8) and its frequency should be exactly equal to the frequency of DSB-SC or SSB carrier. Since the amplitude of the modulated signal is typically within the range of 500 mV_{pp} to 800 mV_{pp} , it is enough to ensure that the detector operates in linear region. The resistor R_5 connected between pins 2 and 3 determines the voltage gain of MC1496.

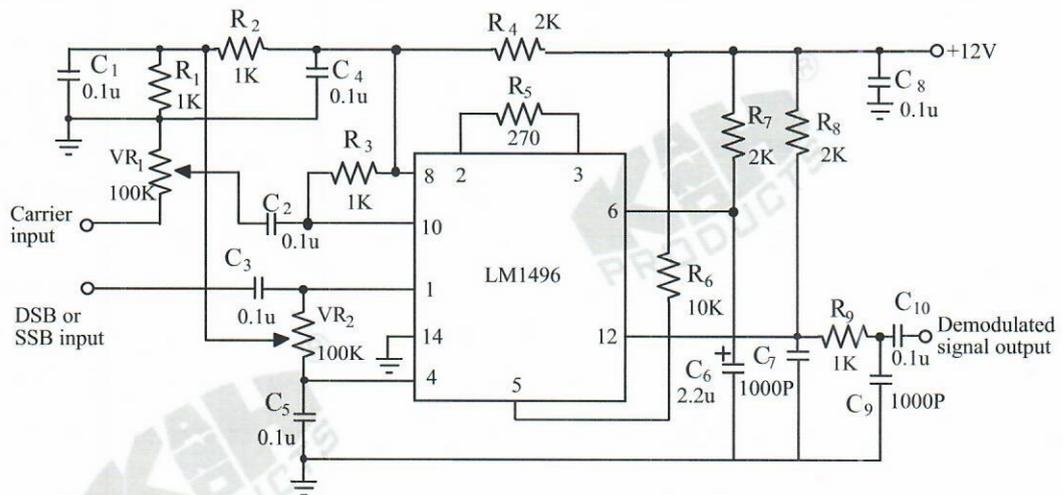


Fig.6-2 Product detector for DSB-SC and SSB signals.

Since the signal generators in laboratory can not generate DSB-SC and SSC signals for our experiment requirements, we will use the DSB-SC modulator output of Fig. 5-1 and the SSB modulator output of Fig. 5-3 for our experiments 6-1 and 6-2, respectively. As mentioned in chapter 5, the SSB modulated signal could be obtained from the DSB-SC modulated signal by removing the upper band or lower band with a filter. Note that the load effect may be caused if the filter added directly. To eliminate this effect, the source follower used in the circuit of Fig. 5-1 is recommended to add between the filter output and the product detector input. Considering the SSB modulated signal connected to the input (pins 1 and 4) of LM1496, the SSB signal can be expressed by

$$x_{ssb}(t) = \frac{kA_m A_c}{2} \cos(\omega_c + \omega_m)t$$

and the input signal between pins 8 and 10 is

$$x_c(t) = A_c \cos \omega_c t$$

Therefore the output signal of LM1496 at pin 12 will be

$$\begin{aligned} x_o(t) &= kx_{ssb}(t) \times x_c(t) \\ &= \frac{k^2 A_m A_c^2}{2} \cos(\omega_c + \omega_m)t \times \cos \omega_c t \\ &= \frac{k^2 A_m A_c^2}{4} [\cos(2\omega_c + \omega_m)t + \cos \omega_m t] \end{aligned}$$

When this output signal passes through the low-pass filter constructed by C_7 , C_9 and R_9 , the high-frequency components will be removed and the demodulated output signal becomes

$$x_o(t) = \frac{k^2 A_m A_c^2}{4} \cos \omega_m t$$

From the equation above, we find that the LM1496 can demodulate the SSB modulated signal to recover the audio signal $A_m \cos \omega_m t$ with a gain $(kA_c)^2/4$. To change the gain of demodulator, we can change the carrier amplitude or the resistance of R_5 (value of k). Consider that a DSB-SC modulated signal is applied to input terminals (pins 1 and 4) of LM1496 and such signal may be expressed by

$$x_{DSB-SC}(t) = \frac{kA_m A_c}{2} [\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$$

and the carrier input signal (pins 8 and 10) is

$$x_c(t) = A_c \cos \omega_c t$$

Thus the output signal of LM1496 at pin 12 will be

$$\begin{aligned} x_o(t) &= kx_{DSB-SC}(t) \times x_c(t) \\ &= \frac{k^2 A_m A_c^2}{2} [\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t] \times \cos \omega_c t \\ &= \frac{k^2 A_m A_c^2}{4} [\cos(2\omega_c + \omega_m)t + \cos(2\omega_c - \omega_m)t + 2 \cos \omega_m t] \end{aligned}$$

High frequencies, the first and second terms on the right side of the equation above, will be removed by the low-pass filter (C_7 , C_9 and R_9) when this signal passes through the filter. Then the demodulated output becomes

$$x_o(t) = \frac{k^2 A_m A_c^2}{2} \cos \omega_m t$$

6.3 EQUIPMENT REQUIRED

- 1 - Module KL-96001
- 2 - Module KL-93003
- 3 - Oscilloscope
- 4 - RF Generator

6.4 EXPERIMENTS AND RECORDS

Experiment 6-1 DSB-SC Product Detector

- 1. This experiment uses the modulated DSB-SC output of DSB-SC Modulator circuit of experiment 5-1 as the DSB-SC input of product detector circuit. First, complete the DSB-SC modulator circuit.
- 2. Connect a 500mVp-p, 500kHz sine wave to the carrier input and a 500mVp-p, 1kHz sine wave to the audio input of DSB-SC modulator. (Carrier and audio signals should be adjusted alone before connecting to circuits, because if you adjust them during circuit testing, there'll be loading errors)
- 3. Turn the VR₁ of DSB-SC modulator to get a DSB-SC modulated signal output.
- 4. Locate the DSB-SC and SSB Product Detector circuit on Module KL-93003. Insert connect plugs in J1 and J3 to set R₅=270Ω and R₆=10kΩ.
- 5. Connect the carrier signal used in step 2 to the carrier input of product detector. Connect the modulated output of DSB-SC modulator to the DSB-SC input of product detector.

- 6. Using the oscilloscope, observe the output signal and turn the VR_1 of product detector circuit to get minimum distortion, and record the result in Table 6-1.
- 7. Change the carrier to a 500mVp-p, 500kHz sine wave and the audio to a 500mVp-p, 3kHz sine wave. Carefully turn the VR_1 to get a DSB-SC modulated output signal.
- 8. Repeat step 6 and record the result in Table 6-2.
- 9. Remove the connect plug from J1 and then insert it in J2 to change R_5 (270Ω) to R_{10} (330Ω). Repeat step 6 and record the result in Table 6-3.
- 10. Remove the connect plug from J3 and then insert it in J4 to change R_6 ($10k\Omega$) to R_{11} ($30k\Omega$). Repeat step 6 and record the result in Table 6-4.

Experiment 6-2 SSB Product Detector

- 1. This experiment uses the modulated SSB output of SSB Modulator circuit of experiment 5-2 as the SSB input of product detector circuit. First, complete the SSB modulator circuit.
- 2. Insert connect plug in J2 to bypass ceramic filters. Connect a 500mVp-p, 457kHz sine wave to the carrier input (I/P1) and a 500mVp-p, 2kHz sine wave to the audio input (I/P2).
(Carrier and audio signals should be adjusted alone before connecting to circuits, because if you adjust them during circuit testing, there'll be loading errors)
- 3. Turn the VR₁ to get a DSB-SC modulated output (O/P). Remove the connect plug from J2 and then insert it in J1 to recover the ceramic filters. The output signal will be the SSB modulated signal.
- 4. Insert connect plugs in J1 and J3 of product detector circuit to set R₅ = 270 Ω and R₆ = 10 kΩ.
- 5. Connect the carrier signal used in step 2 to the carrier input (I/P1) of product detector, and connect the SSB modulated output to the SSB input (I/P2).
- 6. Using the oscilloscope, observe the demodulated output waveform (O/P) and carefully turn the VR₁ and VR₂ to get minimum distortion. Record the result in Table 6-5.
- 7. Remove the connect plug from J1 and insert it in J2 to bypass the ceramic filters of SSB modulator. Change the carrier to a 700mVp-p, 457kHz sine wave and the audio to a 700mVp-p, 2kHz sine wave. Turn

the VR_1 to get a DSB-SC modulated signal, and then remove the connect plug from J2 and inset it in J1 to recover the ceramic filters. Then the output signal will be the SSB modulated signal.

- 8. Repeat step 6 and record the result in Table 6-6.
- 9. Remove the connect plug from J1 and then insert it in J2 to change R_5 (270 Ω) to R_{10} (330 Ω). Repeat step 6 and record the result in Table 6-7.
- 10. Remove the connect plug from J3 and then insert it in J4 to change R_6 (10 k Ω) to R_{11} (30 k Ω). Repeat step 6 and record the result in Table 6-8.

Table 6-1

($R_5=270\Omega$, $R_6=10\text{ k}\Omega$, $V_c=500\text{ mVp-p}$, $V_m=500\text{ mVp-p}$, $f_c=500\text{kHz}$, $f_m=1\text{kHz}$)

Input Waveform	
Output Waveform	

Table 6-2

($R_5=270\Omega$, $R_6=10\text{ k}\Omega$, $V_c=500\text{mVp-p}$, $V_m=500\text{mV}$, $f_c=500\text{kHz}$, $f_m=3\text{kHz}$)

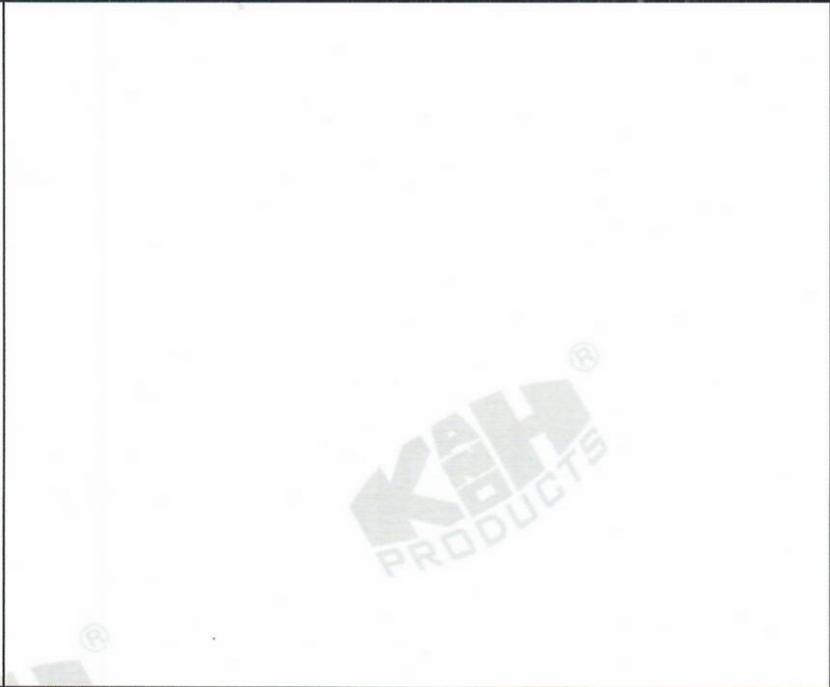
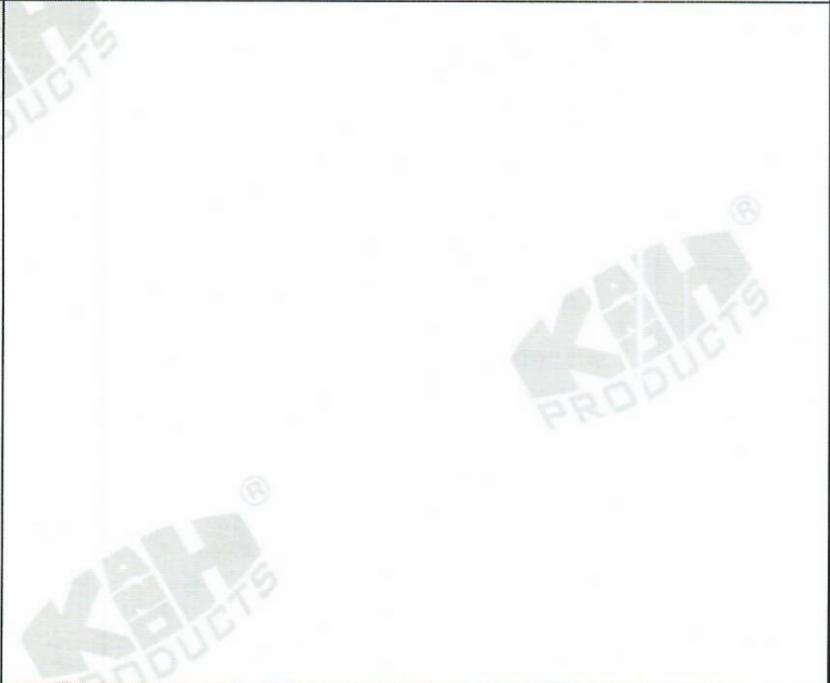
<p>Input Waveform</p>	
<p>Output Waveform</p>	

Table 6-3

($R_5=330\Omega$, $R_6=10\text{ k}\Omega$, $V_c=500\text{mV}$, $V_m=500\text{mV}$, $f_c=500\text{kHz}$, $f_m=1\text{kHz}$)

Input Waveform	
Output Waveform	

Table 6-4

($R_5=330\Omega$, $R_6=30\text{ k}\Omega$, $V_c=500\text{mVp-p}$, $V_m=500\text{mVp-p}$, $f_c=500\text{kHz}$, $f_m=1\text{kHz}$)

Input Waveform	
Output Waveform	

Table 6-5

($R_5=270\Omega$, $R_6=10\text{ k}\Omega$, $V_c=500\text{mVp-p}$, $V_m=500\text{mVp-p}$, $f_c=457\text{kHz}$, $f_m=2\text{kHz}$)

Input Waveform	
Output Waveform	

Table 6-6

($R_5=270\Omega$, $R_6=10\text{ k}\Omega$, $V_c=700\text{mVp-p}$, $V_m=700\text{mVp-p}$, $f_c=457\text{kHz}$, $f_m=2\text{kHz}$)

Input Waveform	
Output Waveform	

Table 6-7

($R_5=330\Omega$, $R_6=10\text{ k}\Omega$, $V_c=500\text{mVp-p}$, $V_m=500\text{ mV}$, $f_c=457\text{kHz}$, $f_m=2\text{kHz}$)

Input Waveform	
Output Waveform	

Table 6-8

($R_5=330\Omega$, $R_6=30\text{ k}\Omega$, $V_c=500\text{mVp-p}$, $V_m=500\text{mVp-p}$, $f_c=457\text{kHz}$, $f_m=2\text{kHz}$)

Input Waveform	
Output Waveform	

6.5 QUESTIONS

1. How does the value of R_5 in Fig. 6-2 affect the output amplitude?
2. How does the value of R_6 in Fig. 6-2 affect the output amplitude?
3. What is the function of VR_1 or VR_2 ?
4. If the modulating frequency goes up, what components should be modified for an undistorted demodulated signal?
5. May a peak detector be used in DSB-SC or SSB demodulation?

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