Design and Performance Analysis of Waveshaping Circuits

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Abstract -- A wave shaping circuit is the one that used to convert from an input waveform to a desired output waveform. Many waveshaping circuits (clipper, clamper, differentiator and integrator) are useful in variety of applications such as radios, television, radar circuits and communications system. In this paper, diode circuits and RC circuits are designed and simulated for various wave shapes including clipping, rectifying, differentiating, and integrating. Circuit simulation is accomplished by using Multisim software. Circuit performance analyses are covered with simulation results.

Index Terms— waveshaping circuits, clipping, rectifying, differentiating, and integrating, multisim

I. INTRODUCTION

There are various waveshaping circuits for different applications. Many wave shaping circuits can be classified based on the components constituting an electrical waveform signal (frequency, amplitude, pulse width, period and direction). Some of the waveshaping functions are clipping, clamping, rectifying, filtering and oscillation. The waveshaping circuits can be used to perform any of the following purpose;

- To alter one waveform to another
- To limit the voltage level of the waveform to some
 preset value and cut-off all other voltage level in
 access of the preset level
- To suppress the negative and positive portions of
 input waveforms
- To hold the waveforms to a particular DC level

In this paper, diode circuits are selected as wave shaping circuits for clipping and recertifying purposes. Clipping is a process that limits the positive and/or negative amplitudes of a waveform so it is also called limiter. Ordinary diodes, zener diodes, and transistors can be used to clip a voltage waveform. Based on the circuit configuration, the clipper can be classified as Series diode clipper and Parallel diode clipper. According to level of clipping, the clippers are positive clipper and negative clippers.

Moreover, RC circuits are designed for differentiated and integrated waveforms. A passive RC circuit is a simple circuit of a resistor in series with a capacitor. If the output is taken across the resistor, the circuit is called a differentiator. A differentiator is used to produce a pip or peaked waveform from square or rectangular waveforms for timing or synchronizing circuits. It is also used to produce trigger or marker pulses. If the output is taken across the capacitor, the circuit is called an integrator. With different values of resistors and capacitors, RC networks will produce different wave shapes.

II. DESIGNED CIRCUITS

Diode clipper circuits and RC circuits are chosen for different wave shaping results.

(i) Clipper circuit

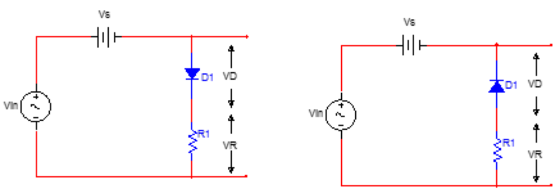
Figure 1 shows the clipping circuit to clip the undesired portion of an input waveform. The wave shaped functions are performed by the circuit components of a diode, a resistor and a voltage source. The input signal V_{in} is time varying signal and the output is taken across diode and resistor as V_D and V_R. The function of the circuit depends on the state of diode switching conditions. For the positive half cycle of input signal, the diode works as a closed switch and the output signal appears across the diode and resistor in Figure 1(a):

$$V_{in} - V_S = V_D + V_R$$

$$V_D = Vin - V_S - V_R$$

$$V_R = V_{in} - V_S - V_D$$

For the negative half cycle, the diode acts an open switch and clips the input signal providing that the output voltage V_R= 0. In Figure 1(b), Reversed operation is occurred by turning the diode around. In reverse operation, the diode is forward-biased during the negative part of the input voltage and reverse-biased for positive part of the input.



(a) (b)

Figure 1. Clipper circuit

(ii) Combination clipper circuit

The clipper circuit can be modified as the combination clipper shown in Figure 2. This clipper serves as both positive limiter and negative limiter. As the input voltage goes positive, diode D_1 conducts and limits the input voltage to $V_{out}= V_{D1}+V_{S1}$. For negative input voltage, Diode D_2 allows the voltage of $-(V_{D2}+ V_{S2})$. So, the circuit can clipped positive voltages above $V_{D1}+V_{S1}$ and negative voltage $-(V_{D2}+ V_{S2})$.

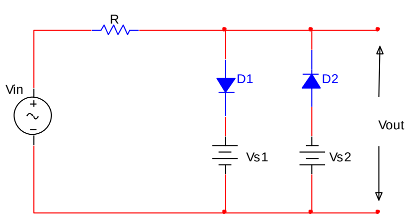


Figure 2. Combination clipper circuit

(iii) Clipping and rectifying circuit

In Figure 3, D_1 and V_S provide clipping the input voltage above the predetermined value and D_2 serves rectification. The circuit will clip above the voltage $V=V_{D1}+V_{S1}$ for positive half cycle and clip all negative voltages.

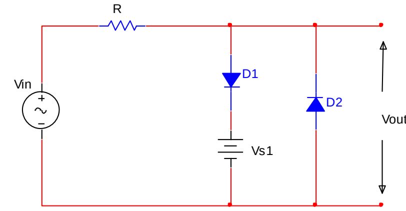


Figure 3.Clipping and rectifying circuit

(iv) Differentiator circuit

Figure 4 shows the differentiator circuit which comprises a resistor in series with a capacitor and the output is taken across the resistor. The differentiator provides a different wave shapes from the square or rectangular waveform for timing and synchronizing circuits. Generally, the current through the capacitor,

$$i_C = C\, dV_{in}/d_t$$

$$V_{out}= V_R= R*i_R$$

$$V_{out}= RC\, dV_{in}/d_t$$

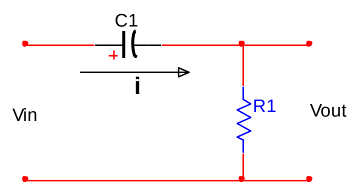


Figure 4. Differentiator circuit

(v) Integrator circuit

The integrator circuit consists of a network including a resistor and a capacitor shown in Figure 5. Input waveform which may be rectangular wave or trigular wave can be shaped by changing RC values. The shaped output waveform can be used in radio, television, radar and computer. In general:

$$V_{out}= \frac{1}{RC}\int V_{in}\, dt$$

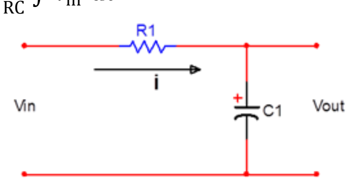


Figure 5. Integrator circuit

III. SIMULATION RESULTS

In this section, all designed circuits are simulated with multisim software and output waveforms are displayed according to their input signals.

Firstly, the clipper circuit shown in Figure 6 (a), a diode (1N4007) is connected in series with a resistor 1KΩ and a battery source of V_1= 2V as a bias clipper. Input voltage 10V (p-p) is directly connected with V_1 in series. The output voltage V_{out} taken across diode, V_D, is tested in Red wire and V_R is measured with Blue color wire. When the input goes positive half cycle, the diode conducts as V_D=0.7V and -12V for negative half cycle because the diode is open for reversed bias. According to the results, the voltage across V_R is V_R=V_{in}-V_1-V_D=7.3V for positive half of 10V (p-p) input and clip off the negative inputs. Figure 6 (b) illustrates clipper circuit with the diode turned around, the circuit clip off the input positive voltage to 8V across the diode for the positive input cycle. When the diode is forward-biased during the negative part of the input voltage, diode voltage,V_D , is held at -0.7 by diode drop. The measured output voltage of resistor V_R is 0V for positive half cycle and -11.3V for negative cycle of input voltage.

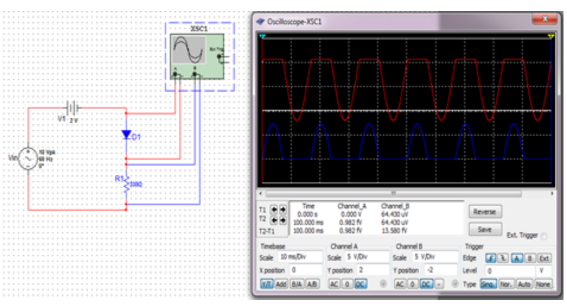


Figure 6(a). Simulation result of the clipper circuit.

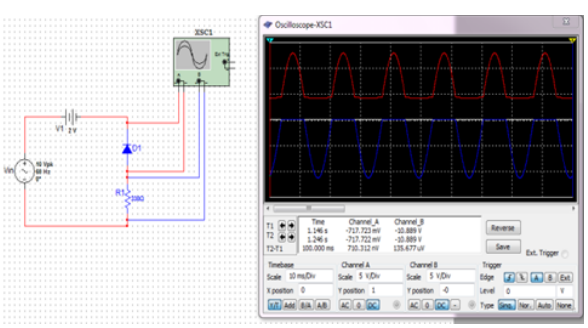


Figure 6(a). Simulation result of the clipper circuit with turned around diode

Two diodes and two biased voltages are used for combination clipper circuit as shown in Figure 7. In this circuit, the input voltage V(p-p)= 10V is supplied to the circuit in series with a 1KΩ resistor and two diodes (1N4007) and two biased voltage 5V are used for clipping both half cycle. When input positive half cycle goes V_{out}= V_S+V_D= 5+0.7=5.7V and V_{out}= -5-0.7= -5.7V for negative half cycle. Therefore, the combination clipper circuit clipped the voltage above the predetermined level of voltage and can be adjusted for desired voltage level according to the application.

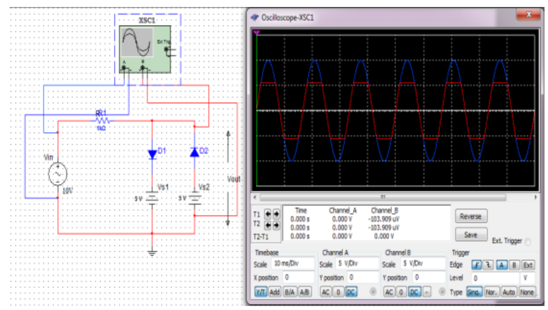


Figure 7. Simulation result of combination clipper circuit

In a clipper circuit described in Figure 8, 10V (p-p) Sine Wave is applied to the circuit as an input signal. In this circuit, the first diode D1 is connected in series with 5V battery for providing clipping function and the second diode D_2 is for rectifying. For positive half cycle, D_1 conducts and limits the voltage V_{out}= V_S+V_D= 5+0.7= 5.7V. The second diode D_2 conducts for negative half cycle and rectifies all negative values of input voltage exclusive of diode forward voltage 0.7V. Therefore, V_{out}= +5.7V and -0.7V wave-shaped output can be seen on the oscilloscope

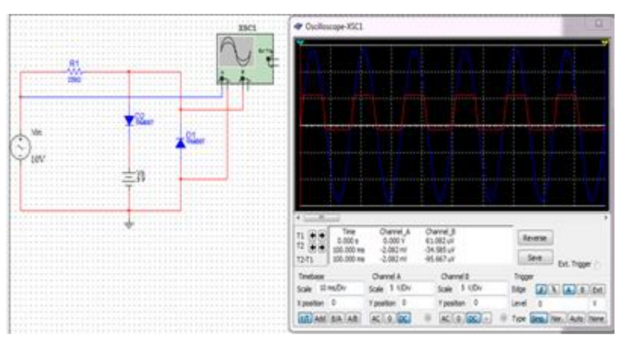


Figure 8. Simulation result of clipped and rectified circuit

In Figure 9, a circuit is designed with a resistor 1kΩ and a capacitor 0.1µF in series for the purpose of differentiated wave shape. The function generator is used in series with the circuit to provide input parameters and is set to produce square wave input voltage 5V (p-p) and frequency 100Hz. According to the time period T=1/F= 1/100= 10ms and the RC time constant τ=1K×1µF =1ms, the resultant wave shape can be observed as a pip or peaked waveform on the oscilloscope in red color as shown in Figure 9 (a). Figure 9 (b) and Figure 9 (c) illustrate the output waveforms of differentiator circuit for medium and long time constant values, 5ms and 10ms, at fixed frequency 100Hz.

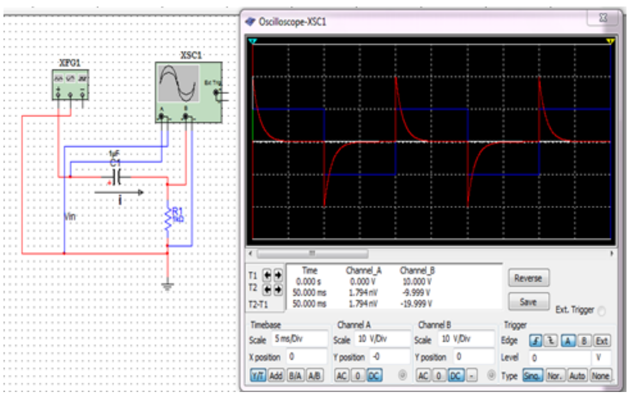


Figure 9 (a). Simulation result of the differentiator circuit for short time constant

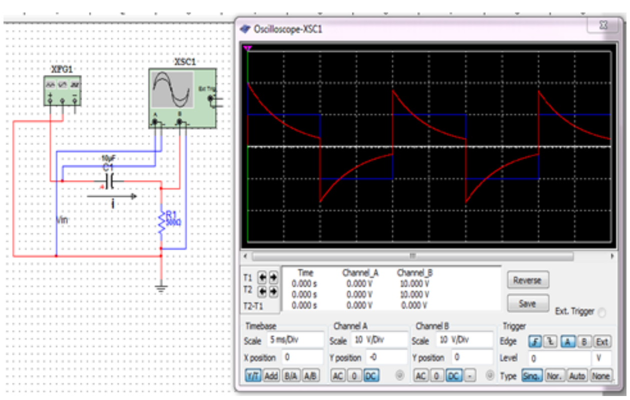


Figure 9 (b). Simulation result of the differentiator circuit for medium time constant

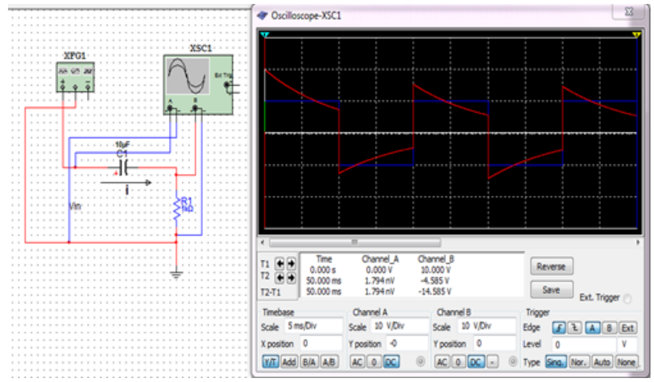


Figure 9 (c). Simulation result of the differentiator circuit for long time constant

An integrator circuit that is opposite to the differentiator circuit is designed with a resistor 1KΩ and a capacitor 1µF as shown in Figure (10). The square wave input voltage V_{in} =5 V (p-p) and frequency F=100Hz are provided by the function generator for the circuit. Since the RC time constant for this circuit is τ= 1K×1µF = 1ms and a input pulse duration is 5ms, five times constant, the capacitor will charge to 99.3% of its charge. As The input pulse amplitude is 5 V, the voltage drop across the capacitor, $V_{c(max)}$, will be 4.965V as Figure 10 (a). The integrator can change the output waveforms with different RC time constant. Figure 10 (b) and Figure 10 (c) show the output wave forms of medium and long time 5ms and 10ms of integrator circuit. The integrator output waveforms are displayed on oscilloscope by red color for all simulations.

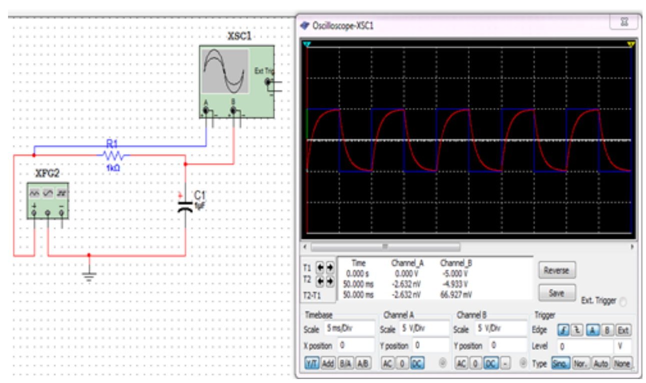


Figure 10 (a). Simulation result of the integrator circuit for short time constant

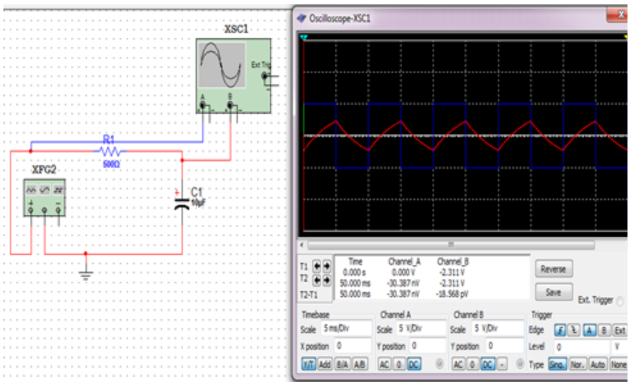


Figure 10 (b). Simulation result of the integrator circuit for medium time constant

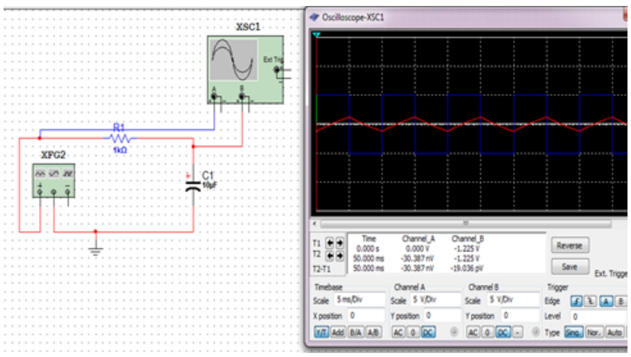


Figure 10 (c). Simulation result of the integrator circuit for long time constant

IV. CONCLUSION

In this paper, three diode circuits and two RC circuits have been tested through the simulations to analysis their performances. The results indicated how the circuits can produce the different wave shapes from various input waveforms. The integrator and differentiator circuits have been simulated for short, medium and long time constants with fixed frequency. The resultant outputs are very closely to the theoretical output. Depend on the applications, the linear and nonlinear wave shaping circuits can be designed with different circuit elements.

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