Ryerson University

Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

Course Title:	Electronic Circuits I
Course Number:	ELE404
Semester/Year (e.g.F2016)	W2025

Instructor:	Md Waselul Haque Sadid

Assignment/Lab Number:	Lab 4
Assignment/Lab Title:	Wave Shaping Circuits

Submission Date:	Mar 7, 2025
Due Date:	Mar 7, 2025

Student LAST Name	Student FIRST Name	Student Number	Section	Signature*
Malik	Hamza	501112545	11	Ham Malik

*By signing above you attest that you have contributed to this written lab report and confirm that all work you have contributed to this lab report is your own work. Any suspicion of copying or plagiarism in this work will result in an investigation of Academic Misconduct and may result in a "0" on the work, an "F" in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at: http://www.ryerson.ca/senate/current/pol60.pdf

ELE 404: Electronics I
Lab 4: Wave-shaping Circuits

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 $V_1 = -V_4 = 3.33\,V$, $V_2 = -V_3 = 1.67\,V$, a forward voltage drop of $0.7\,V$ for the diodes, and $R_2/(R_1 + R_2) = 0.5$, manually (analytically) derive and sketch as **Graph P1** the input-output transfer characteristic of the circuit of **Figure 1** (that is, a plot of v_O versus v_I). 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 work.

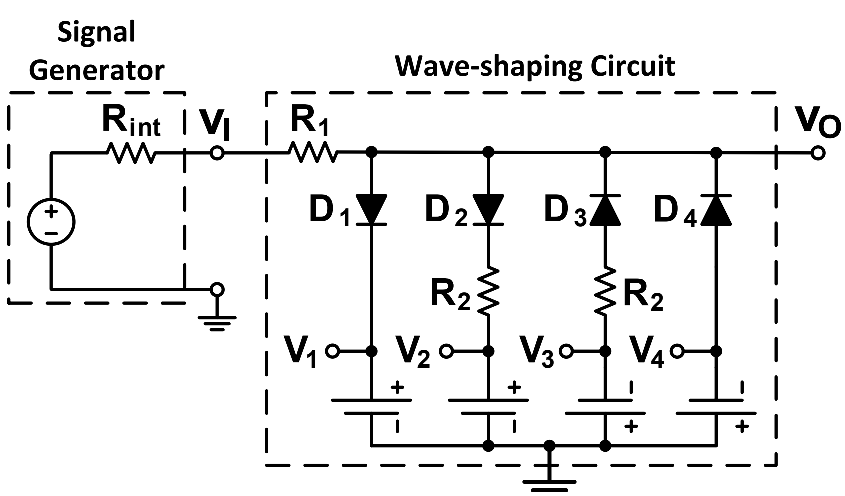
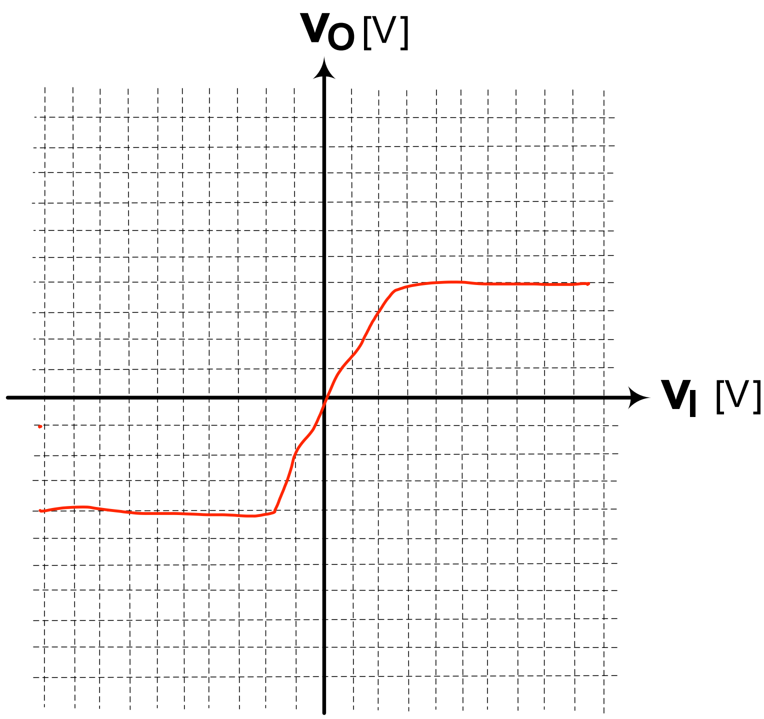


Figure 1. Wave-shaping circuit with multiple DC voltage sources (batteries).



Graph P1. Input-output transfer characteristic of the circuit of Figure 1.

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

a. The two resistors exist in your lab kit
b. They are larger in resistance than 500 Ω, and
c. With an input of $v_I = 8\ V$ (or $-8\ V$) to the circuit, no conducting diode has a current smaller than $0.5\ mA$.

Show all the work.

$$V_i = \pm 8V$$

$$V_o = \frac{R_2}{R_1+R_2} V_i$$

$$\frac{R_2}{R_1+R_2} = 0.5$$

$$R_2 = R_1$$

$$R_1, R_2 > 500\Omega$$

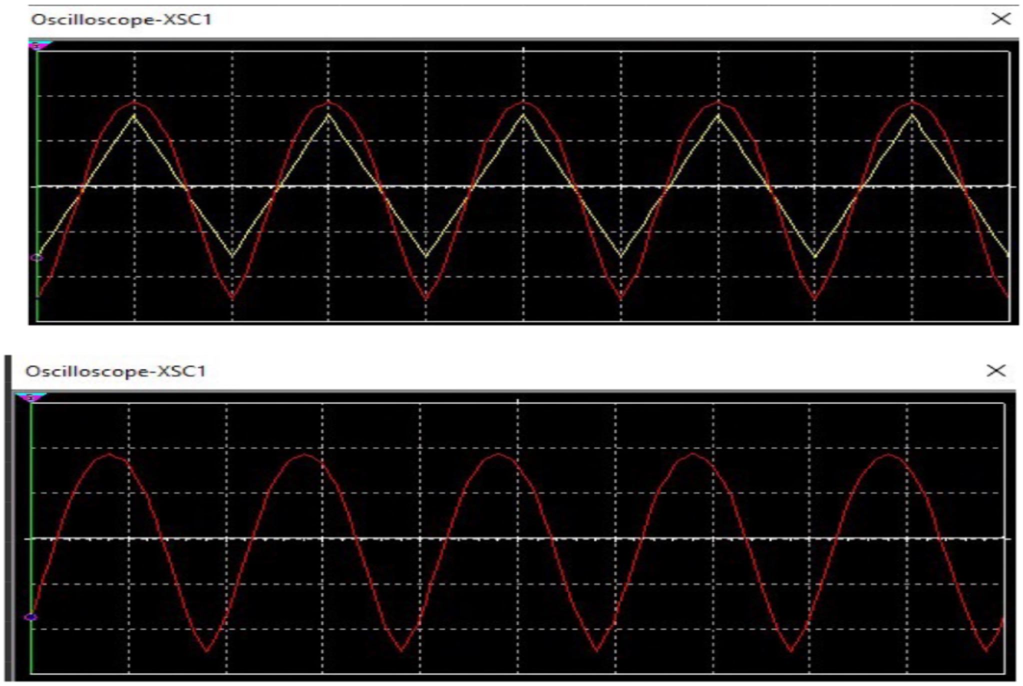
$$R_1 = R_2 = 1k\Omega$$

$$I = \frac{V - V_D}{R}$$

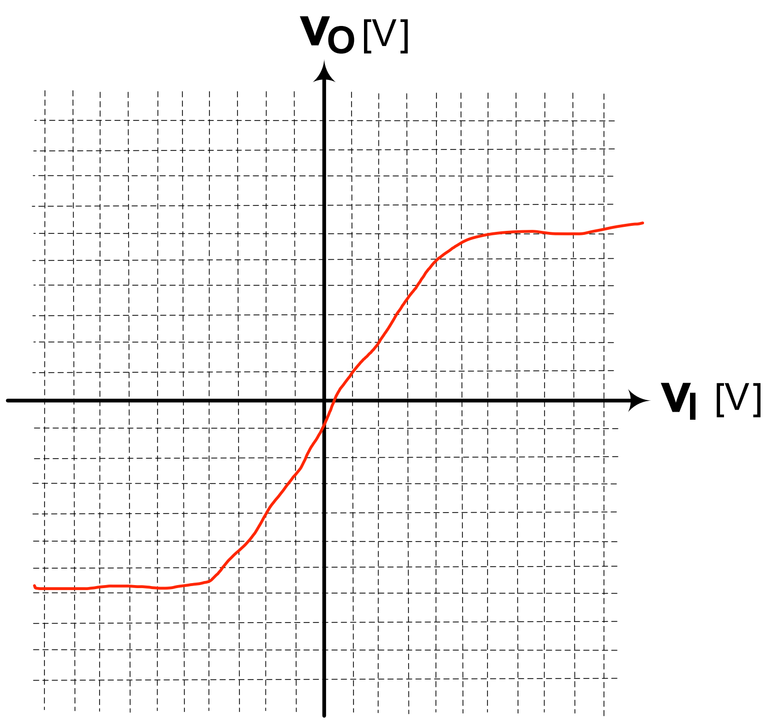
$$I = \frac{8V - 0.7V}{1k\Omega} = 7.3 mA$$

$$\therefore R_1 = R_2 = 1k\Omega$$

P3. Assuming the values you have determined for R_1 and R_2 in **Step P2**, simulate the circuit of **Figure 1** with a **10-kHz, symmetrical triangular input signal whose magnitude is 16 *V* 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 v_O versus v_I to capture the input-output transfer characteristic of the circuit, and present the curve as **Graph P3(b)**.



Graph P3(a). Input and output voltage waveforms.



Graph P3(b). Input-output transfer characteristic.

P4. Now assume that you must build the circuit of **Figure 1**. One (major) practical difficulty is the need for four voltage sources (shown as batteries in **Figure 1**). Most electronic circuits are, however, 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, assume that you have access to a dual-output power supply, and determine the resistances R_3 through R_5 in the voltage-dividing network of **Figure 2** to obtain the voltages that circuit of **Figure 1** requires, that is, $V_1 = -V_4 = 3.33\,V$ and $V_2 = -V_3 = 1.67\,V$. Assume that your dual-output power supply offers $V_{CC} = 12\,V$ (that is, $-V_{CC} = -12\,V$). Due to your lab kit limitations, choose the resistances in such a way that the obtained voltages are as close to the aforementioned (ideal) values as possible. Further, determine the resistances in such a way that the current drawn from the positive power supply is something in the range 15 mA to 25 mA (and, therefore, the current sunk by the negative power supply is in the same range).

Show all the work.

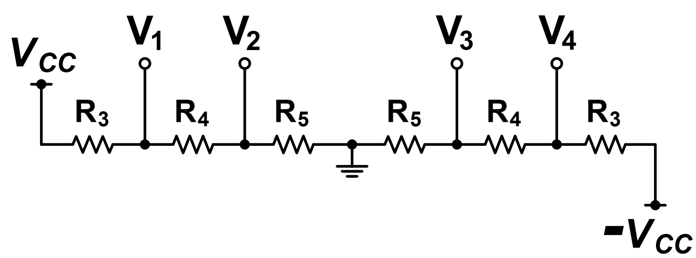


Figure 2. Voltage-dividing network that produces the DC voltages required by the wave-shaping circuit of Figure 1.

$V1 = 3.33\,V$ $\quad$ $VCC = \pm 12$

$V2 = 1.67\,V$

$V3 = -1.67\,V$

$V4 = -3.33\,V$

$Vx = VCC - I \Sigma Rx$

$V1 = VCC - I(R1)$

$V2 = VCC - I(R1 + R2)$

$V3 = -VCC + I(R4 + R3)$

$V4 = -VCC + I(R4)$

$I = \frac{VCC}{R_{total}}$

$R_{total} = \frac{12V}{20mA} = 600\Omega$

$R1 = \frac{12V - 3.3V}{20mA} = \frac{8.67V}{0.02A} = 433.5\Omega$

$R2 = \frac{3.3V - 1.67V}{20mA} = \frac{1.66V}{0.02A} = 83\Omega$

$R3 = \frac{1.67V - (-1.67V)}{20mA} = \frac{3.34V}{0.02A} = 167\Omega$

$R4 = \frac{-1.67V - (-3.33V)}{20mA} = \frac{1.66V}{0.02A} = 83\Omega$

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

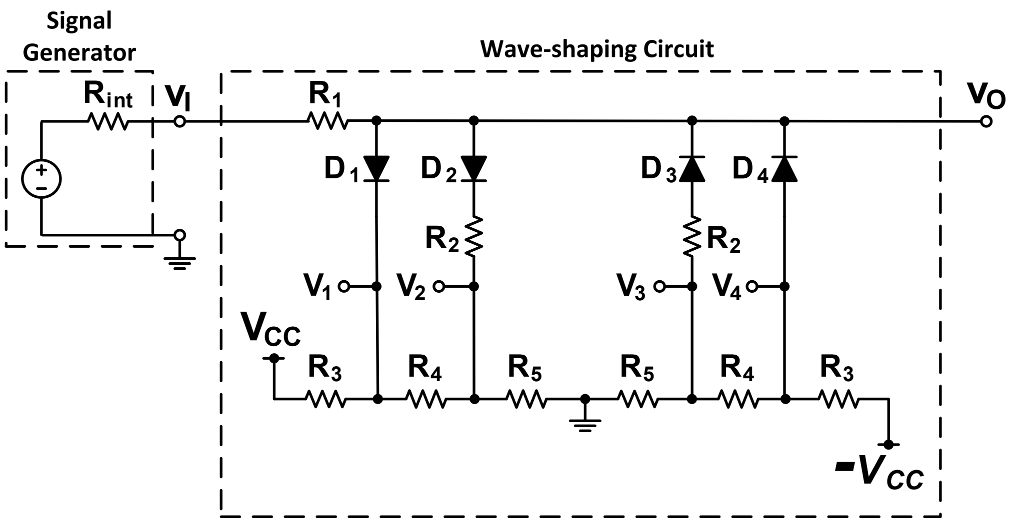
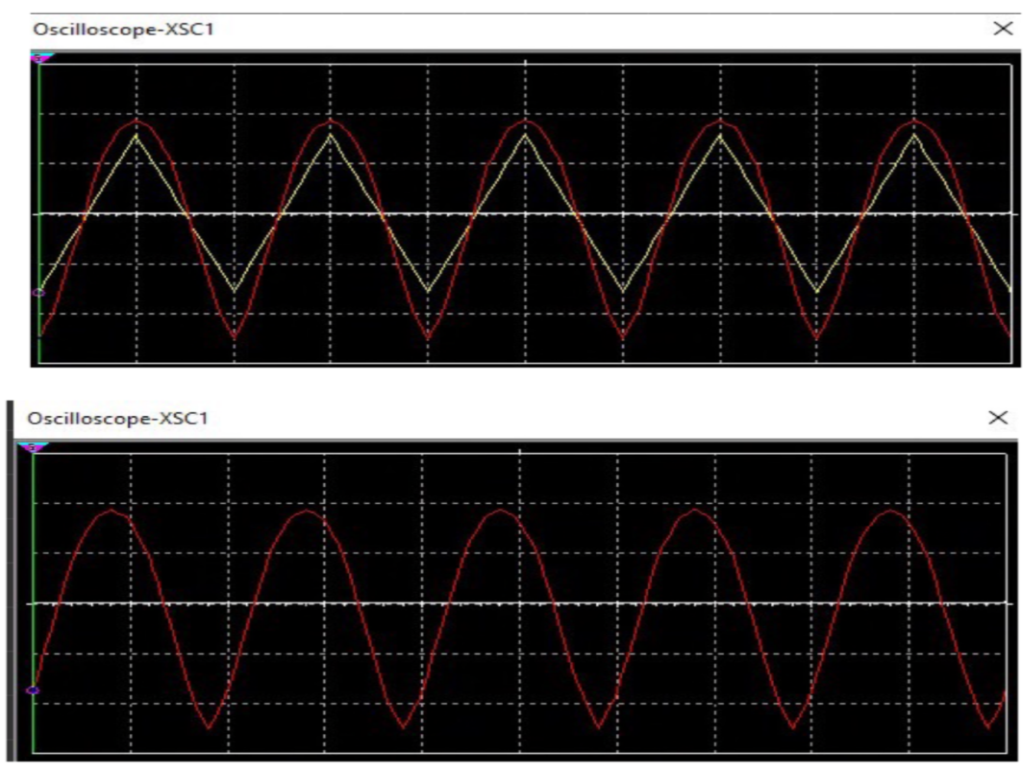
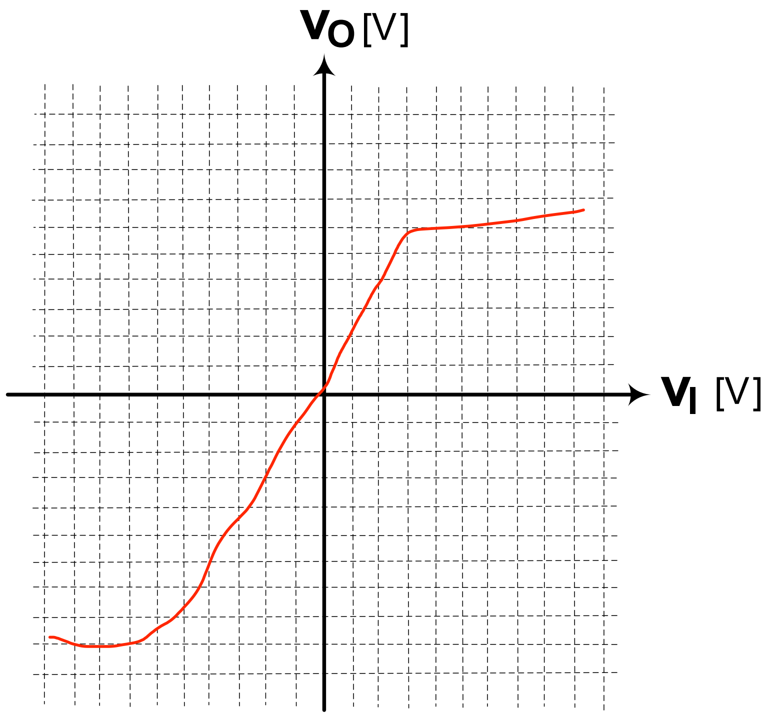


Figure 3. Wave-shaping circuit of Figure 1 in which the DC voltages are obtained from the voltage-dividing network of Figure 2.



Graph P5(a). Input and output voltage waveforms of the wave-shaping circuit of Figure 3.



Graph P5(b). Input-output transfer characteristic of the wave-shaping circuit of Figure 3.

P6. In the modified wave-shaping circuit of **Figure 3**, make R_3 through R_5 10 times larger relative to their values in the previous steps, while you keep R_1 and R_2 unchanged. The resultant circuit is shown as **Figure 4**, below. Then repeat the simulation of **Step P5** on the circuit of **Figure 4**. Record the input and output signal waveforms as **Graph P6(a)** and the transfer characteristic as **Graph P6(b)**.

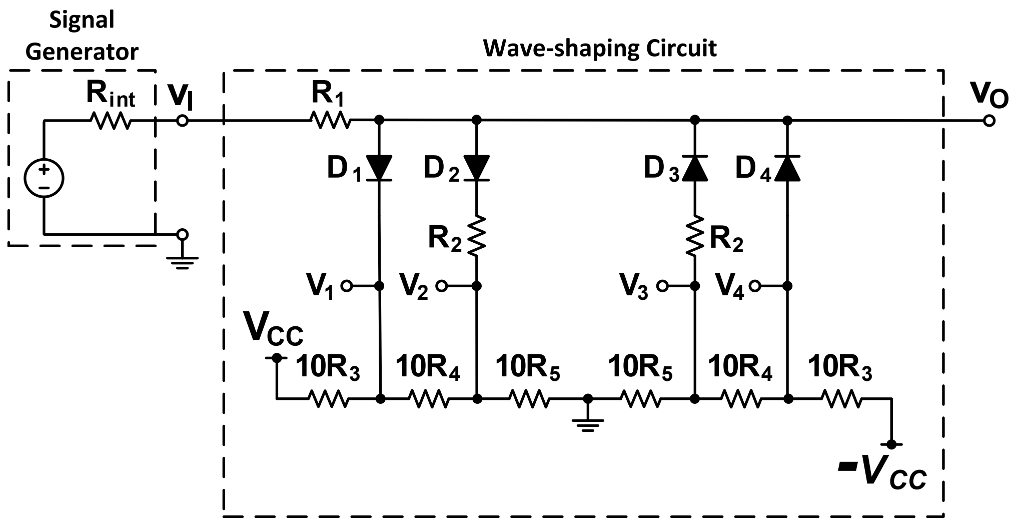
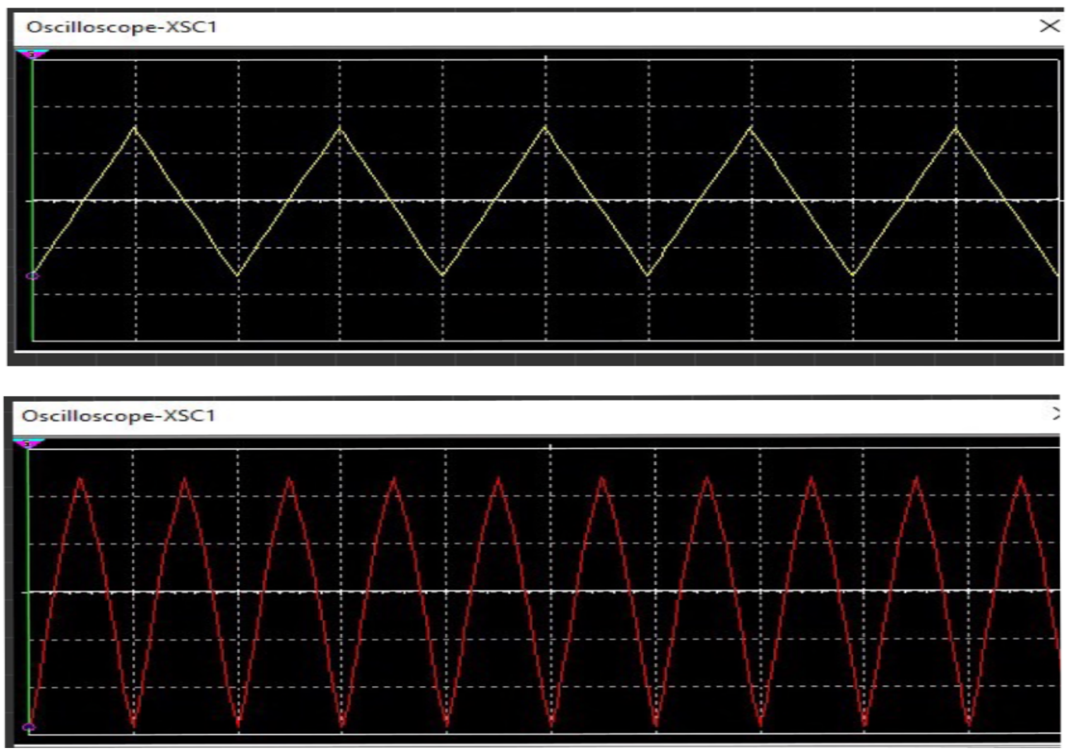
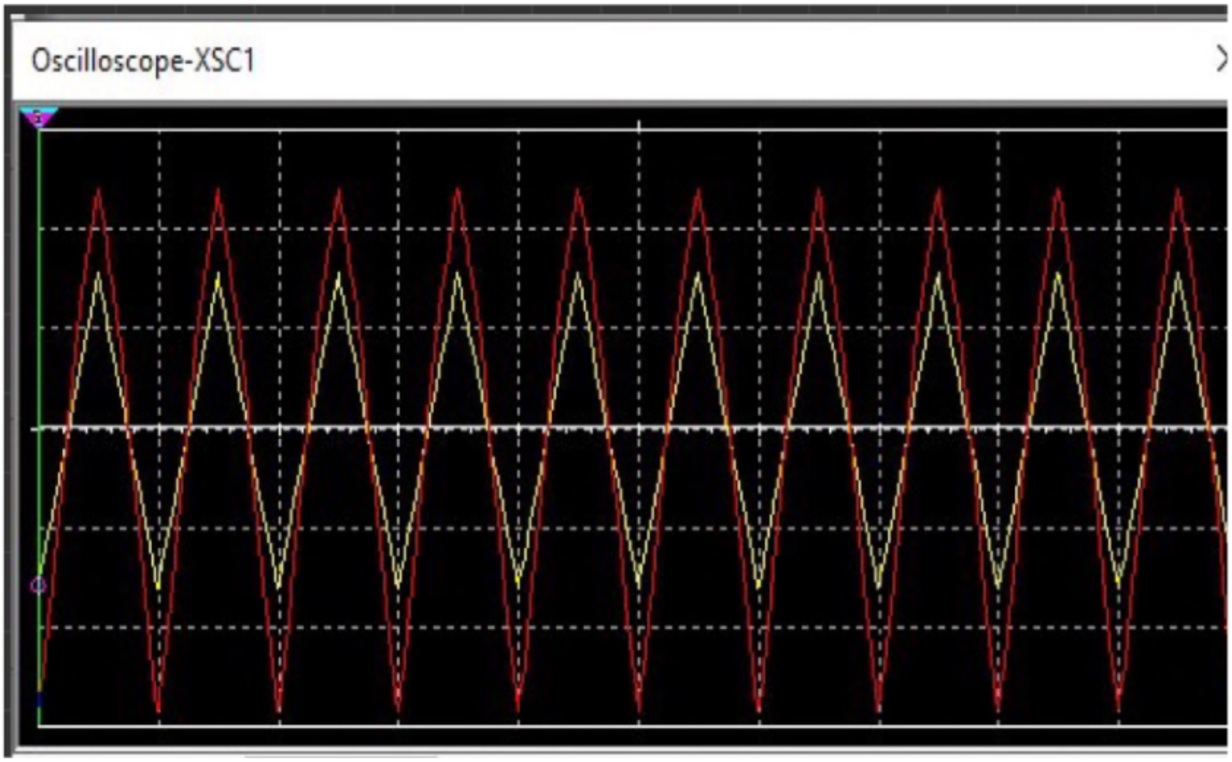


Figure 4. Wave-shaping circuit of Figure 3 in which R_3 through R_5 have been made 10 times larger.



Graph P6(a). Input and output voltage waveforms of the wave-shaping circuit of Figure 4.



Graph P6(b). Input-output transfer characteristic of the wave-shaping circuit of Figure 4.

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 a corresponding 10-μF capacitor as shown in **Figure 5**; the nodes are then said to be ***bypassed*** by the capacitors. Then, simulate the circuit of **Figure 5**. Record the input and output signal waveforms as **Graph P7(a)** and the transfer characteristic as **Graph P7(b)**.

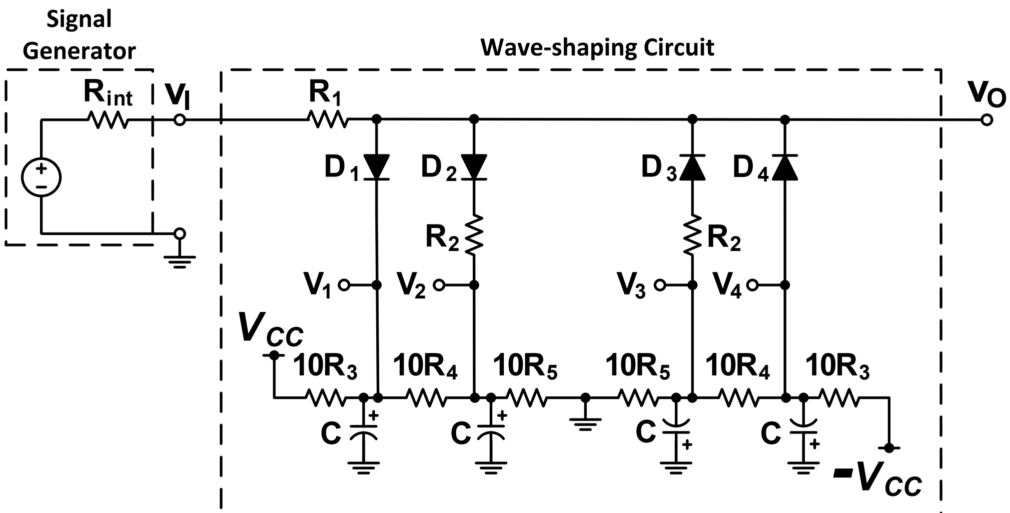
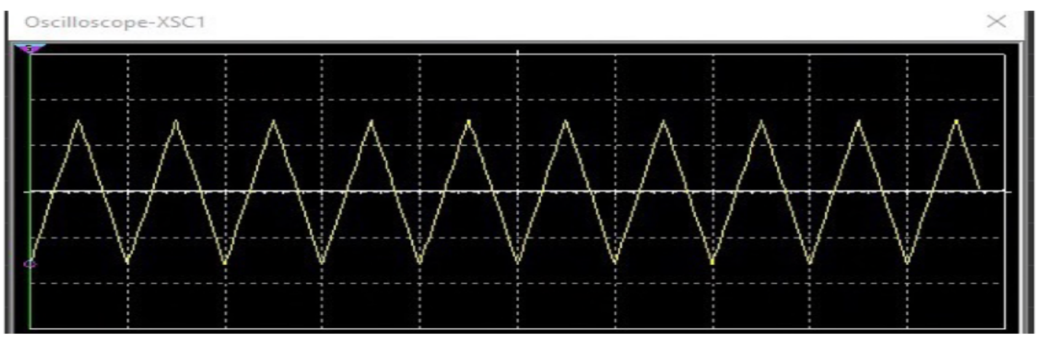
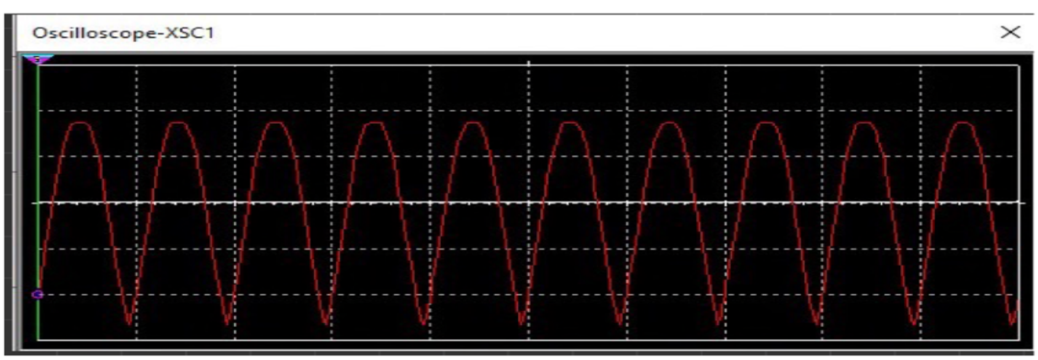
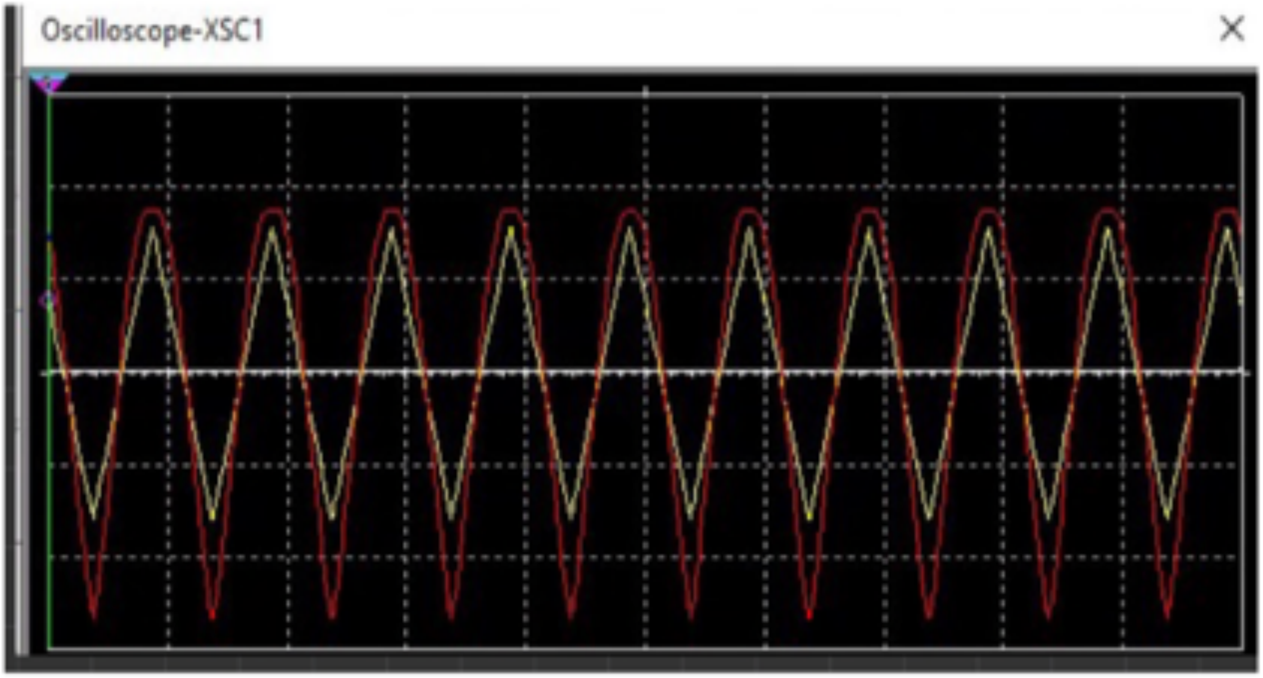


Figure 5. Modified wave-shaping circuit with resistances R_3 through R_5 made 10 times larger and bypassed by electrolytic capacitors.





Graph P7(a). Input and output voltage waveforms of the wave-shaping circuit of Figure 5.



Graph P7(b). Input-output transfer characteristic of the wave-shaping circuit of Figure 5.

Experiments and Results

E1. Construct the wave-shaping circuit of **Figure 3**, using **1N4148** diodes, and with $R_1 = R_2 = 3.3\ k\Omega$, $R_3 = 470\ \Omega$, 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 $V_{CC} = -V_{CC} = 12\ V$. Then, monitor the input and output signals (i.e., v_I and v_O) by **Channel 1** and **Channel 2** of the oscilloscope, respectively. Thus, set the signal generator in such a way that v_I is a **10-kHz symmetrical triangular signal whose magnitude is 16 V peak-to-peak**. Make sure that the two oscilloscope channels are in the **DC Coupling** mode (otherwise the waveforms may seem distorted). Set the ***voltage per division gain*** of the oscilloscope in such a way that the waveforms more or less fit the screen. Also, set the ***time per division gain*** of the oscilloscope in such a way that you fit about four to six cycles of the waveforms on the screen. Using the USB utility of the oscilloscope, save the input and output waveforms as **Graph E1(a).** Then, put the oscilloscope into the **X-Y display mode** and save the input-output transfer characteristic of the circuit as **Graph E1(b)**.

E2. Power off your 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, $10R_3 = 4.7\ k\Omega$ and $10R_4 = 10R_5 = 910\ \Omega$). Power the circuit up and repeat **Step E1**, this time saving the results as **Graph E2(a)** and **Graph E2(b).**

E3. Power off your wave-shaping circuit and bypass each DC-voltage tap of the circuit by a 10-μF electrolytic capacitor, to arrive at the circuit of **Figure 5.** Electrolytic capacitors are polarized, **with their negative terminal marked** on their cases. If connected in reverse, they can badly load the circuit, heat up, and even explode. Therefore, install them exactly as shown in **Figure 5**. Power up the circuit and repeat **Step E1**, this time saving the results as **Graph E3(a)** and **Graph E3(b).**

Conclusions and Remarks

Answer the following questions regarding the different aspects of the lab. Please *fully answer* these questions. Short answers may be correct but they do not necessarily show any understanding of what has happened during the lab.

C1. Based on the transfer characteristic of **Graph P3(b)**, explain what output voltage waveform 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 their agreement (or disagreement). Provide reasons for discrepancies, if any.

C3. Compare the transfer characteristic of **Graph P1** with each of the characteristics **Graph P5(b)** and **Graph P6(b)**, and comment on their agreements (or disagreements). Provide reasons for discrepancies, if any. In addition, in view of 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 effect of the bypass capacitors and the reason behind the 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 their agreements (or disagreements). Provide reasons for the discrepancies, if any.

TA Copy of Results

	Partner's Name	Set-Up (out of 10)	Data Collection (out of 10)	Participation (out of 5)
1	Hamza Malik	✓	✓	✓
2	Ryan Taing	✓	✓	✓