EE230: Lab 3
Half and Full Wave Precision Rectifiers

Kalpit Borkar, 200070029

January 29, 2022

1 Overview of the experiment

1.1 Aim of the experiment

To understand the design and workings of the half-wave and full-wave precision rectifiers by simulating them in NGSpice and observing their output voltages against their input voltages.

1.2 Methods

We first build the half-wave rectifier in NGSpice of which the design is provided to us. We then simulate the circuit for a given sinusoidal input signal and observe the trends of the output voltage. By implementing the half-wave precision rectifier as a sub-circuit, we simulate and observe the output voltage for the full-wave precision recitifer as well.

2 Design

2.1 Half-wave Precision Rectifier - type A

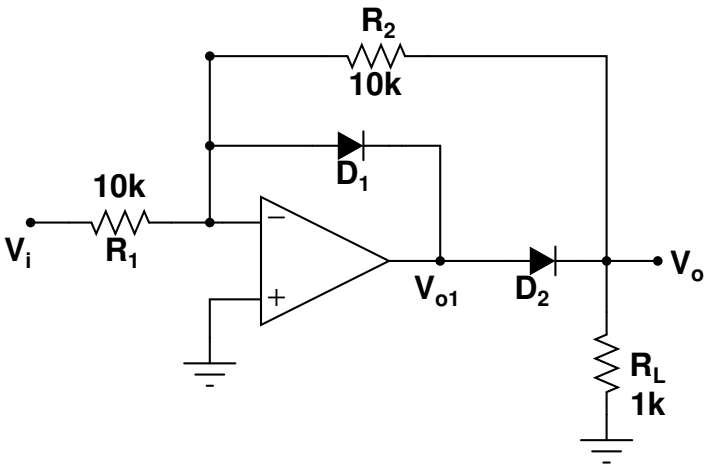

Figure 1: Half-wave Precision Rectifier - type A

The Half-wave Precision Rectifier consists of an op-amp with a resistor attached to it's inverting terminal and another between the inverting terminal and the output voltage. Two diodes namely D_1 and D_2 are attached in the circuit as shown in the figure 1 above. Note the orientation of the above diodes, labelled as type A.

2.2 Half-wave Precision Rectifier - type B

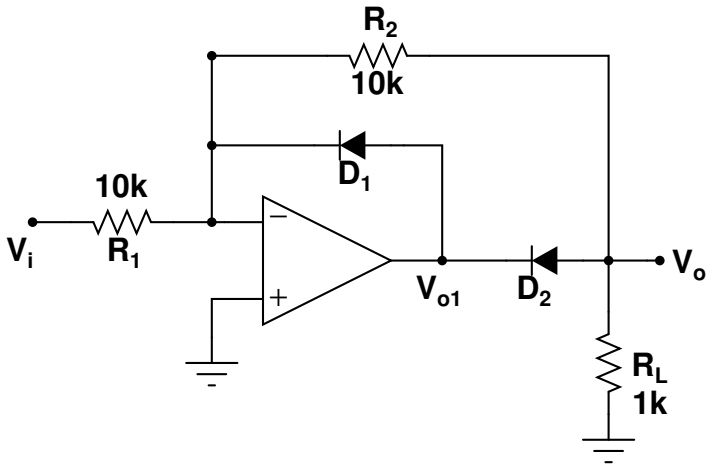

Figure 2: Half-wave Precision Rectifier - type B

The type B Half-wave Precision Rectifier is similar to the type A rectifier, but the orientation of the two diodes D_1 and D_2 is reversed as seen in the figure 2. The difference in the working of these two rectifiers can be observed from their output voltages.

2.3 Full-wave Precision Rectifier

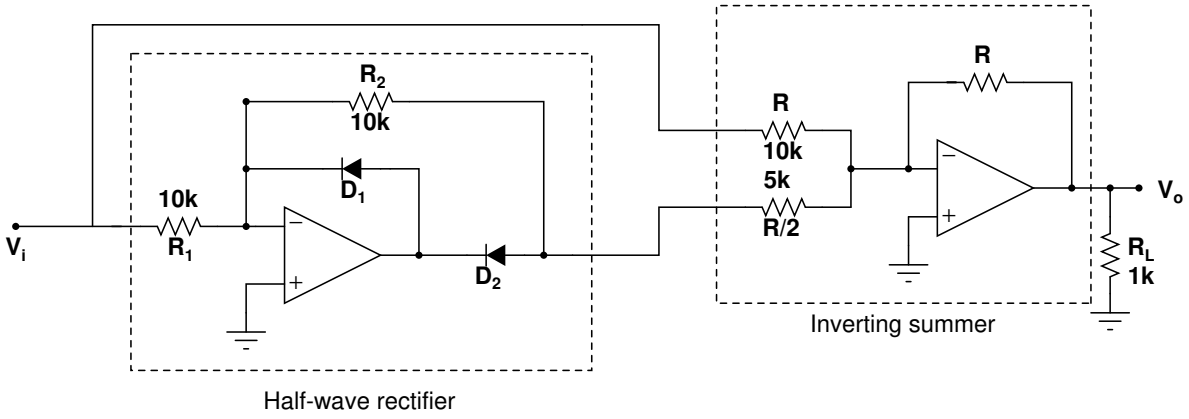

Figure 3: Full-wave Precision Rectifier

The Full-wave Precision Rectifier comprises of the Half-wave Precision Rectifier as a sub-circuit. A half-wave precision rectifier is connected to an inverting summer which comprises of three resistors connected to an op-amp as shown in the figure 3 above. One of the inputs of the inverting summer is the input voltage V_i and the other input is the output from the half wave rectifier.

3 Simulation results

3.1 Code snippets

3.1.1 Half-wave Precision Rectifier

Half Wave precision rectifier

```
.include ua741.txt
.include Diode_1N914.txt

vin 1 0 sin(0 5 1k)
v1 3 0 -15
v2 4 0 15
```

```
x1 0 2 4 3 5 ua741
r1 1 2 10k
r2 2 6 10k
D1 2 5 1N914
D2 5 6 1N914

*For type B Half-wave rectifier
*D1 5 2 1N914
*D2 6 5 1N914

.tran 0.02ms 5ms
.control
run

plot v(1) v(5) v(6)

.endc
.end
```

3.1.2 Full-wave Precision Rectifier

Full Wave Precision rectifier

```
.include ua741.txt
.include Diode_1N914.txt

vin 1 0 sin(0 5 1k)

.subckt hwr_b 1 4 0
va 13 0 15
vb 14 0 -15
x1 0 2 a b 3 ua741
r1 1 2 10k
r2 2 4 10k
d1 3 2 1N914
d2 4 3 1N914
.ends
```

```
x1 1 4 0 hwr_b
r1 1 5 10k
r2 4 5 5k
r3 5 6 10k
r4 6 0 1k
x2 0 5 13 b 6 ua741
vb 14 0 -15
va 13 0 15

.tran 0.001ms 10ms
.control
run

plot v(1) v(6)

.endc
.end
```

3.2 Simulation results

3.2.1 Half-wave Precision Rectifier - type A

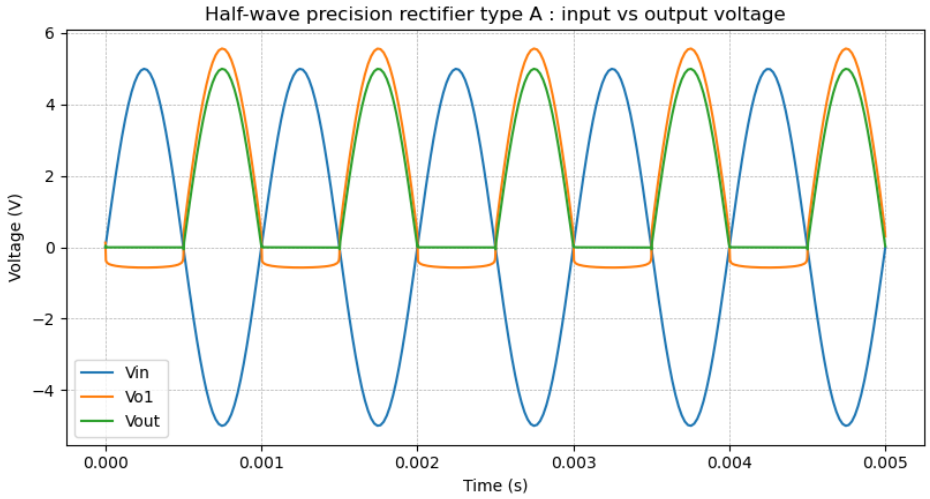

Figure 4: Half-wave Precision Rectifier - type A : Output Voltage

3.2.2 Theoretical explanation

Case 1: $V_{in} > 0$
During the positive input cycle $V_{in} > 0$, the output of the op-amp is negative. This implies that the diode D_1 is forward biased.

$$\therefore V_{o1} = -0.7V \tag{1}$$

$\therefore$D$_2$ is reversed biased.
Therefore, the **output voltage is 0V**.

Case 2: $V_{in} < 0$
During the negative input cycle $V_{in} < 0$, the output of the op-amp is positive. This implies that the diode D_1 is reversed biased and diode D_2 is forward biased.

Therefore the output voltage in this case is:

$$\therefore V_o = -\frac{R_2}{R_1} V_{in} \tag{2}$$

Thus, we get a positive output during the negative half cycle.

3.2.3 Half-wave Precision Rectifier - type B

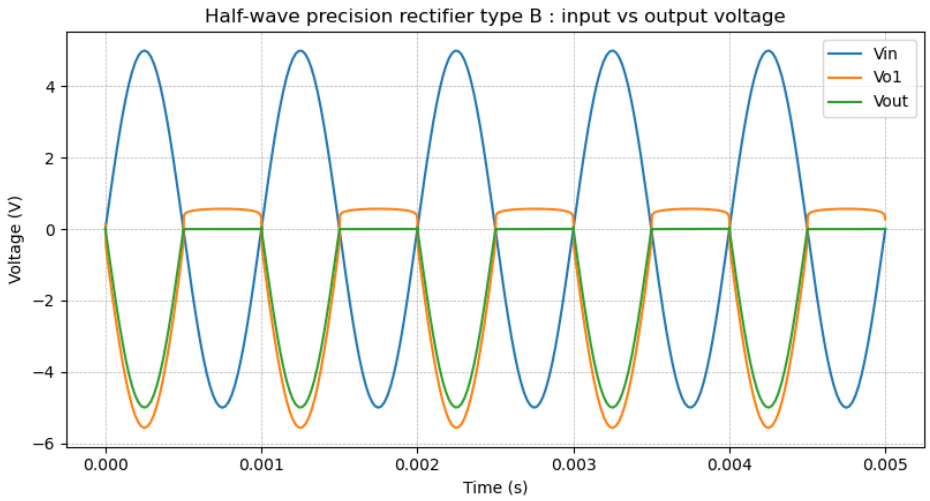

Figure 5: Half-wave Precision Rectifier - type B : Output Voltage

3.2.4 Theoretical explanation

The analysis for Half-wave Precision Rectifier - type B is similar to type A analysis.
In this case, the orientation of the diodes is reversed as compared to type A. So by a similar analysis we can conclude that, the output voltage is 0V for the negative half cycle of the input ($V_{in} > 0$).
For the positive half cycle, the circuit acts as an inverting gain amplifier, with the output voltage being

$$V_o = -\frac{R_2}{R_1} V_{in} \tag{3}$$

Thus, the output voltage is negative for a positive half cycle.

3.2.5 Full-wave Precision Rectifier

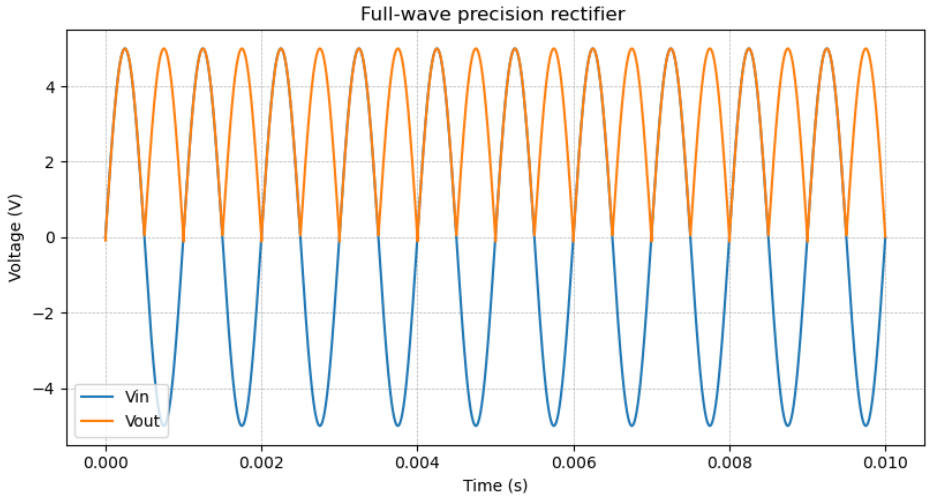

Figure 6: Full-wave Precision Rectifier : Output Voltage

3.2.6 Theoretical explanation

The inverting summer has two input terminals - one of them is connected to the input voltage V_i and the other is connected to the output from the half-wave rectifier (type B).
Case 1 : $V_{in} > 0$
When $V_{in} > 0$ the output voltage from the half-wave rectifier is **negative**.
One of the terminals of the inverting summer is the negative output from the half wave rectifier and the other terminal is the input voltage V_{in}.
By performing KCL and KVL on the inverting terminal of the inverting summer, we get that $V_o = V_{in}$ for this case.
Case 2 : $V_{in} < 0$
When $V_{in} < 0$ the output voltage from the half-wave rectifier is **zero**.
One of the terminals of the inverting summer is the zero output from the half wave rectifier and the other terminal is the input voltage V_{in}.
By performing KCL and KVL on the inverting terminal of the inverting summer, we get that $V_o = V_{in}$ for this case.

Thus, we get the output as shown in the figure 6 above.

4 Comparison with Experimental results

4.1 Half-wave Precision Rectifier - type A

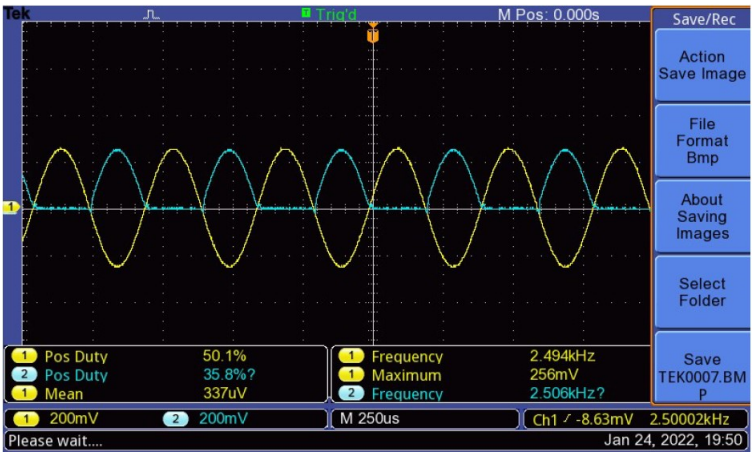

Figure 7: Half-wave Precision Rectifier - type A : Experimental results

4.2 Half-wave Precision Rectifier - type B

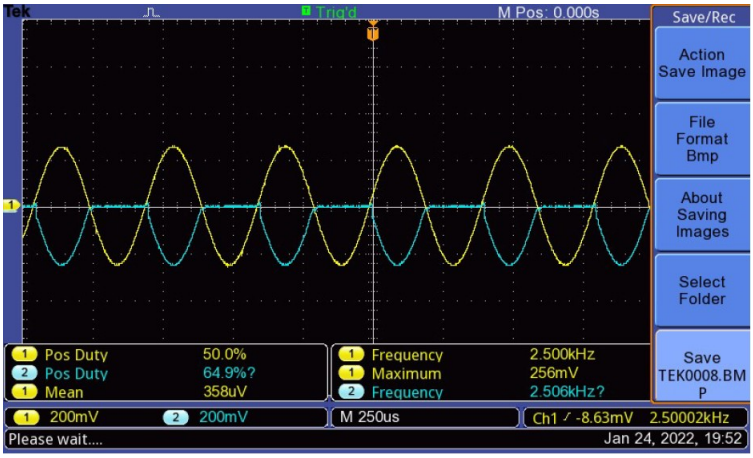

Figure 8: Half-wave Precision Rectifier - type B : Experimental results

4.3 Full-wave Precision Rectifier

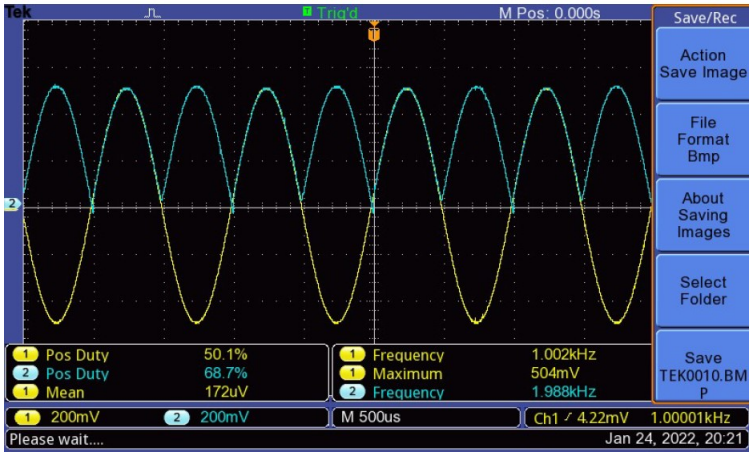

Figure 9: Full-wave Precision Rectifier : Experimental results

From the sections 3.2.1, 3.2.3 and 3.2.5 observe that the experimental and the simulations results are consistent. Thus, our simulations were in accordance with the theoretical analysis done in the sections 3.2.2, 3.2.4 and 3.2.6.