(7) PWM MODULATION

1. OBJECTIVES

(1) Implementing a pulse-width modulator with μA741.

(2) Studying the characteristics and basic circuits of LM555.

(3) Implementing a pulse-width modulator with LM555.

(4) Measuring and evaluating a pulse-width modulator circuit

2. DISCUSSION OF FUNDAMENTALS

Pulse-width modulation (PWM) is a modulation technique, which converts an analog signal into a digital signal for transmission. The PWM converts an audio signal (the amplitude-varying signal) into a sequence of pulses having a constant frequency and amplitude, but the width of each pulse is proportional to the amplitude of the audio signal. The relationship between audio and PWM signals is illustrated in Figure 7-1.

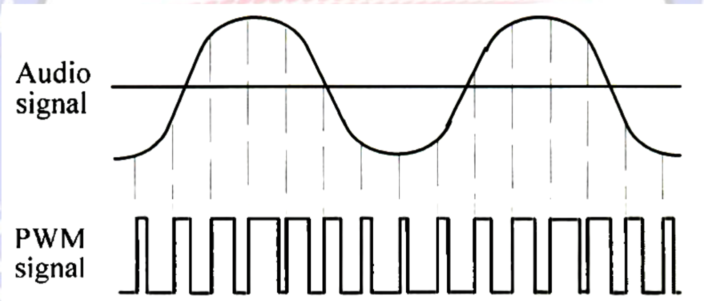

Figure 7-1 Relationship between audio and PWM signals

A square-wave generator or a monostable multi-vibrator can be used to generate the PWM signal. Figure 7-2 shows a square generator whose output pulse width is determined by the values of R2, C2 and Vin(+). The μA741 operational amplifier acts as a voltage comparator. The reference voltage at Vin(+) input (pin 3) is determined by the resistor values of R1 and VR1 The combination of R2 and C2 provides the path for charging and discharging. When no audio signal is applied, the dc reference voltage at Vin(+) input can be changed by adjusting the VR1 value. If dc level of Vin(+) is fixed and an audio signal is applied to the audio input, the audio signal is added to the fixed de level and the reference voltage will be changed with the change of audio amplitude. The resulting PWM signal presents at the output of the comparator.

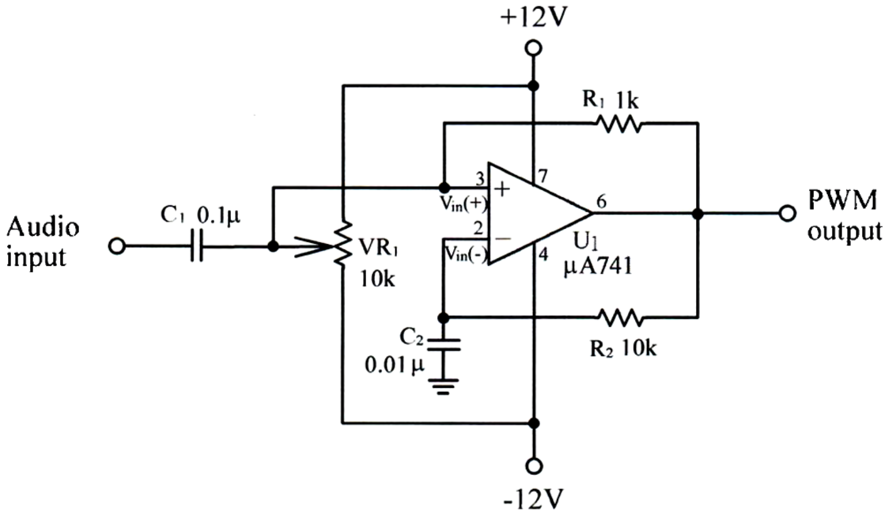

Figure 7-2 The pulse width modulator based on μA741

The connection diagram and equivalent circuit of LM555 timer are illustrated in Figs. 11-3 and 11-4, respectively. It comprises five major sections: (1) the lower comparator or trigger comparator; (2) the upper comparator or critical comparator; (3) flip-flop (FF); (4) discharge transistor; and (5) output driver.

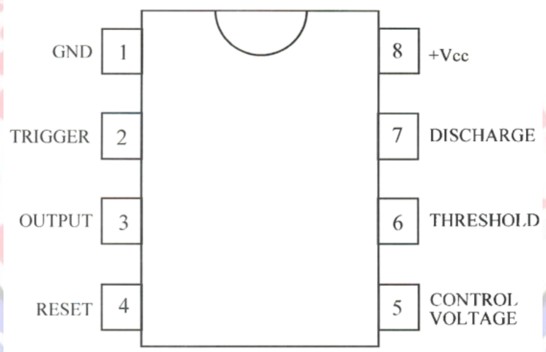

Figure 7-3 LM 555 pin configuration

If no signal is applied to the control voltage terminal (pin 5), the reference voltages of the upper and lower comparators are of 2Vcc/3 and Vcc/3, respectively. These reference voltages can be externally applied a voltage to the control voltage pin. In practice, the control voltage pin should be grounded through a 0.01 μF bypass capacitor if it is not available.

An astable multi-vibrator with the LM555 timer is shown in Figure 7-4. The output waveform is a square wave and the frequency is determined by the values of R1, R2 and C1. According to time constant formula, the charging time L is 0.693×(R1+R2)×C1 and the discharging time t2 is 0.693×R2×C1, and the period is T = t1+t2 = 0.693×(R1 + 2×R2)×C1. The waveforms at major test points are illustrated in Figure 7-5.

The circuit of Figure 7-6 is a monostable multivibrator implemented by LM555 timer IC. When the trigger level changes from high (+12V) to low (0V), a pulse will be occurred at output terminal and its pulse width T is determined by R1×C1 and approximately 1.1×R1×C1. For example, suppose R1 = 10kΩ and C1 = 0.01µF, then T is about 110µS. If the trigger input (pin 2) is triggered by a less than 12 kHz clock signal (the output of the circuit in Figure 7-5 is available), the output will be a positive pulse. Connecting an audio signal to the control voltage pin, the PWM signal should appear at the output.

Figure 7-7 shows a pulse-width modulator using two LM555 timers. In this circuit the U1 and U2 perform the astable and monostable multivibrators, respectively. Combining these two sections, the pulse width modulator is completed. The trigger clock of monostable multivibrator (U2) comes from the output (pin 3) of astable multivibrator (U1). The audio signal is connected to the U2 control voltage input (pin 5) and the PWM signal appears at the output (pin 3).

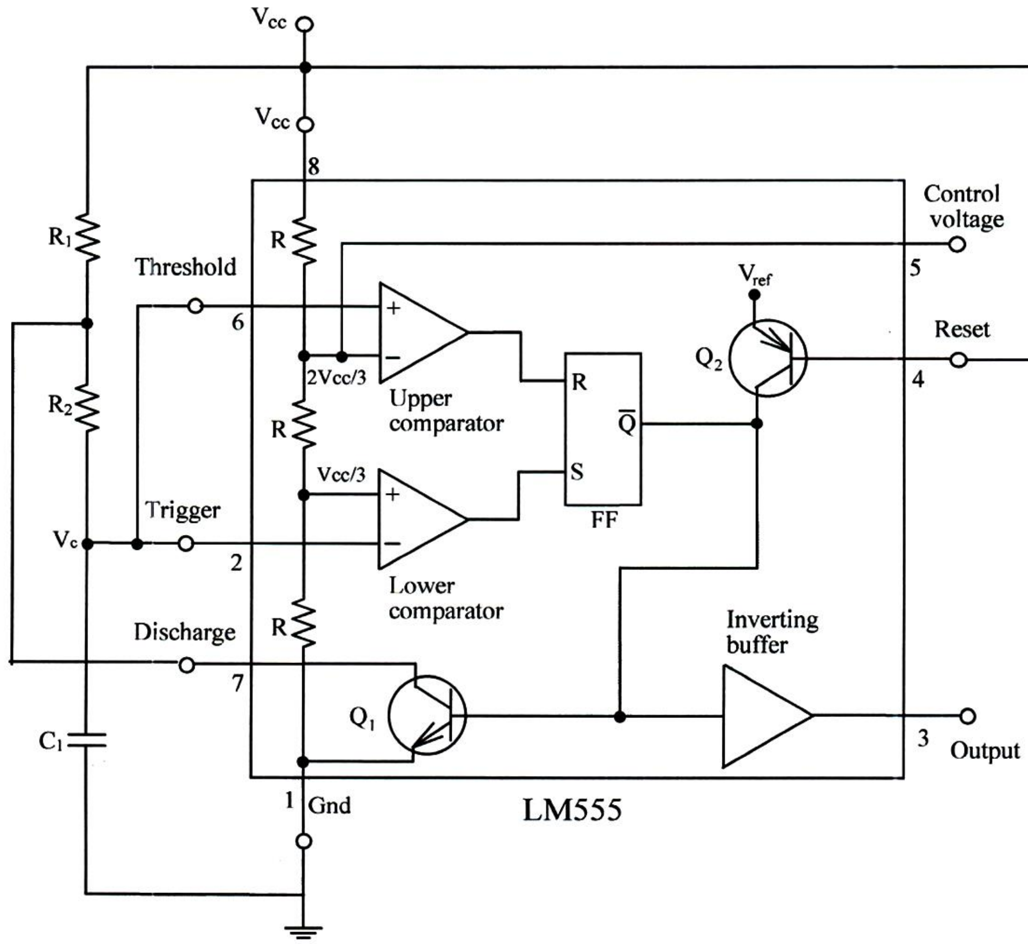

Figure 7-4 Fig 11-4 LM555 astable multi-vibrator

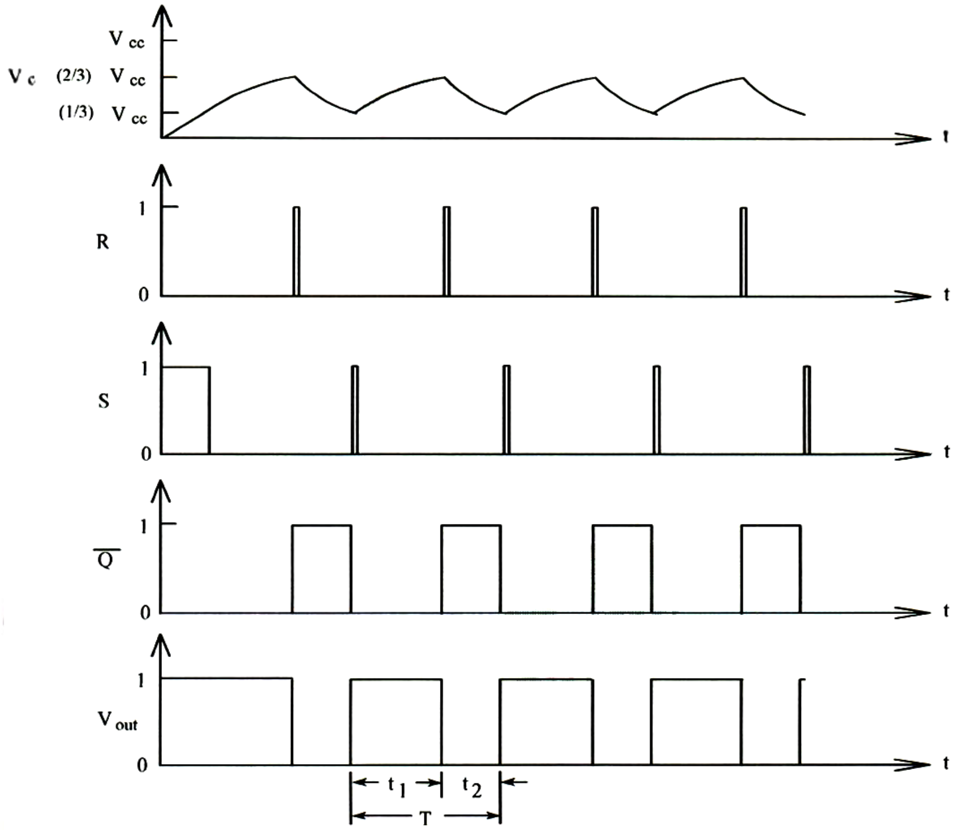

Figure 7-5 Waveforms of LM555 astable multi-vibrator

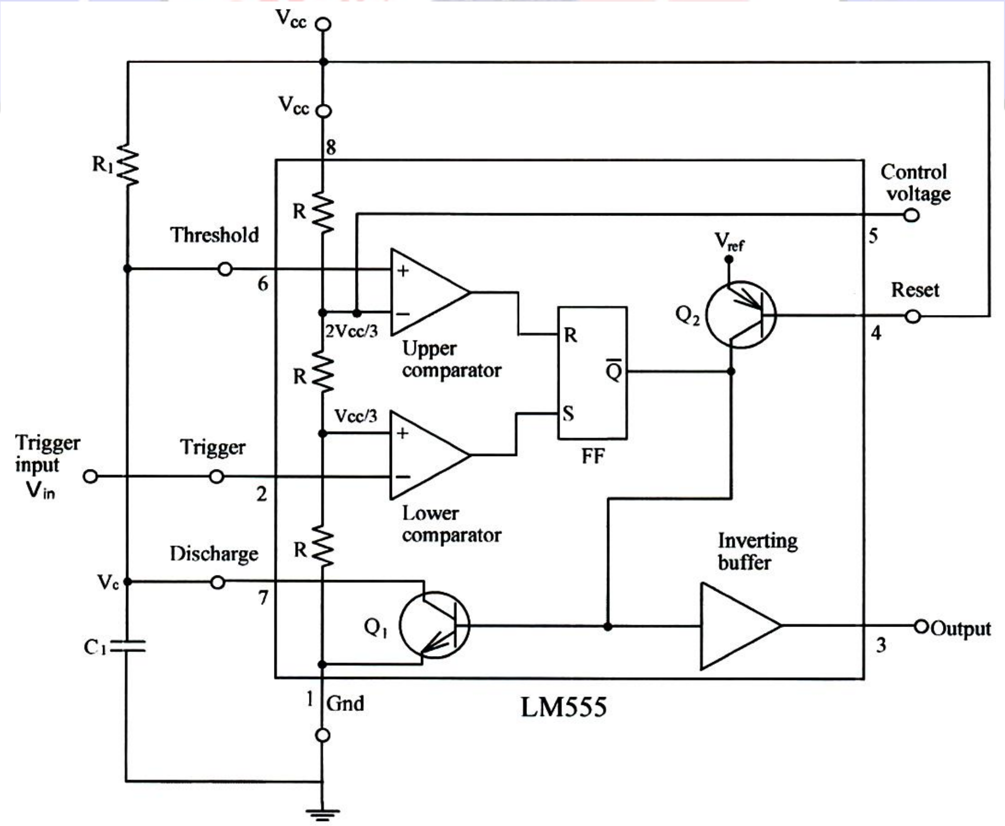

Figure 7-6 LM555 monostable multi-vibrator

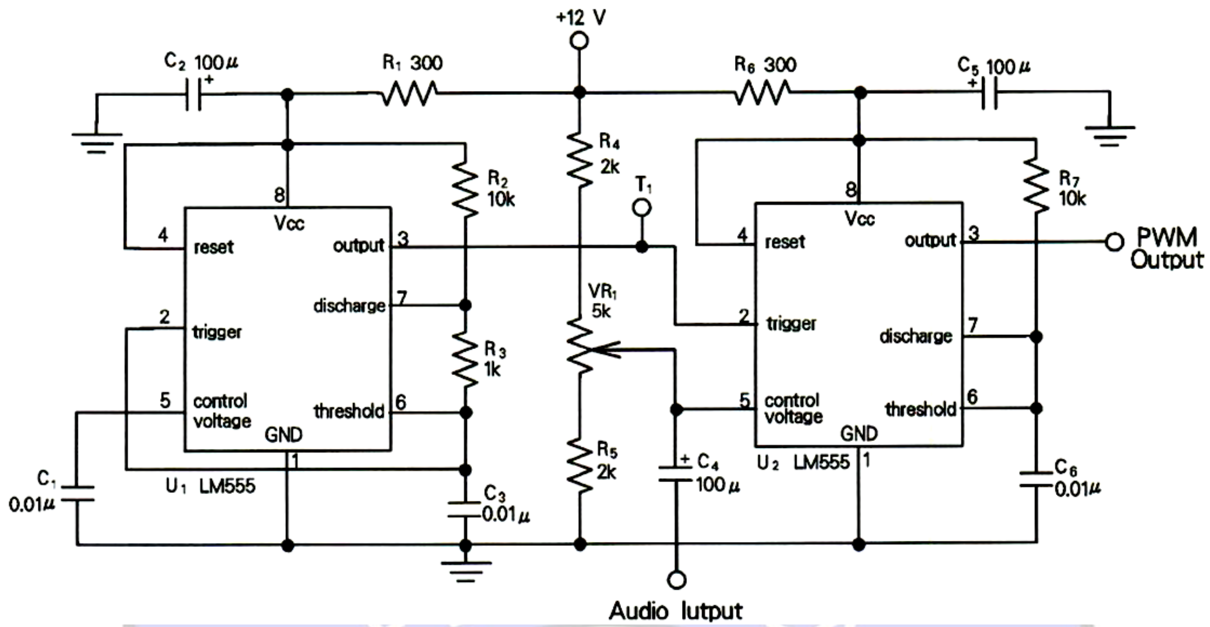

Figure 7-7 Fig 11-7 Pulse Width Modulator

3. EQUIPMENT REQUIRED

(1) Module KL-92001

(2) Module KL-94002

(3) Oscilloscope

4. EXPERIMENTS AND RECORDS

Experiment 11-1 Pulse Width Modulator using µA741

(1) Locate the LM741 PWM Modulator circuit on Module KL-94002.

(2) Adjust the VR1 to get the voltage of 0V at the Vin(+) input terminal, and then insert the connect plug in J1.

(3) Connect a 4Vp-p, 500Hz sine wave to the audio input.

(4) Using the oscilloscope, observe the audio input and output (pin 6) waveforms and record the results in Table 7-1.

(5) Remove the connect plug from J1 and the audio input signal. Adjust the VR1 to get the voltage of 6V at Vin(+) input terminal.

(6) Recover the connect plug and the audio input signal.

(7) Using the oscilloscope, observe the audio input and the output (pin 6) waveforms and record the results in Table 7-1.

(8) Remove the connect plug from J1 and the audio input signal. Adjust the VR1 to get the voltage of -6V at Vin(+) input terminal.

(9) Recover the connect plug and the audio input signal.

(10) Using the oscilloscope, observe the audio input and output (pin 6) waveforms and record the results in Table 7-1.

(11) Remove the connect plug from J1 and the audio input signal. Adjust the VR1 to get the voltage of 0V at the Vin(+) input terminal and then insert the connect plug in J1.

(12) Change the audio amplitude to 10Vp-p. Repeat steps 4 to 10 and record the results in Table 7-2.

Experiment 11-2 Pulse Width Modulator using LM555

(1) Locate the PWM Modulator circuit on Module KL-94002.

(2) Connect a 5Vp-p, 1kHz square wave to the audio signal input.

(3) Using the oscilloscope, observe the T1 test point and the output waveforms and adjust the VR1 to get a rectangular wave (duty cycle is not equal to 50%) at T1.

(4) Switch the coupling mode of oscilloscope to DC position. Observe and record the output waveform in Table 7-3.

(5) Change the input signal to triangle wave and repeat step 4.

(6) Change the input signal to sine wave and repeat step 4.

(7) Change the input amplitude to 3Vp-p and repeat steps 4 to 6 and record the results in Table 7-4.

5. QUESTIONS

(1) What is the function of VR1 in Figure 7-2 and Figure 7-7.

(2) If the C6 value in Figure 7-7 is changed to 0.1 μF, is the output still a PWM waveform? Explain.

(3) In a point of view of voltage polarity, what is the difference between the output PWM signals in experiments 11-1 and 11-2?

Table 7-1 (Vm=6Vp-p , fm=500Hz)

DC Bias at Vin(+)	Input Waveform	Output Waveform
0V		
6V		
-6V		

Table 7-2 (Vm=10Vp-p , fm=500Hz)

DC Bias at Vin(+)	Input Waveform	Output Waveform
0V		
6V		
-6V		

Table 7-3 (Vm=5Vp-p , fm=1kHz)

DC Bias at Vin(+)	Input Waveform	Output Waveform
Square Wave		
Triangle Wave		
Sine Wave		

Table 7-4 (Vm=3Vp-p , fm=1kHz)

DC Bias at Vin(+)	Input Waveform	Output Waveform
Square Wave		
Triangle Wave		
Sine Wave		