



Inspiring Excellence

BRAC UNIVERSITY

CSE 350: Digital Electronics and Pulse techniques

Exp-06: Analysis of Triangular Wave Generator

Name:	Section:
ID:	Group:

Objectives

1. To analyze a bipolar triangular wave generator.

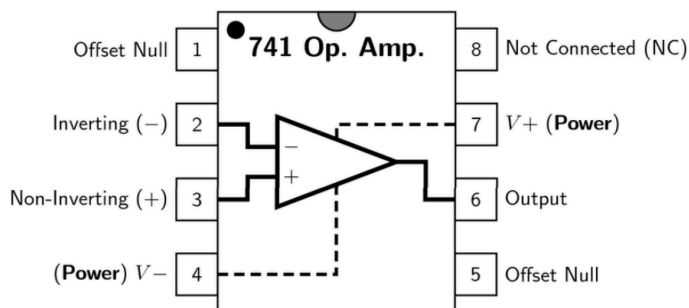
Equipment and component list

Equipment

1. Oscilloscope
2. Trainer board

Component

- Operational amplifier - UA741 - x2 piece
- Capacitor ($0.47\mu\text{F}$) - x1 piece
- Resistors -
 - $10\text{ K}\Omega$ - x2 pieces
 - $4\text{ K}\Omega$ - x1 piece



741 IC pin diagram

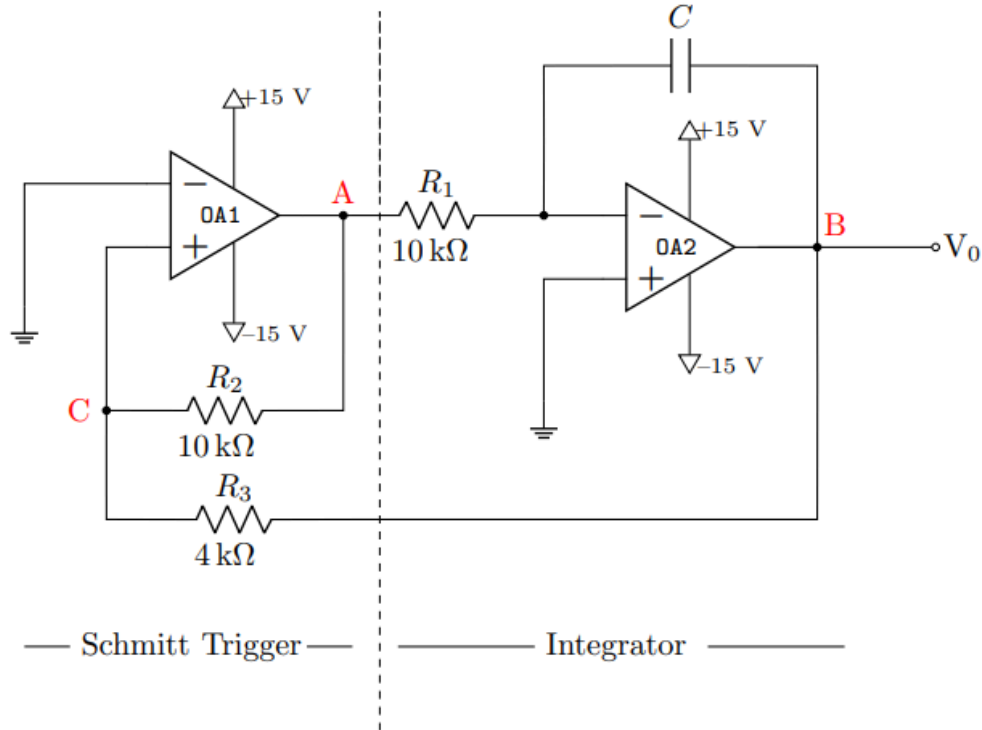


Figure 1: Bipolar Triangular wave generator

Task-01: Bipolar Triangular Wave Generator THEORY

As can be seen in the figure, the triangular wave oscillator is composed of a Schmitt Trigger circuit and an integration circuit whose operation is explained below. Notice that the output of Schmitt Trigger (A) is connected to the input of the integrator and the output of the integrator (B) is in turn connected to an input terminal of the Schmitt Trigger through resistor R_3 at point C. We shall observe a square wave at point A and a triangular wave at point B. Whenever point B will rise towards a HIGH value, point A will fall LOW and vice versa.

The integrator circuit is composed of a capacitor, a resistor and an op-amp (OA2) in the negative feedback configuration. In the negative feedback operation, there are two very important rules to remember. **Firstly**, no current flows either into or out through the input terminals of the op-amp. **Secondly**, the voltages of the two input terminals of the op-amp are equal. As the non-inverting input terminal of OA2 (op-amp 2) is connected to ground, both this and the inverting input terminal of the op-amp will be at zero volt. Hence, the left terminal of the capacitor will always be fixed at zero volt.

Now let us shift our focus to the Schmitt Trigger for a moment. Here, the op-amp OA1 is in positive feedback configuration unlike OA2. In this mode, the op-amp acts like a comparator. It compares the voltages of the two input terminals and sets the output voltage accordingly. If the voltage of the positive terminal is greater than the negative terminal ($V_+ > V_-$), then the output (A) will be HIGH. As the negative input terminal is connected to ground, the output A will be HIGH whenever the voltage at the positive terminal becomes greater than zero. In case of turning on, the output of the Schmitt circuit (point A) becomes equal to either the positive or negative saturated voltage. In the following explanation, we will assume that initially the output at point A is at the positive saturated

voltage (+15V). As a result, electric current starts flowing from point A toward point B through the resistor R_1 .

Remember that as **OA2** is in negative feedback configuration, there is no current flow either in or out through the input terminals of **OA2**. Hence, all the current flows through the capacitor C to point B when the A point becomes positive. Due to this current flow from A to B, the electric charge begins to store up in the left side of the capacitor. Consequently, the voltage of the left side must rise higher than the right side. However, the left terminal of the capacitor is fixed at zero volt due to the negative feedback of **OA2**. Hence, the voltage of the right side of the capacitor (point B) starts to fall. Thus, when the output of Schmitt Trigger (A) is HIGH, the voltage of the output (B) of the integration circuit falls gradually. This rise-drop can be seen in the wave of figure 2 between time T_0 and T_1 .

Now, point B is in turn connected to the positive input terminal of Schmitt Trigger circuit (**OA1**) at point C through the resistor R_3 . Due to this connection, the voltage at this point C (V_C) will also fall along with the fall of point B. After a certain time, V_C will fall below zero. At this time, the op-amp **OA1** will sense that the voltage of the positive input terminal has fallen below the negative input terminal (0V) and so, the output of **OA1** will now become equal to the negative saturated voltage (-15V) rapidly. **(For the voltage of the C point to fall below 0 V, the condition of $R_2 > R_3$ is necessary.)**

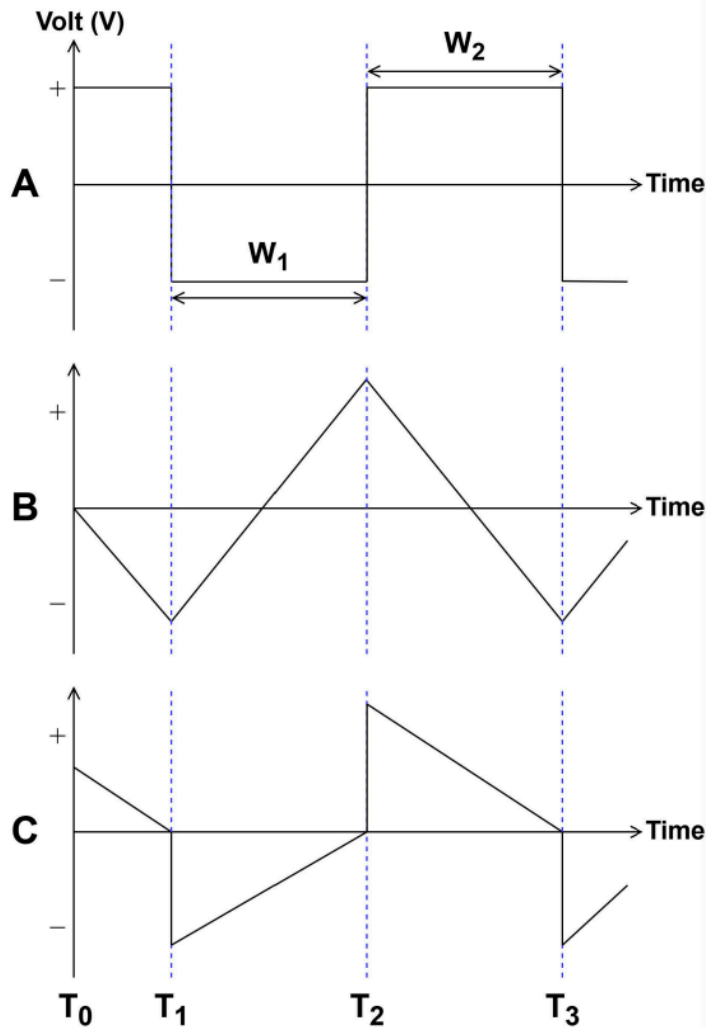


Figure 2: Bipolar Triangular Waveshape

As point A is now negative, the process discussed upto now will be inverted. The current will now flow from point B towards point A through the capacitor and R_1 . This current flow will force the capacitor to charge in the opposite direction from before. Meaning, the right side of the capacitor must rise above the left side. Hence, the right side of the capacitor (B) will now gradually rise. This is the rising portion of the triangular wave between time T_1 and T_2 in figure 2.

Similar to the process discussed before, the rise of point B will cause an increase in the voltage of point C. When this voltage rises above 0V, the op-amp OA_1 senses this and sets its output A at a HIGH value. Thus, the output of the Schmitt circuit (A) again changes into the positive saturated voltage as we initially assumed. **(The condition of $R_2 > R_3$ is necessary for the voltage of the C point to rise above 0 V, too)**

Now the process will repeat and the current will flow from point A to point B forcing the voltage at point B to become negative again. This is the falling portion of the triangular wave between time T_2 and T_3 in figure 2.

This operation is repeated continuously. The voltages of points A and B influence each other to rise and fall cyclically and thus, the square wave is generated at the A point and the triangular waveform is generated at the B point.

We can find that the frequency of oscillation is defined by the expression:

$$F = \left(\frac{1}{4 \times R_1 \times C} \right) \times \left(\frac{R_2}{R_3} \right) \quad (1)$$

The time period will simply be the inverse of the frequency. This indicates how long it takes for the wave to complete one cycle and repeat itself. In figure 2, a cycle or period is between T_1 to T_3 . As we can see, a wave is both HIGH and LOW during a complete period. When the signal is high, we call this "on time". To describe the amount of "on time", we use the concept of duty cycle. Duty cycle is measured in percentage. The percentage duty cycle specifically describes the percentage of time a digital signal is HIGH during a complete period. If a digital signal spends 7 seconds as HIGH and 3 seconds as LOW, we would say the digital signal has a duty cycle of 70%. We can define the duty cycle of the square wave and triangular wave in figure 2 by the expressions:

$$\text{Triangular wave, } D_T = \left(\frac{W_1}{W_1 + W_2} \right) \times 100\% \quad (2)$$

$$\text{Square wave, } D_s = \left(\frac{W_2}{W_1 + W_2} \right) \times 100\% \quad (3)$$

Procedure:

1. Construct the circuit as shown in figure 1.
2. Connect the outputs of the op-amp 1 (A) and op-amp 2 (B) with the two channels of the oscilloscope.
3. Observe the wave shapes and collect the plots from the oscilloscope. Measure the frequency F and time period T of the waves on the oscilloscope.

Data Tables

Fill up the table for the Triangular Wave.

Theoretical Frequency	Experimental Time Period, T (ms)	Experimental Frequency, F (Hz)	HIGH Time (ms)	LOW Time (ms)

Table 1: Data Table for Triangular Wave Generator

Signature

Lab Tasks

Please complete the following tasks within the lab class.

1. Measure the HIGH and LOW times of the two waves and calculate the duty cycles. Explain if there is any relation between the two values.

Ans.

2. Change the value of R_1 to $22\text{k}\Omega$ and measure the frequency of the output waves. Does the effect on frequency match with the theory? Explain with theoretical calculations.

Ans.

Report

Please complete the following tasks briefly in the given space.

1. What will be the frequency of the output Triangular wave if R_2 is $2\text{k}\Omega$? Explain briefly with theoretical calculations. [**Hint**: Read the theory carefully!]

2. Suppose, we need a square wave which is HIGH when The Triangular wave is rising and is LOW otherwise. Could we feed our observed square wave as input to one of the circuits from our previous experiments for this? Draw a block diagram of how you will implement this circuit:

Ans.

3. Can it be possible to use the above circuit to create a variable frequency wave generator? Justify your answer with theoretical calculations.

Ans.

4. Give a theoretical description of the graph C that you have observed. Derive an equation that accurately expresses that periodic waveform of C.

5. Draw the output wave shapes at point A and B in the given graph paper. Keep the time in the horizontal axis and the voltage in the vertical axis. Also attach the photos that you have taken for graphs A, B, and C at the end of your report.
6. Add a Discussion on an extra page regarding experimental and theoretical insights you have gained, challenges you have faced and mistakes you have made during implementing this experiment.

