Chapter 5

DSB-SC AND SSB MODULATORS

5.1 OBJECTIVES

1. Learning how to generate double-sideband suppressed carrier and single-sideband modulated signals.
2. Learning how to test and adjust double-sideband suppressed carrier and single-sideband balanced modulators.

5.2 DISCUSSION OF FUNDAMENTALS

The principle of circuit operations of this chapter is similar to that of Chapter 3 mentioned before. The circuit of Fig. 5-1 is a double-sideband suppressed-carrier (DSB-SC) modulator. The balance circuit consisted by the VR_1 is used to control the LM1496 operating in balance state. By adjusting the VR_1 properly, this will ensure that the modulator operates in balance state. In short, the major difference between DSB-SC and AM modulated signals is the DSB-SC modulated signal containing no carrier. To achieve the requirement of suppressing carrier, we should first connect the audio input to ground, and then observe the LM1496 output to ensure no carrier presented by carefully adjusting the VR_1. If this is made and then reconnects the audio signal, the DSB-SC modulated signal containing the upper- and lower-sideband signals will be presented at LM1496 output.

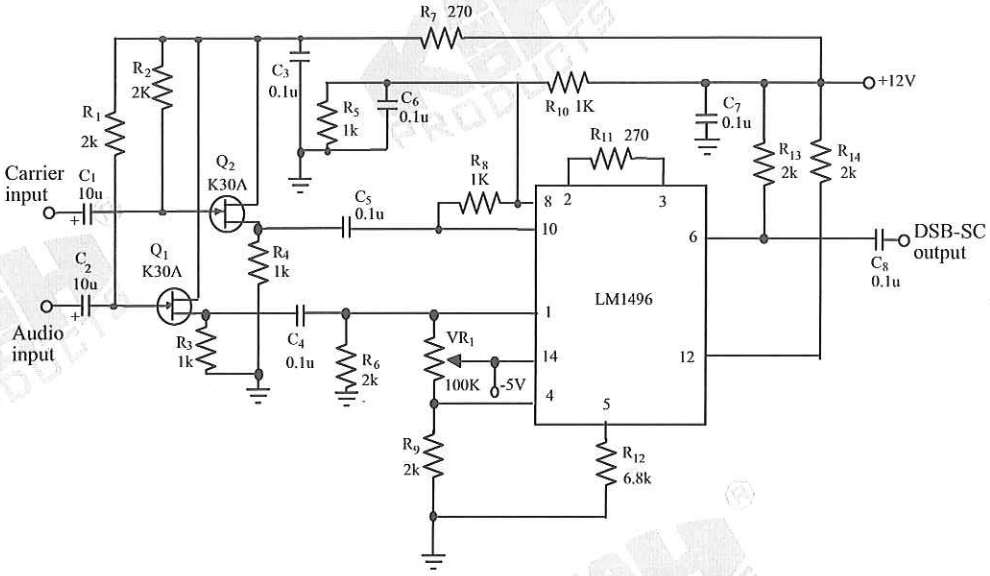

Fig.5-1 DSB-SC modulator circuit

Carrier voltage level is a very important factor, which affects the carrier suppressing. If the carrier level is too low, it will be not enough to start the carrier amplifier completely; Reversely, a too high level will occur carrier feedthrough. In general, the optimum input range is about 0.2 V_{pp} to 0.8 V_{pp} when the carrier frequency is 500 kHz.

To identify AM, DSB-SC or SSB modulated signals, we assume a typical audio spectrum shown in Fig. 5-2a. Where f_{mh} is the highest frequency and f_{ml} is the lowest frequency in audio signal. If using this audio signal to modulate the amplitude of sine carrier, we will obtain an AM spectrum as shown in Fig. 5-2b. The AM spectrum includes three components below:

1. Carrier frequency f_c
2. Upper sideband with the highest frequency (f_c+f_{mh})
3. Lower sideband with the highest frequency (f_c-f_{ml})

Since the amplitude-modulated signal contains these two sideband signals, it is sometimes called as double-sideband AM. In double sideband suppressed carrier modulation, the carrier signal is removed or suppressed by the balanced modulator, and the modulated signal containing no carrier as shown in Fig. 5-2c. Notice that these two sidebands contain the same audio signal when the modulated signal is transmitted, while receivers may recover the audio signal from each sideband signals by demodulation technique. This means that only one of two sidebands is need in transmitting process. Thus an amplitude modulation called single-sideband (SSB) is shown in Fig. 5-2d.

Suppose the audio input signal (pins 1 and 4) of LM1496 is $A_m \cos 2\pi f_m t$ and the carrier input signal (pins 8 and 10) is $A_c \cos 2\pi f_c t$, then its output signal at pin 6 should be

$$V_o(t) = k(A_m \cos 2\pi f_m t)(A_c \cos 2\pi f_c t)$$

$$= \frac{kA_m A_c}{2}[\cos 2\pi (f_m + f_c)t + \cos 2\pi (f_m - f_c)t] \qquad (5\text{-}1)$$

where k is the modulator gain, and (f_c+f_m) and (f_c-f_m) are the upper and lower sideband modulated signals, respectively.

In Fig. 5-1, the source follower consisted of Q_1 and Q_2 acts as a buffer due to the characteristics of high input impedance and low output impedance. The coupling capacitors C_1, C_2, C_4, C_5 and C_8 are used for blocking dc signal while coupling ac signal. The R_{11} is for adjusting the gain of the balanced modulator and the R_{12} is for bias current adjustment. Resistors R_1, R_2, R_{13} and R_{14} provide dc bias for operating requirement. Resistors R_5 and R_{10} are for AGC control. Capacitors C_3, C_6 and C_7 are used to bypass undesired noise. The VR_1 are for balancing, optimum operating point, minimizing distortion and determining types of output signal (i.e., AM or DSB-SC).

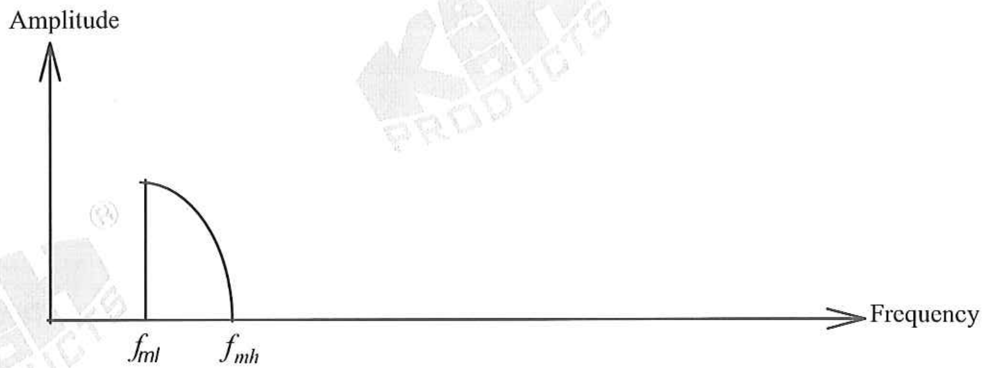

Fig. 5-2a Spectrum of audio signal

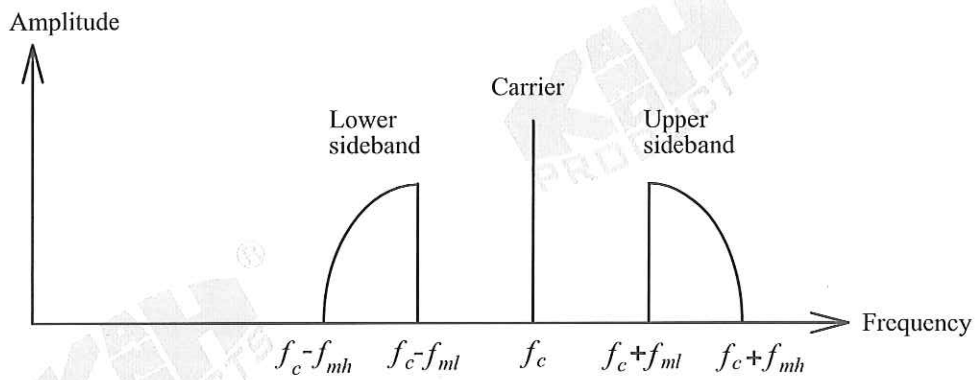

Fig. 5-2b Spectrum of AM signal

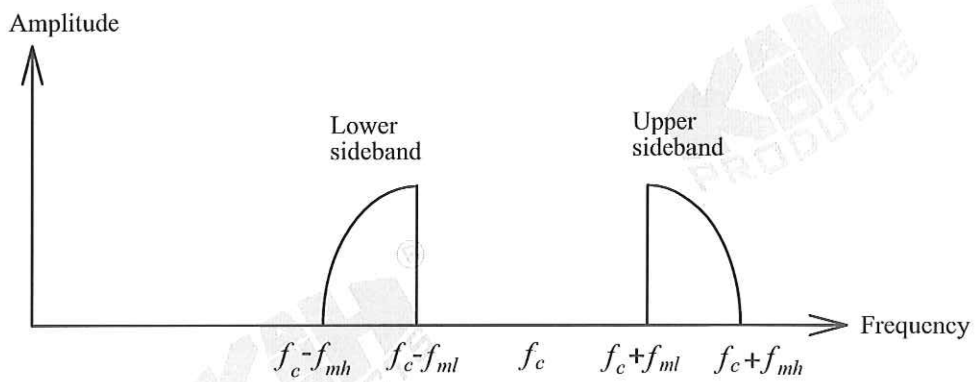

Fig. 5-2c Spectrum of DSB-SC signal

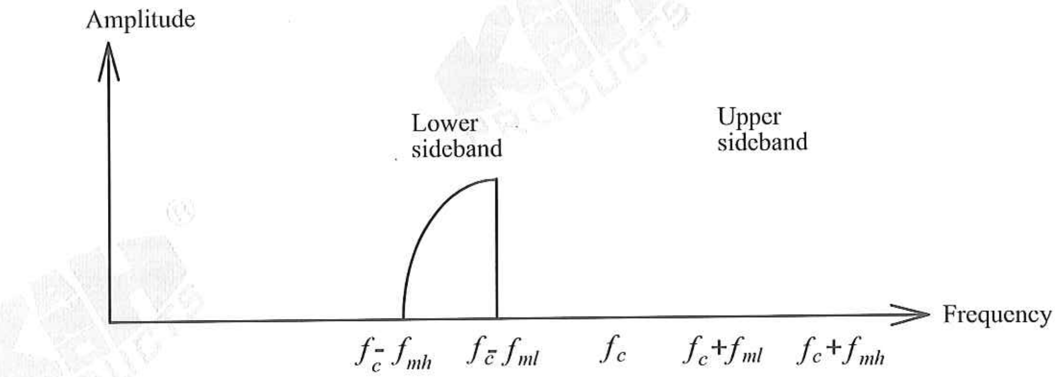

Fig. 5-2d Spectrum of SSB signal

To generate a SSB modulated signal from DSB-SC, a low-pass or high-pass filter is commonly used to filter one sideband signal. Unfortunately, it is difficult to take out single sideband signal from DSB-SC signal with 1st- or 2nd-order low- or high-pass filters because these two sideband spectrums are so close to each other. A good solution of this problem is the use of ceramic or crystal filters. For example, we use the FFD455 ceramic band-pass filter to take out the upper sideband signal in experiment circuit, as shown in Fig. 5-3.

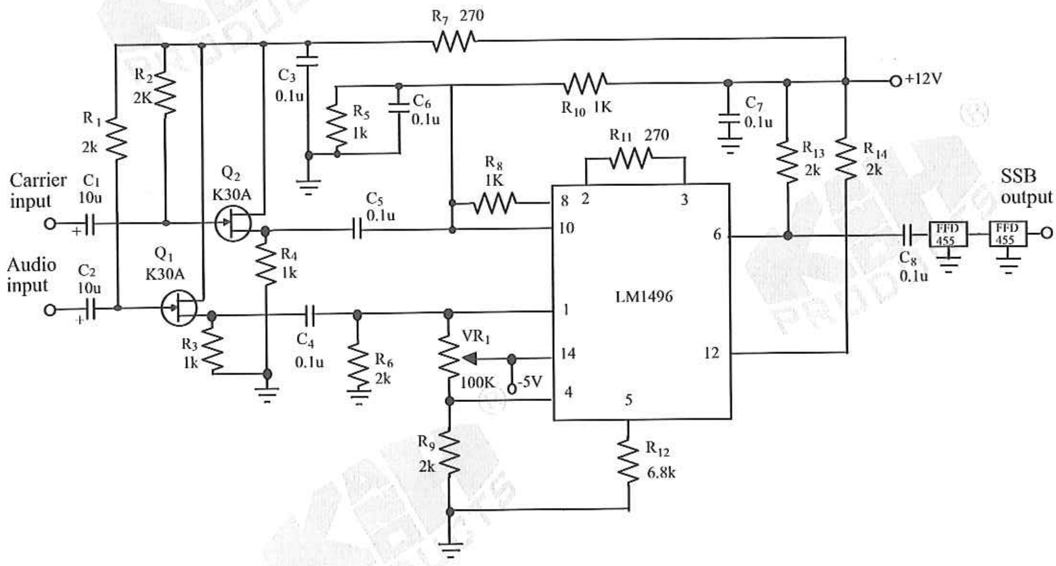

Fig. 5-3 SSB modulator circuit.

5.3 EQUIPMENT REQUIRED

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

5.4 EXPERIMENTS AND RECORDS

Experiment 5-1 DSB-SC Modulator

□1. Locate DSB-SC Modulator circuit on Module KL-93003. Insert connect plugs in J1 and J3 to set R_{11} = 270Ω and R_{12} = 6.8kΩ。

□2. Check each of source follower circuits for a proper bias. Set the vertical input of oscilloscope to AC and observe the source output and the input signals. Ensure that these two signals are the same but the output amplitude is slightly smaller than the input amplitude. If done, insert connect plugs in J5 and J6.

□3. Turn the VR_1 to its mid-position.

□4. Connect the audio input (I/P2) to ground and connect a 500mVp-p, 500 kHz sine wave to the carrier input (I/P1). Carefully adjust the VR_1 to get the output signal of zero or minimum.

□5. Connect a 300mVp-p, 1kHz sinewave to the audio input and change the carrier amplitude to 300mVp-p.

☐6. Using the oscilloscope, measure and record the waveforms listed in Table 5-1.

☐7. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-1.

☐8. Change the audio amplitude to 600mVp-p. Measure and record the waveforms listed in Table 5-2 using the oscilloscope.

☐9. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-2.

☐10. Change the carrier amplitude to 600mVp-p. Measure and record the waveforms listed in Table 5-3 using the oscilloscope.

☐11. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-3.

☐12. Change the audio amplitude to 300 mVp-p and frequency to 2kHz, and the carrier amplitude to 300mVp-p and frequency to 1MHz. Using the oscilloscope, measure and record the waveforms listed in Table 5-4.

☐13. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-4.

☐14. Remove the connect plug from J1 and insert it in J2 to change R_{11} (270Ω) to R_{15} (330Ω). Change the audio amplitude to 600mVp-p and frequency to 1kHz, and the carrier amplitude to 600mVp-p and frequency to 500kHz. Hold VR_1 position. Using the oscilloscope, measure and record the waveforms listed in Table 5-5.

☐15. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-5.

☐16. Remove the connect plug from J3 and then insert it in J4 to change R_{12} (6.8 kΩ) to R_{16} (10 kΩ). Using the oscilloscope, measure and record the waveforms listed in Table 5-6.

☐17. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-6.

Experiment 5-2 SSB Modulator

□1. Locate SSB Modulator circuit on Module KL-93003. Insert the connect plug in J2 to bypass ceramic filters.

□2. Check each of source follower circuits for a proper bias. Set the vertical input of oscilloscope to AC and observe the source output signal and the input signal. Ensure that these two signals are the same but the output amplitude is slightly smaller than the input amplitude. If done, insert connect plugs in J3 and J4.

□3. Turn the VR_1 to its mid-position.

□4. Connect the audio input (I/P2) to ground and connect a 500mVp-p, 457 kHz sine wave to the carrier input (I/P1). Carefully adjust VR_1 to get a minimum output or zero. Then remove the connect plug from J2 and insert it in J1.

□5. Connect a 300mVp-p, 2kHz sine wave to the audio input and change the carrier amplitude to 300mVp-p.

□6. Using the oscilloscope, measure and record the waveforms listed in Table 5-7.

□7. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-7.

□8. Change the audio amplitude to 600mVp-p. Measure and record the waveforms listed in Table 5-8 using the oscilloscope.

□9. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-8.

□10. Change the carrier amplitude to 600mVp-p. Measure and record the waveforms listed in Table 5-9 using the oscilloscope.

□11. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-9.

□12. Change the audio amplitude to 300mVp-p and frequency to 1kHz, and the carrier amplitude to 300mVp-p. Using the oscilloscope, measure and record the waveforms listed in Table 5-10.

□13. Using the spectrum analyzer, observe and record the output signal spectrum in Table 5-10.

Table 5-1

(R_{11}=270Ω, R_{12}=6.8kΩ, V_c=300mVp-p, V_m=300mVp-p, f_c=500kHz, f_m=1kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

Table 5-2

(R_{11}=270Ω, R_{12}=6.8kΩ, V_c=300mVp-p, V_m=600mVp-p, f_c=500kHz, f_m=1kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

Table 5-3

(R_{11}=270Ω, R_{12}=6.8kΩ, V_c=600mVp-p, V_m=600mVp-p, f_c=500kHz, f_m=1kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

Table 5-6

(R_{11}=330Ω, R_{12}=10kΩ, V_c=600mVp-p, V_m=600mVp-p, f_c=500kHz, f_m=1kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

Table 5-7

(R_{11}=270Ω, R_{12}=6.8kΩ, V_c=300mV, V_m=300mV, f_c=457kHz, f_m=2kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

Table 5-8

(R_{11}=270Ω, R_{12}=6.8kΩ, V_c=300mVp-p, V_m=600mVp-p, f_c=457kHz, f_m=2kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

Table 5-9

(R_{11}=270Ω, R_{12}=6.8kΩ, V_c=600mVp-p, V_m=600mVp-p, f_c=457kHz, f_m=2kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

Table 5-10

(R_{11}=270Ω, R_{12}=6.8kΩ, V_c=300mVp-p, V_m=300mVp-p, f_c=457kHz, f_m=1kHz)

Carrier Waveform	
Audio Waveform	
Output Waveform	
Output Spectrum	

5.5 QUESTIONS

1. Comment on the difference between AM, DSB-SC and SSB signals from the angle of bandwidth.

2. Comment on the difference between AM, DSB-SC and SSB signals from the angle of transmission efficiency.

3. What is the function of R_{11} or R_{12}?

4. What is the function of VR_1? If turning the VR_1 arbitrarily, does the output DSB-SC signal become the AM signal?

5. Compare the results observed on the scope and comment on the difference between AM and DSB-SC waveforms.