Title of the experiment:

Two Output Precision Half-Wave Rectifier Using Op-Amp

1. Introduction

The precision half-wave rectifier circuit is created to deliver two different output signals and having high accuracy of rectifying AC signal. This simulation gives an insight of the circuit functionality and its use with a more hands-on involving some signal processing technique.

2. Theory

The precision half-wave rectifier circuit uses an operational amplifier to overcome the diode's forward voltage drop, enabling accurate rectification of low-level AC signals. The circuit produces two outputs, corresponding to the positive and negative halves of the input signal. By leveraging the op-amp's feedback mechanism, the rectifier achieves high precision in signal processing. This design is critical in applications requiring minimal signal distortion and precise waveform reproduction.

2.1. Basic Operation

1. Operational Amplifier Compensation: The circuit uses an operational amplifier (op-amp) to compensate for the forward voltage drop of the diode. This allows the rectifier to accurately process even very low-amplitude input signals, which would otherwise be distorted in a standard diode rectifier.
2. Signal Rectification: When an AC signal is applied to the input, the op-amp controls the diode, ensuring that it conducts only during the desired half-cycle of the waveform. This results in the rectification of the input signal, where only the positive (or negative) half-cycle is allowed to pass through to the output.
3. Two-Output Design: In a two-output precision half-wave rectifier, the circuit is designed to provide separate outputs for the positive and negative halves of the input signal. Each output corresponds to one half of the AC waveform, allowing for further processing of both components individually.
4. High Accuracy: The precision rectifier's design ensures that the output closely follows the input signal during the active half-cycle, minimizing any voltage drop or distortion. This high accuracy is crucial for applications requiring precise signal processing, such as in instrumentation and measurement systems.

2.2. Working Mechanism

1. Input Signal Application: An AC signal is applied to the input of the circuit. The operational amplifier (op-amp) receives this signal and compares it with a reference (usually ground).
2. Positive Half-Cycle: During the positive half-cycle of the input signal, the op-amp drives the diode into conduction. The op-amp output forces the diode to conduct, allowing the positive half of the input signal to pass through to the output without significant voltage drop.
3. Negative Half-Cycle: In the negative half-cycle, the op-amp output reverses, causing the diode to block the signal. As a result, the output remains at zero or ground level, preventing the negative half-cycle from passing through.
4. Two-Output Configuration: In a two-output configuration, the circuit splits the rectified signal, providing one output for the positive half-cycle and another for the negative half-cycle. Each output can be further processed or utilized depending on the application.

3. Circuit Diagram

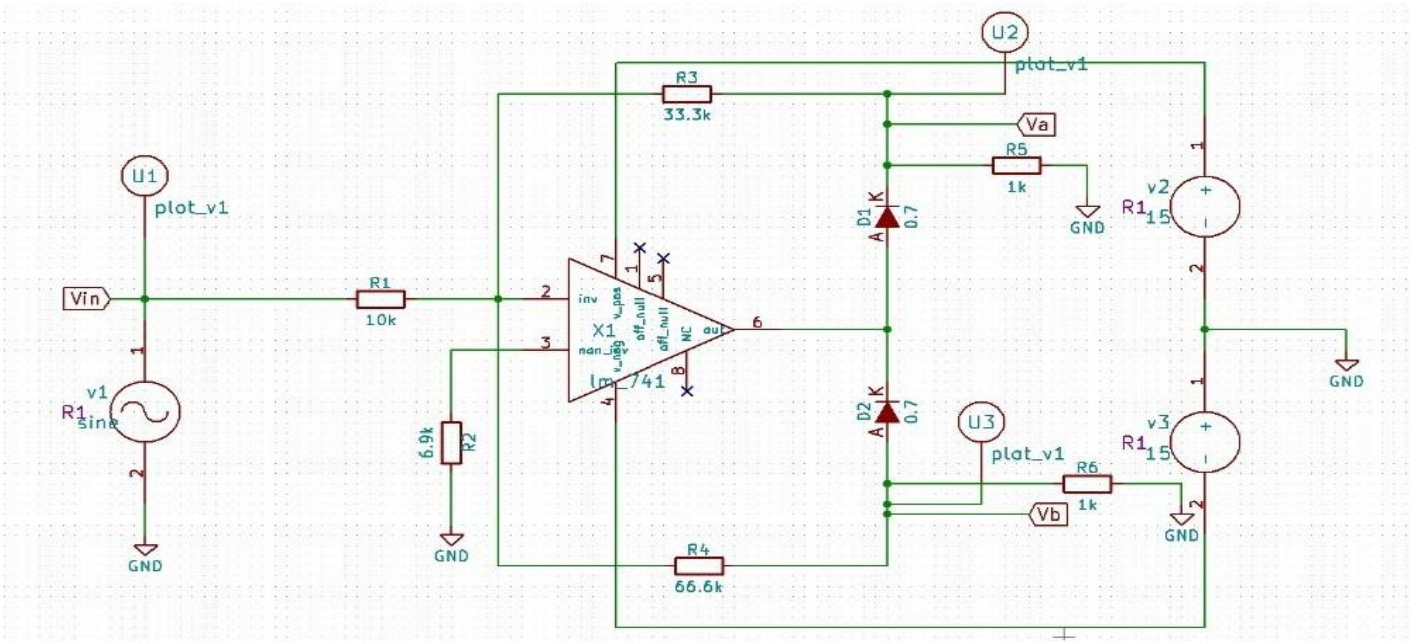

Figure 1: Schematic Diagram of Two output Half Wave Rectifier.

- **Op-Amp (LM-741):** Acts as a high-gain amplifier, amplifying the input signal. Its differential input allows it to compare the input signal to a reference voltage (often ground).
- **Diodes (D1, D2):** Ensure that current flows in only one direction, rectifying the AC signal. In a precision rectifier, diodes are often used in a back-to-back configuration to achieve both positive and negative rectification.
- **Resistors (R1, R2, R3, R4, R5, R6):** Set the gain of the op-amp and provide feedback to stabilize the circuit. Their values can be adjusted to control the output voltage levels.
- **Power Supply:** Provides the necessary DC voltage to power the op-amp and other components in the circuit.

4. Design Steps

Sl No.	Steps	Working
1.	Input voltage of sine wave	Vin = 300mV
2.	Required Peak output at terminal ‘a’	Va = 1V
3.	Required Peak output at terminal ‘b’	Vb = 2V
4.	Assume the value of Resister R1	R1=10 kΩ
5.	Calculate R3 and R4 $R3 = \frac{Va \times R1}{Vin}$ $R4 = \frac{Vb \times R1}{Vin}$	R3=33.33 kΩ R4=66.66 kΩ
6.	Calculate R2 $R2 = \frac{R3 \times R4}{R3 + R4}$	R2=6.9 kΩ
7.	Assume Resistors R5 and R6	R5=1 kΩ R6=1 kΩ

5. Analysis

Ng-spice Plots:

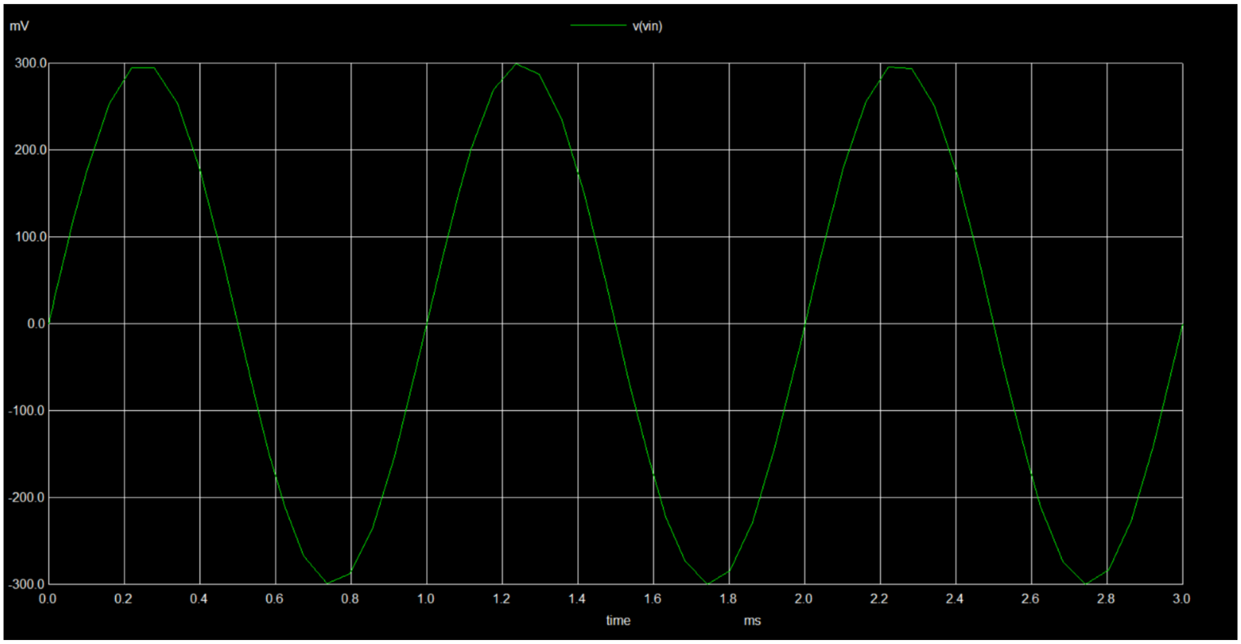

Figure 2: Ng-spice Input Plot

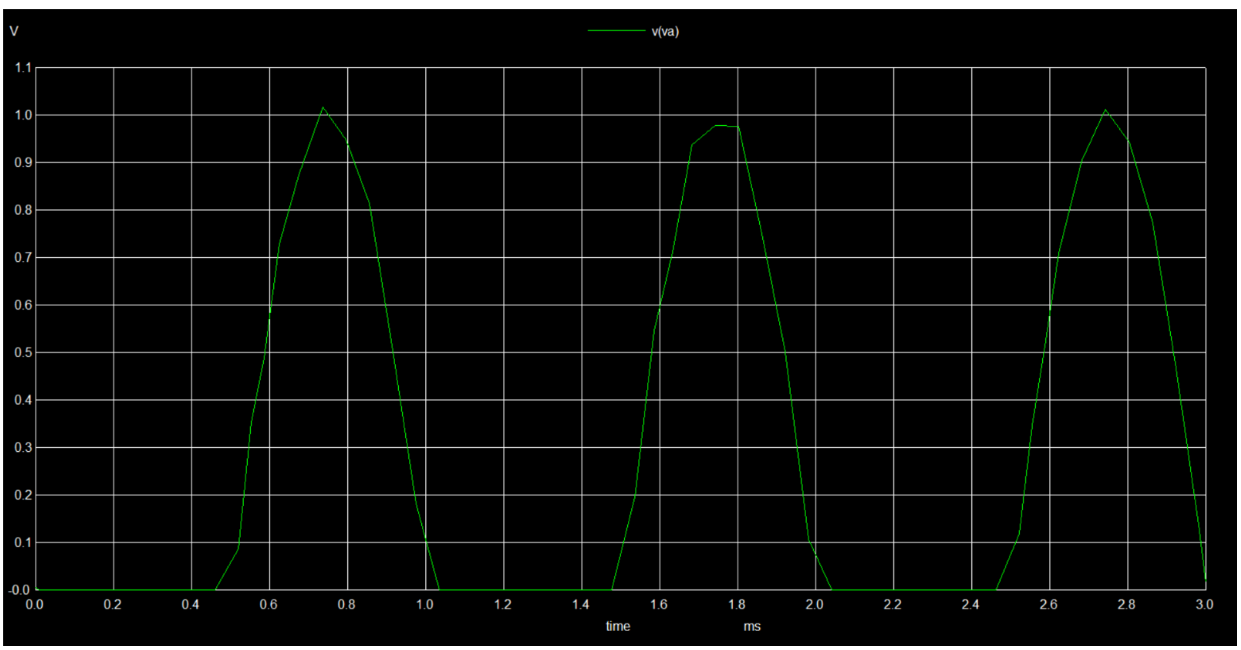

Figure 3: Ng-spice Output at Va Plot

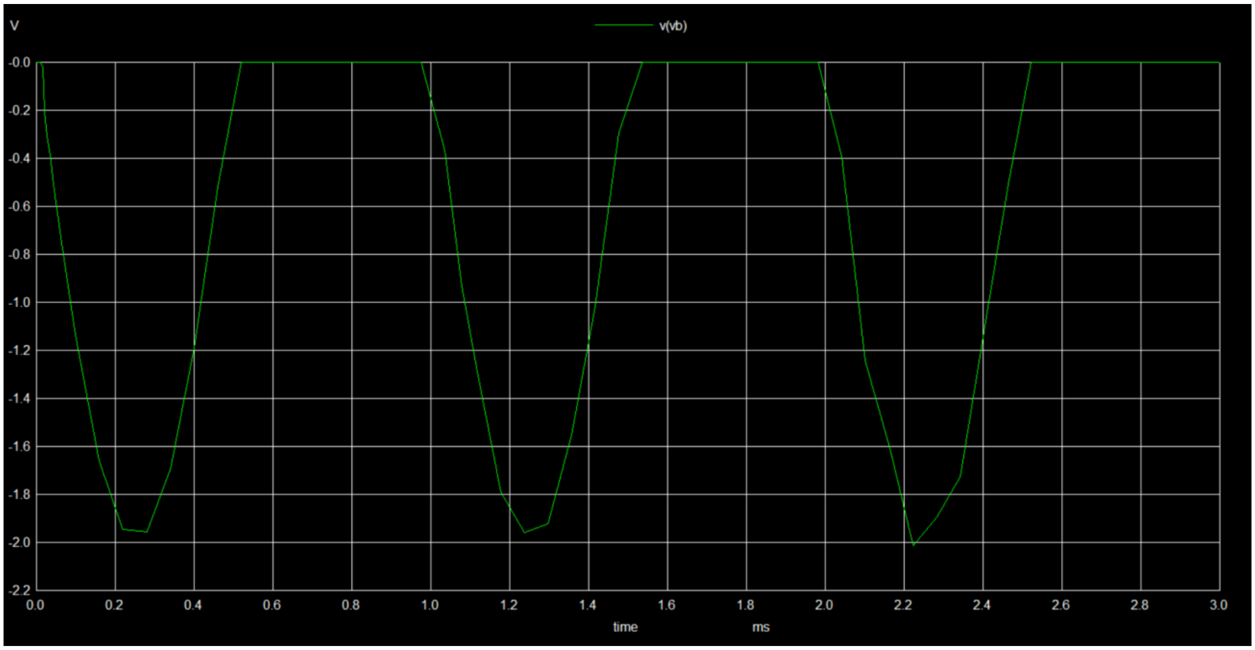

Figure 4: Ng-spice Output at Vb Plot

The output waveform can be further analyzed by focusing on the rectified signal. The rectifier's performance can be assessed by observing how well it converts the AC input into a pulsating DC output, emphasizing the importance of the diode's role in allowing only one half of the AC cycle to pass through. The duty cycle of the rectified waveform can be influenced by the characteristics of the multivibrator circuit, ensuring that the output is optimized for the specific rectification process.

6. Graphical Analysis of Two Output Half Wave Rectifier Output

6.1 . Python Plots:

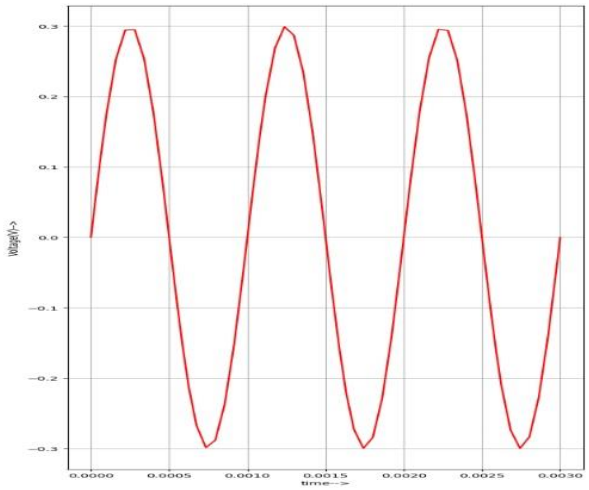

Figure 5: Input

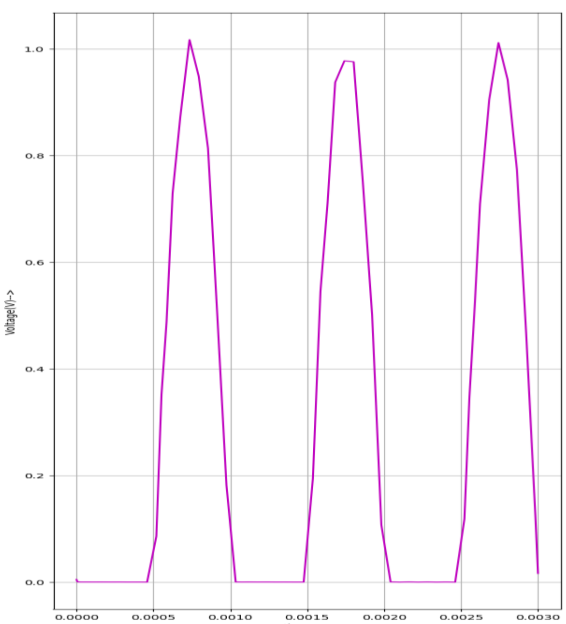

Figure 6: Output at Va

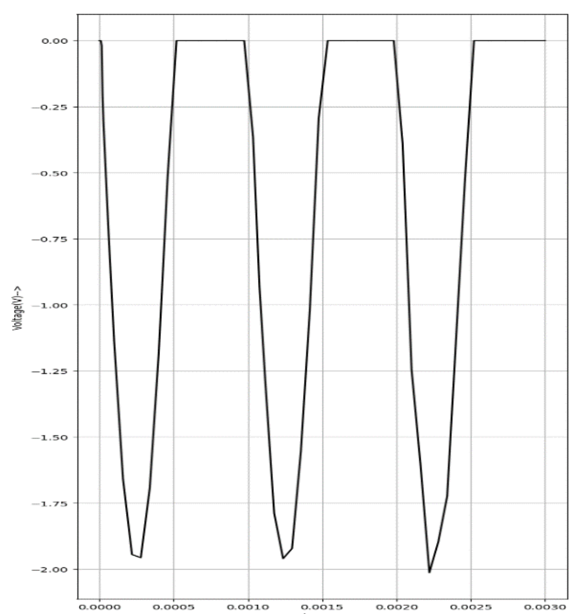

Figure 7: Output at Vb

- **Positive Half-Cycle Output: The** second waveform on the graph corresponds to the positive half-cycle output. In this case, the circuit allows only the positive half of the input sine wave to pass through, blocking the negative half. The result is a series of positive pulses corresponding to the positive half-cycles of the input wave. The waveform is zero during the negative half-cycles.
- **Negative Half-Cycle Output: The** third waveform on the graph represents the negative half-cycle output. Here, the circuit inverts the function, allowing only the negative half of the input sine wave to pass through, blocking the positive half. The result is a series of negative pulses corresponding to the negative half-cycles of the input wave. The waveform is zero during the positive half-cycles.

6.2. Key Observations

- **Separation of Half-Cycles:** The circuit effectively separates the input sine wave into two distinct waveforms, one representing the positive half-cycles and the other representing the negative half-cycles.
- **Rectification of Input Signal:** Each output waveform is a rectified version of the input signal, with one output containing only the positive half-cycles and the other containing only the negative half-cycles.
- **Zero Output During Blocked Cycles:** For each output, the waveform is zero during the half-cycle that is blocked. The positive output waveform is zero during the negative half-cycle, and the negative output waveform is zero during the positive half-cycle.
- **Absence of DC Offset:** Both rectified outputs lack a DC component since each output only includes either positive or negative pulses without any continuous DC level.
- **Ideal Diode Behavior:** The circuit assumes ideal diode behavior where the diodes perfectly conduct during the allowed half-cycle and block entirely during the opposite half-cycle.
- **Waveform Shape:** The rectified waveforms maintain the shape of the input sine wave during their respective half-cycles, showing that the circuit preserves the input waveform's frequency and phase characteristics.

7. Practical Applications

- **Signal Demodulation:** Used in AM radio receivers and other communication systems to demodulate the amplitude-modulated signals by extracting the original audio or data signal from the carrier wave.
- **Bi-phase Mark and Space Detection:** In digital communication systems, a two-output precision HWR can be used to detect and separate the mark and space signals (representing binary data) in bi-phase encoded signals.
- **Phase Detector Circuits:** Employed in phase-locked loops (PLLs) to detect phase differences between the input signal and a reference signal by processing the positive and negative cycles separately.
- **Waveform Generation:** Used to generate precise pulsed waveforms for timing circuits or other digital applications where separate processing of positive and negative halves of a signal is required.
- **Analog Signal Processing:** Useful in applications like audio processing, where separate handling of positive and negative halves of the waveform allows for specialized signal conditioning or effects.
- **Temperature or Pressure Sensing:** In sensor systems that produce AC output, such as certain temperature or pressure sensors, a two-output precision HWR can be used to separately analyze the positive and negative excursions of the sensor signal for more detailed monitoring.

8. Conclusion

The two-output precision half-wave rectifier is a versatile circuit with various practical applications in signal processing, communication, and measurement systems. By separately processing the positive and negative half-cycles of an input signal, it enables detailed analysis and control of AC signals. This capability is particularly useful in applications such as demodulation, phase detection, and waveform generation. The precision nature of the circuit ensures accurate rectification, which is essential in high-performance instrumentation and sensor systems. Additionally, its ability to handle AC signals with minimal distortion makes it valuable in audio and video processing. Overall, the two-output precision half-wave rectifier is a critical component in both analog and digital electronics, enabling enhanced functionality in a wide range of applications.

9. References:

- Precision Full-wave | Half-wave rectifier circuit using OP-AMP | ElecCircuit
- Half Wave and Full Wave Precision Rectifier Circuit using Op-Amp (circuitdigest.com)