Introduction

In this lab, you will investigate the ability of a diode circuit to shape an input signal towards a different (desirable) waveform. Such an ability of a diode circuit capitalizes on the nonlinear voltage-current characteristic of a diode and is not offered by a linear circuit (i.e., a circuit that only uses resistors, capacitors, or inductors).

Pre-lab Assignment

P1. Assuming $V_1 = V_4 = 3.33V, V_2 = -V_3 = 1.67V$, a forward voltage drop of $0.7V$ for the diodes, and $R_2/(R_1 + R_2) = 0.5$, manually (analytically) derive and sketch the input-output transfer characteristic of the circuit in Figure 1. That is, draw a plot of v_O versus v_I. Present the characteristic as Graph P1. You can do this systematically by moving from an infinitely negative input voltage to an infinitely positive input voltage, and determining the output in terms of the input for every combination of conduction states for the diodes. Show all of your work.

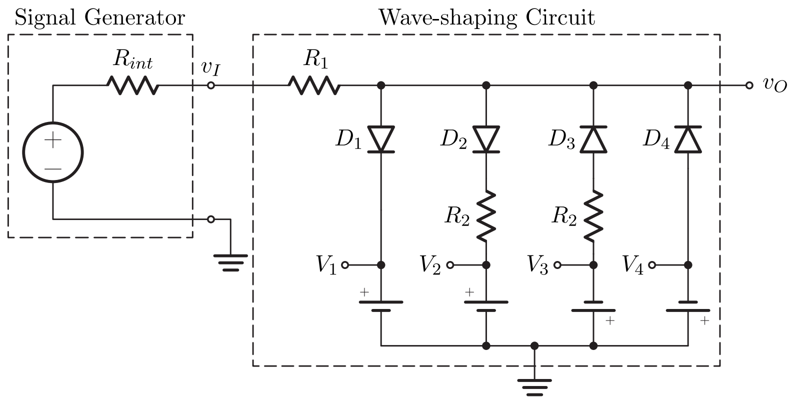

Figure 1: Wave-shaping circuit with multiple DC voltage sources (batteries).

P2. For the circuit of Figure 1, and assuming the same conditions as those specified in P1, determine R_1 and R_2 in such a way that:

1. The two resistors exist in your lab
2. They have a resistance that is larger than 500Ω, and
3. With an input of $v_I = 8V$ (or $-8V$) to the circuit, no conducting diode has a current that is smaller than $0.5mA$.

Show all of your work.

P3. Using the resistor values that you determined in P2, simulate the circuit of Figure 1 with a $10kHz$ symmetrical triangular input voltage whose magnitude is $16V$ peak-to-peak. Capture the waveforms of v_I and v_O, and present them in one frame for four cycles as Graph P3(a). Also, plot the v_O versus v_I to capture the input-output transfer characteristic of the circuit and present the plot as Graph P3(b).

P4. Assume that you must build the circuit of Figure 1. One practical difficulty is the need for four voltage sources (shown as batteries in Figure 1) since most electronic circuits are energized by a single-output power supply (offering a positive voltage relative to the ground) or by a dual-output power supply (giving both positive and negative voltages relative to the ground). Thus, assuming that you have access to a dual-output power supply, determine the resistances R_3, R_4, and R_5 in the voltage-dividing network on Figure 2 needed to obtain the voltages that the circuit of Figure 1 requires ($V_1 = -V_4 = 3.33V$ and $V_2 = -V_3 = 1.67V$). Assume that your dual-output power supply offers $\pm V_{cc} = \pm 12V$. Due to your lab kit limitations, choose the resistances in such a way that the obtained voltages are as close to the aforementioned values of V_1 through V_4 as possible. Also, determine the resistances in such a way that the current drawn from the positive power supply is within the range of $15mA - 25mA$ (meaning the current sunk by the negative supply is in the same range). Show all of your work

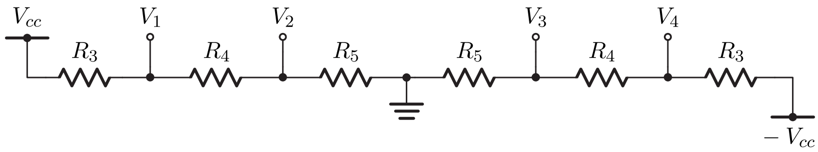

Figure 2: Voltage-dividing network that produces DC voltages required by the wave-shaping circuit of Figure 1.

P5. Figure 3 shows the wave-shaping circuit of Figure 1 from which the four DC voltage sources (batteries) have been removed, and for which the voltages V_1 through V_4 have been obtained from the voltage-dividing network of Figure 2. With the values that you arrived at in the previous steps for the circuits of Figure 2 and Figure 3, simulate the circuit of Figure 3 with a $10kHz$ symmetrical triangular input voltage whose magnitude is $16V$ peak to peak. Capture the input and output signals over four cycles and present the waveform as Graph P5(a). Also, capture the input-output transfer characteristic of the wave-shaping circuit of Figure 3 and present the plot as Graph P5(b).

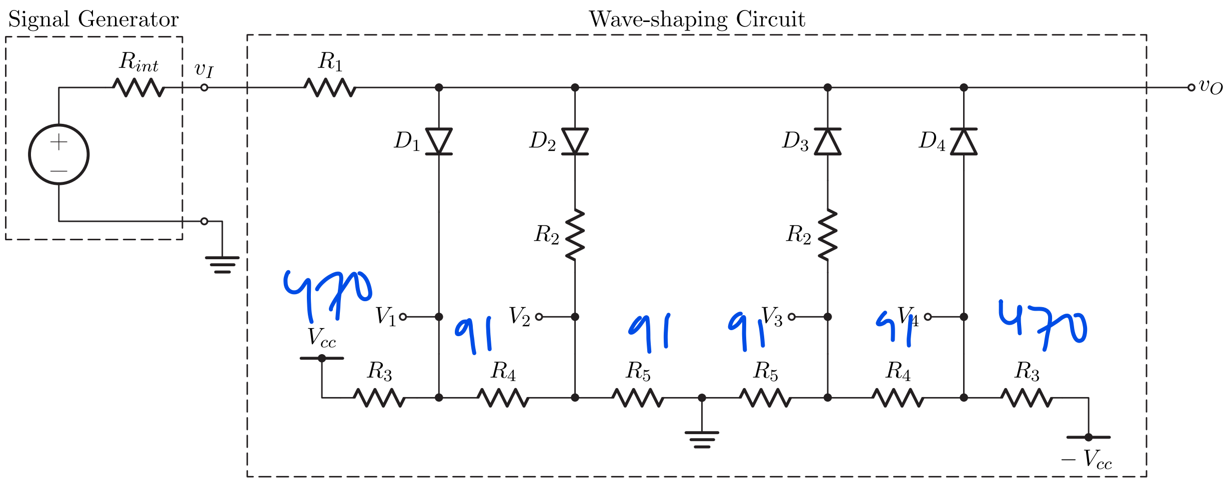

Figure 3: Wave-shaping circuit of Figure 1 in which the DC voltages are obtained from the voltage-dividing network of Figure 2.

P6. In the modified wave-shaping circuit of Figure 3, make R_3 through R_5 10 times larger than their previously chosen values, while keeping R_1 and R_2 unchanged. The resulting circuit is shown as Figure 4 below. Then, repeat the simulation of P5 on the circuit of Figure 4. Record the input and output signal waveforms and present them as Graph P6(a), and present the transfer characteristic as Graph P6(b).

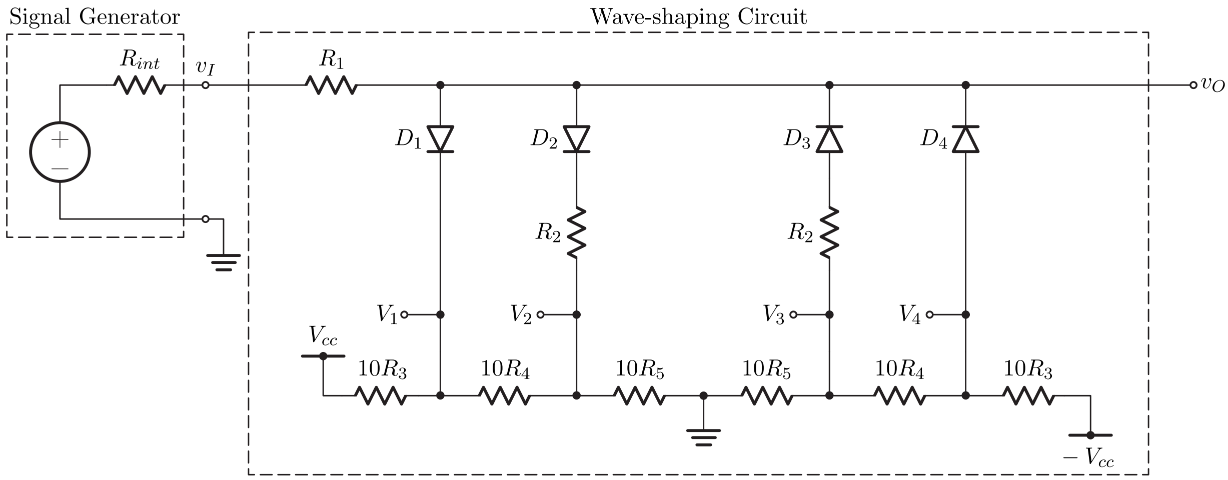

Figure 4: Wave-shaping circuit of Figure 3 in which R_3 through R_5 have been made 10 times larger.

P7. In the circuit of Figure 4, connect each of the nodes V_1, V_2, V_3 and V_4 to the ground via their own respective $10\mu F$ capacitors as shown in Figure 5. In this case, the nodes are said to be ***bypassed*** by the capacitors. Then, simulate the circuit of Figure 5. Record the input and output waveforms and present them as Graph P7(a). Also, show the transfer characteristic and present it at Graph P7(b).

Experiment and Results

E1. Construct the wave-shaping circuit of Figure 3 using 1N4148 diodes, and with $R_1 = R_2 = 3.33k\Omega, R_3 = 470\Omega$, and $R_4 = R_5 = 91\Omega$. Make sure that the two outputs of the dual-output power supply have the same ground, and set the power supply voltage to $V_{cc} = -V_{cc} = 12V$. Note, the power supply automatically sets the negative channel voltage equal to the positive channel's magnitude. Then, monitor the input and output signals, v_I and v_O, by Channel 1 and Channel 2 of the oscilloscope, respectively. Then, set the signal generator in such a way that v_I is a $10kHz$ symmetrical triangular waveform whose magnitude is $16V$ peak-to-peak. Make sure that the two oscilloscope channels are in the DC coupling mode (otherwise the waveforms may become distorted). Set the voltage per division gain of both channels such that both waveforms can fit on the screen. Also, set the time per division gain of the oscilloscope in such a way that the screen shows 4-6 cycles of the waveforms. Use the USB utility (or your phone) to save pictures of the waveforms. Present these waveforms as Graph E1(a). Then, put the oscilloscope in the X-Y display mode. This mode shows the input-output transfer characteristic of the circuit. Again, use the USB utility (or take a picture with your phone) and present these waveforms as Graph E1(b).

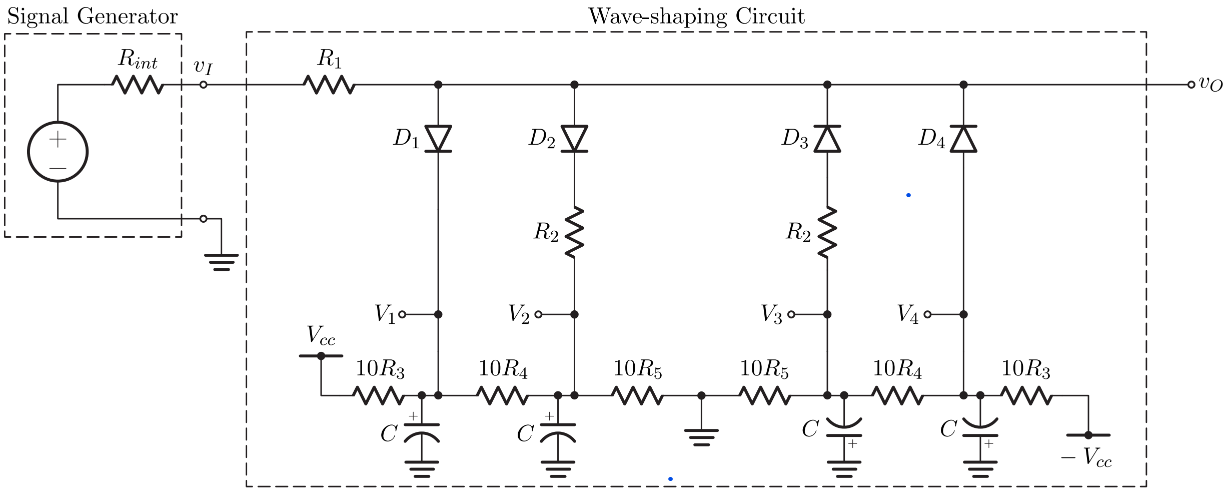

Figure 5: Wave-shaping circuit of Figure 3 in which R_3 through R_5 have been made 10 times larger and bypassed by electrolytic capacitors.

E2. Power off the wave-shaping circuit and replace each of the voltage-dividing resistances by resistances that are ten times larger, to arrive at the circuit of Figure 4 (specifically, $10R_3 = 4.7k\Omega$ and $10R_4 = 10R_5 = 910\Omega$). Power up the circuit and repeat E1, this time saving the results as Graph E2(a) and Graph E2(b).

E3. Power off the circuit again and bypass each DC-voltage tap using 10-μF electrolytic capacitors to arrive at the circuit of Figure 5. Note, electrolytic capacitors are polarized, and their negative terminals are marked on their cases. If connected in reverse, they can heavily load the circuit, heat up, and even explode. Therefore, install them as they are shown in the figure, paying close attention to the "+" sign. Again, power up the circuit and repeat E1. This time, save the results as Graph E3(a) and Graph E3(b)

Conclusion

Answer the following questions based on the various aspects of the lab. Questions must be *fully answered* and you must demonstrate that you have full understanding of the concepts observed in this lab to achieve full marks.

C1. Based on the transfer characteristic of Graph P3(b), explain what the output voltage waveform of the circuit of Figure 1 synthesizes from a symmetrical periodic triangular input voltage.

C2. Compare the transfer characteristics of Graph P1 and Graph P3(b), and comment on how they agree and/or disagree. Provide reasons for discrepancies, wherever relevant.

C3. Compare the transfer characteristics of Graph P1 with each of the characteristics shown of Graph P5(b) and Graph P6(b). Comment on the agreement and/or disagreement between these figures. Provide reasons for discrepancies, wherever relevant. Based on your observations, comment on the main consideration(s) behind the selection of the voltage-dividing resistances.

C4. Compare the transfer characteristic of Graph P1 with those of Graph P6(b) and Graph P7(b), and comment on the effect of the bypass capacitor. Explain the reason behind the observed effect.

C5. Compare the transfer characteristic of Graph P1 with each of the experimental transfer characteristics Graph E1(b), Graph E2(b), and Graph E3(b), and comment on the agreement and/or disagreement between the plots. Provide reasons for discrepancies, wherever relevant.

TA Copy of Results

Student Name	Pre-lab (/20)	Set-up (/10)	Data Collection (/10)	Participation (/5)