PULSE WIDTH MODULATION

INFORMATION:

Pulse width modulation (PWM), also known as pulse duration modulation (PDM), is a digital modulation technique whereby the *width* of a pulse carrier is made to vary in accordance with the modulation voltage. The leading edge of the carrier pulse remains fixed and the occurrence of the trailing edge of the pulse varies. Figure 1 illustrates the PWM signal along with a simple 555 timer circuit configured as a monostable multivibrator and used to generate the PWM signal. Operation of the PWM circuit is as follows.

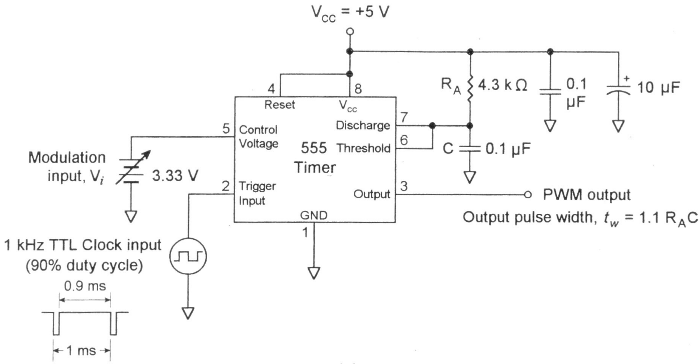
In the monostable mode of operation, the 555 timer acts as a one-shot that is triggered by the clock input signal shown at pin 2. The output pulse width, t_w, at pin 3 is governed by the equation: $t_w = 1.1\ R_A\ C$. The output pulse width is modulated by the modulation input voltage, V_i, applied at pin 5 of the 555 timer. The voltage at pin 5 is internally biased at 2/3 V_{CC}. Since we are using +5 V as a supply, this is approximately 3.33 V. By altering this internal bias above and below this potential, the width of the pulse, governed by the above equation, can be made to vary.

OBJECTIVE:

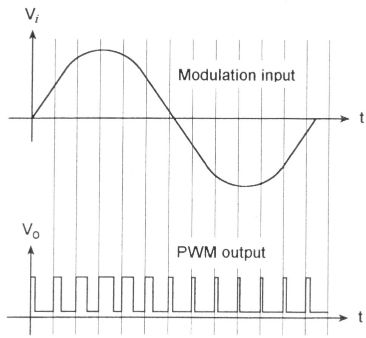
In this experiment, our objective is to measure and observe PWM. We will trigger the PWM generator circuit shown in Figure 1 with a 1 kHz TTL clock input. The unmodulated output pulse width of the circuit will be designed for approximately 500 µs. A DC potential will be applied at the modulation input above and below 2/3 V_{CC} (3.33 V) and the resulting PWM signal will be measured.

EQUIPMENT AND MATERIALS:

1. 2-DC power supplies and leads
2. Oscilloscope and probes
3. Pulse generator and leads
4. Sine wave generator and leads
5. DVOM and leads
6. 1-555 timer IC
7. 1-4.3 kΩ 1/4 watt resistor
8. 2-0.1 µF capacitors
9. 1-10 µF capacitor
10. 1-100 µF capacitor



(a)



(b)

Figure 1 (a) PWM generator circuit; (b) input versus PWM output waveforms.

DIRECTIONS:

1. Connect the circuit shown in Figure 1 (a).

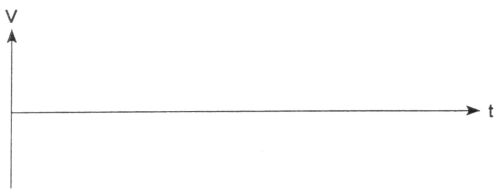
2. Using your oscilloscope, set your pulse generator for a 1 kHz TTL wave at 90% duty cycle and apply it to the Trigger input (pin 2) of the 555 timer. Duty cycle = $[(t_d / T) \times 100\%]$. For a 90% duty cycle pulse train, the HIGH period of the wave, $t_d = 0.9$ ms and the LOW period of the wave is 0.1 ms for a total period, T, of 1 ms (1 kHz).

3. Using your DVOM, set the modulation input DC supply to 3.33 V. DO NOT apply the supply to your circuit yet.

4. Given the output pulse width equation for t_w shown in Figure 1 (a), compute the unmodulated output pulse width using $R_A = 4.3\ k\Omega$ and $C = 0.1\ \mu F$.

   t_w = ______________

5. Measure and record the period, T, pulse width, t_w, and peak voltage, V_p, of the unmodulated PWM output at pin 3 of the 555 timer circuit. Draw the output wave form below and label these three values on your diagram.



6. Compute the percent error between the measured and computed pulse width in steps 4 and 5 above.

   % error = [(measured – calculated) / (calculated)] × 100%

   = ______________

7. Using your DVOM, measure the voltage at pin 5, the modulation input, without the DC supply connected. This should be internally set at approximately 2/3 of V_{CC}, or +3.33 V.

   $V_{pin\ 5}$ = ______________

8. With your modulation input DC supply set to 3.33 V, connect the supply to the modulation input, V_i, at pin 5 of the PWM generator. At the same time, monitor the output pulse width with your oscilloscope and the DC supply voltage with your DVOM. The output pulse width should not change by much since the external DC supply voltage of 3.33 V equals the internally set voltage of 3.33 V.

9. The modulation input DC supply now controls the width of the pulse since it is the modulation voltage. Vary the input voltage above and below +3.33 V by no more than ± 1 V and verify that PWM is occurring on the output pulse width.

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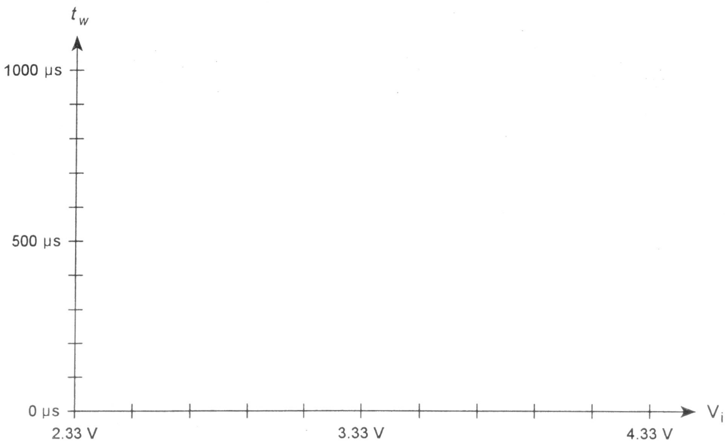
10. We will now check to see how linear your PWM generator is. Measure and record the following data for t_w, based on the following values of V_i. Use your oscilloscope to measure t_w and your DVOM to set the modulation input voltage, V_i.

Modulation voltage, V_i	PWM output pulse width, t_w
2.33 V	
2.53 V	
2.73 V	
2.93 V	
3.13 V	
3.33 V	
3.53 V	
3.73 V	
3.93 V	
4.13 V	
4.33 V	

11. On the graph below, plot the pulse width, t_w, versus the modulation input voltage, V_i.



12. Disconnect the modulation input DC supply and replace it with a 100 Hz 2 $V_{p\text{-}p}$ sine wave generator. The sine wave generator must be AC coupled to the modulation input. Use the 100 µF capacitor for this. Be sure to apply the positive (+) side of the capacitor to the modulation input and the negative side (–) to the generator.

13. Set your oscilloscope to the alternate mode for dual trace operation.

14. Connect channel 1 of your oscilloscope to the modulation input and monitor the input sine wave.

15. Connect channel 2 of your oscilloscope to the PWM output at pin 3 of the 555 timer.

16. With your oscilloscope triggered off of the channel 1 sine wave input, verify that PWM is occurring at the PWM output of the 555 timer. NOTE: Since the sine wave modulation input is running asynchronous to the TTL clock input (which is used to derive the PWM signal), you will not be able to see the signals synchronized as in Figure 1 (b). However, you will see the output pulse width vary in proportion to the sine wave input voltage.

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QUESTIONS:

1. Where does the intelligence reside in a PWM signal?

2. For the PWM signal shown in Figure 1 (b), what can be said about the period of the wave in comparison to the pulse width?

3. What is another name for pulse width modulation (PWM)?

4. In step number 11, how linear was the PWM generator circuit? Is the output pulse width truly proportional to the modulating voltage?

5. Explain how you would modify the PWM generator circuit so that the unmodulated output pulse width is changed from approximately 500 μs to approximately 250 μs.