INTRODUCTION TO ELECTRONICS LAB EC29003 EXPERIMENT 03

STUDY ON RECTIFIERS AND POWER SUPPLY

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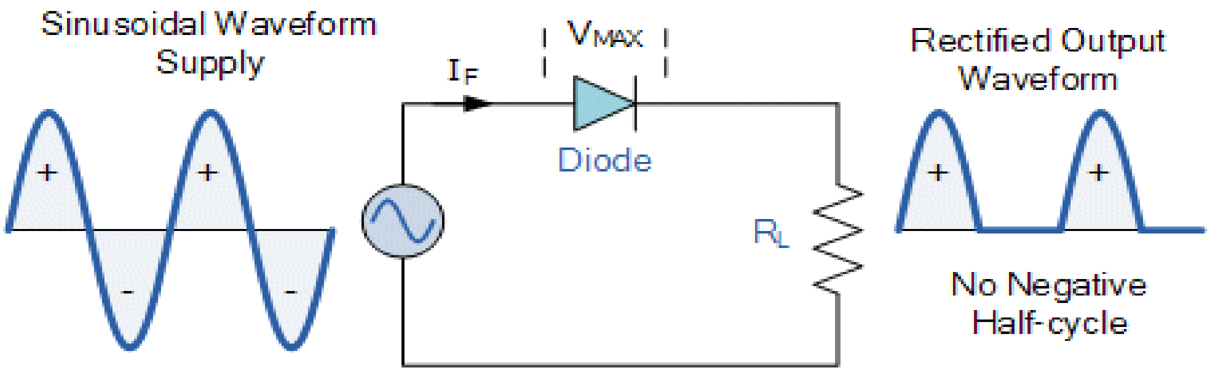
EXPERIMENT O3

STUDY ON RECTIFIERS AND POWER SUPPLY

AIM: To study half-wave rectification and full-wave bridge rectification and experimentally determining some important parameters from the output waveform. To study the use of filter on a full-wave rectified output. To study Zener regulation.

THEORY:

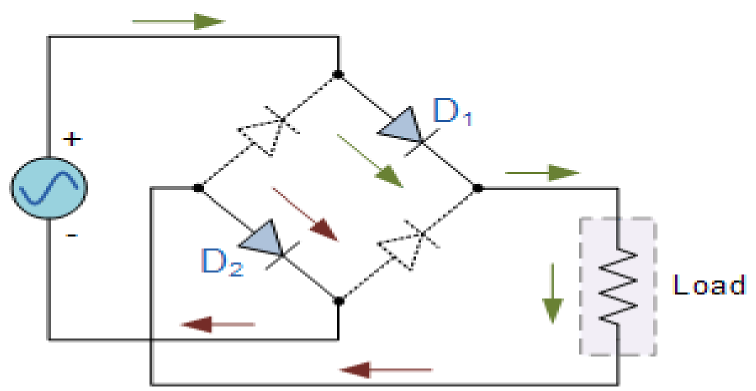
When the diode is forward biased, it is on and conducts current which produces an output voltage taken across the load resistance. During the negative half of the cycle, the diode turns off and the potential drop across the load drops to zero. Therefore, a rectified voltage output is obtained as shown below.



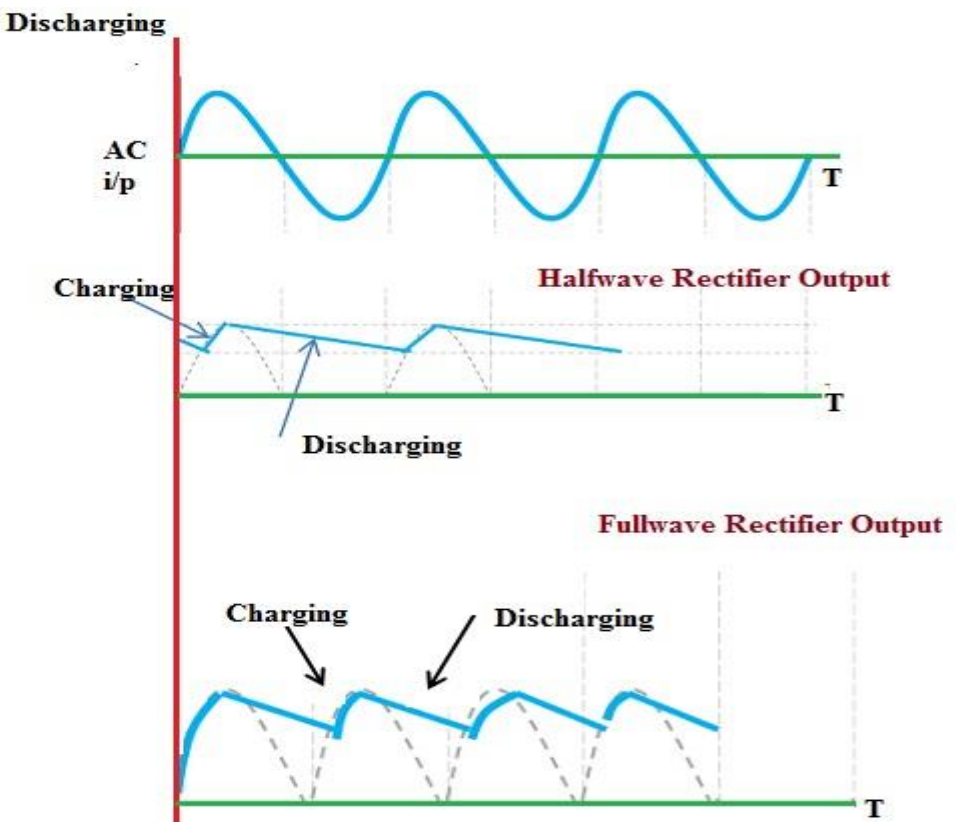
A full wave rectifier is twice as efficient as the half wave rectifier because it does not clip the input voltage that is in the negative half of the cycle.

$$\eta\ (efficiency) = \frac{{V_{dc}}^2}{{V_{rms}}^2}$$

The average value of the DC output voltage is twice of that in the case of half wave rectifier and rms value of the AC input voltage is 1.414 times of that for the half wave rectifier.



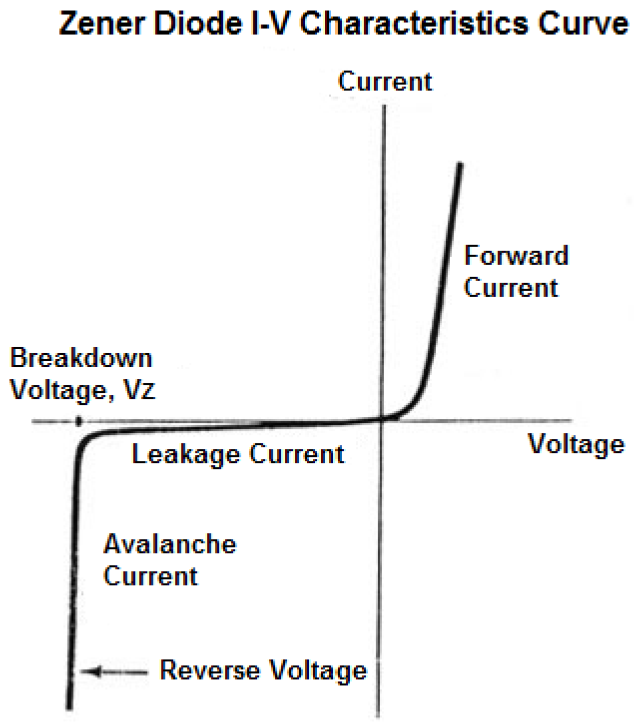
The voltage obtained from the rectifier is passed through a filter. The capacitor initially charges to the peak value of the rectified input. The diode turns off immediately when the input voltage starts to decrease from its peak value and then the output voltage decreases exponentially with time. During the next cycle of the input voltage, there is a point when the input voltage is greater than the capacitor voltage causing the diode to turn back on. The continuous charging and discharging of capacitor maintain a nearly regular potential difference across the capacitor, hence reducing the ripple factor and bringing the input voltage closer to DC voltage.



The graph shows the filtered output for a half-wave and a full-wave rectified input. The ripple factor for a half-wave rectified input is more than that for a full-wave rectified input. Therefore, when a full wave rectified input is used, the filtered output voltage waveform looks closer to DC than in the case of half-wave rectified input. The ripple voltage for a full-wave rectified input is as follows.

$$V_{ripple} = \frac{V_{max-out}}{2fRC}$$

Following are the I-V characteristics of a diode. When the reverse bias voltage reaches the reverse breakdown voltage, the potential drop across the diode remains constant for any value of current. Zener diode operates in the reverse breakdown region. To make the reverse breakdown voltage practically attainable it is heavily doped to reduce its value.

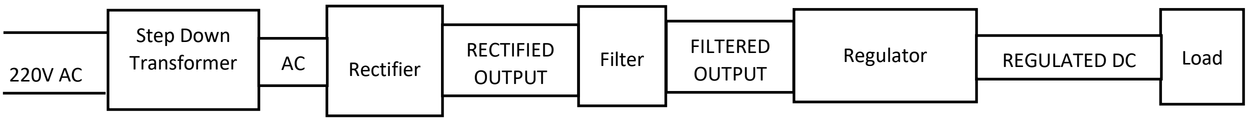


The filtered output obtained from the filter can be fed, along with some series resistance, to a Zener diode connected in parallel to a load resistor. If the voltage is taken across the Zener diode, it will come out to be constant. Practically, some small variations might be observed due to internal resistance of the Zener diode. Figures of merit like source regulation and load regulation can account for those shortcomings and hence the values of the parameters can be adjusted to obtain a DC output within some range of approximation.

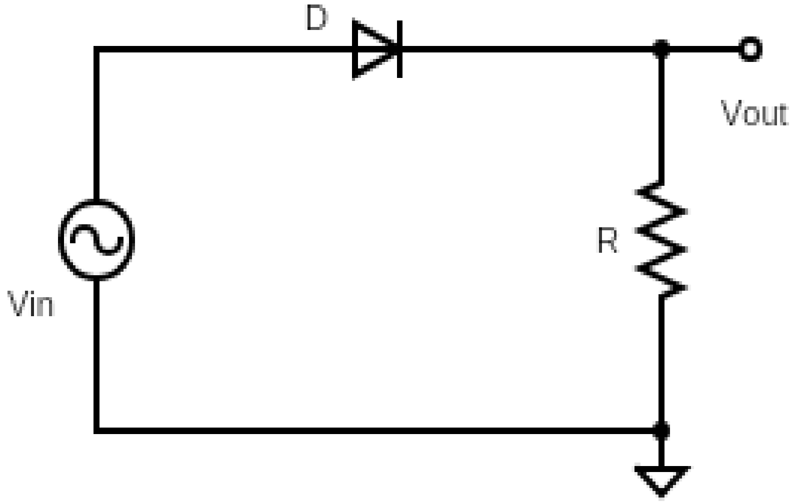
$$Source\ Regulation\ S.R. = \frac{\Delta V_{out}}{\Delta V_{in}} * 100$$

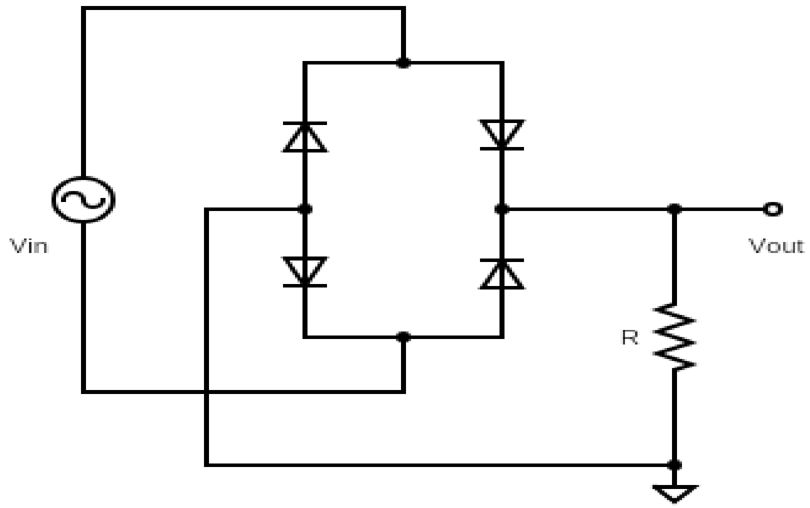
$$Load\ Regulation\ L.R. = \frac{V_{out,no-load} - V_{out,full-load}}{V_{out,full-load}} * 100$$

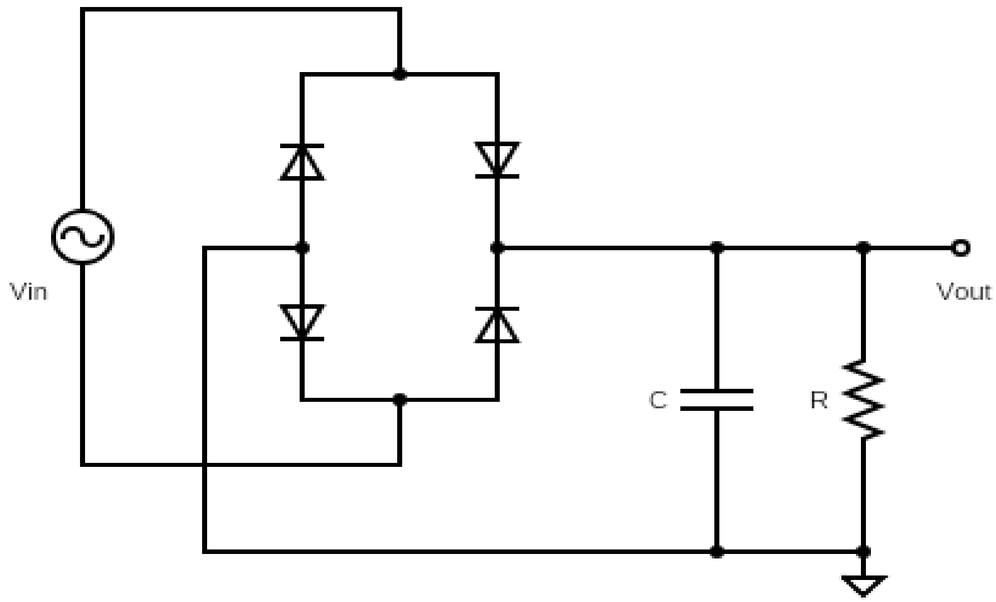
POWER SUPPLY BLOCK DIAGRAM:

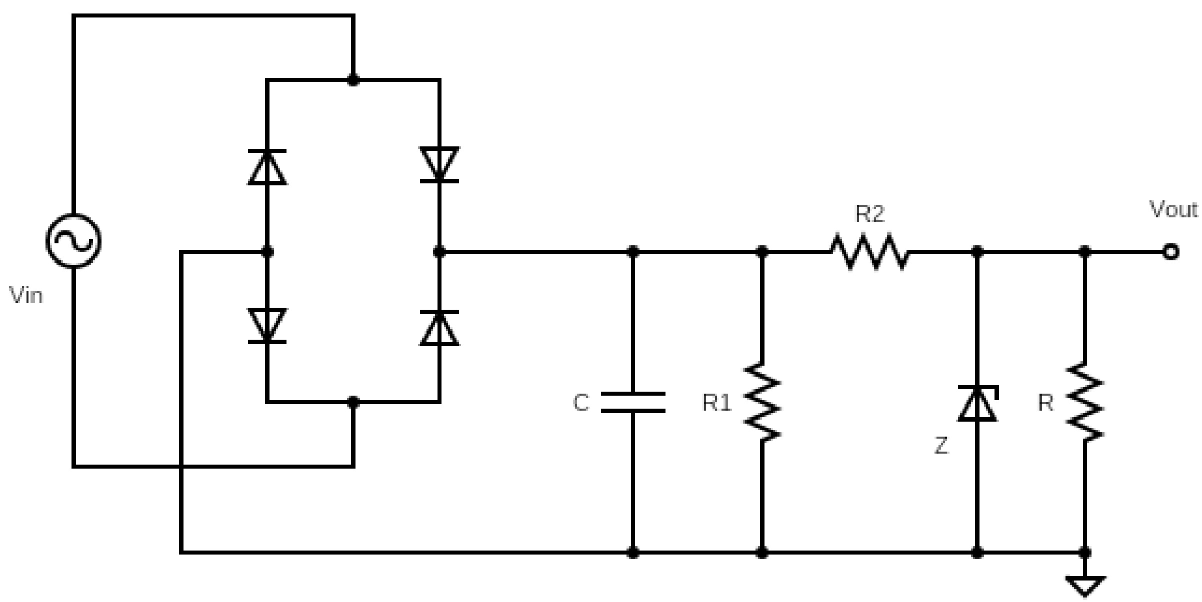


CIRCUIT DIAGRAMS:




Vin
Vout
R

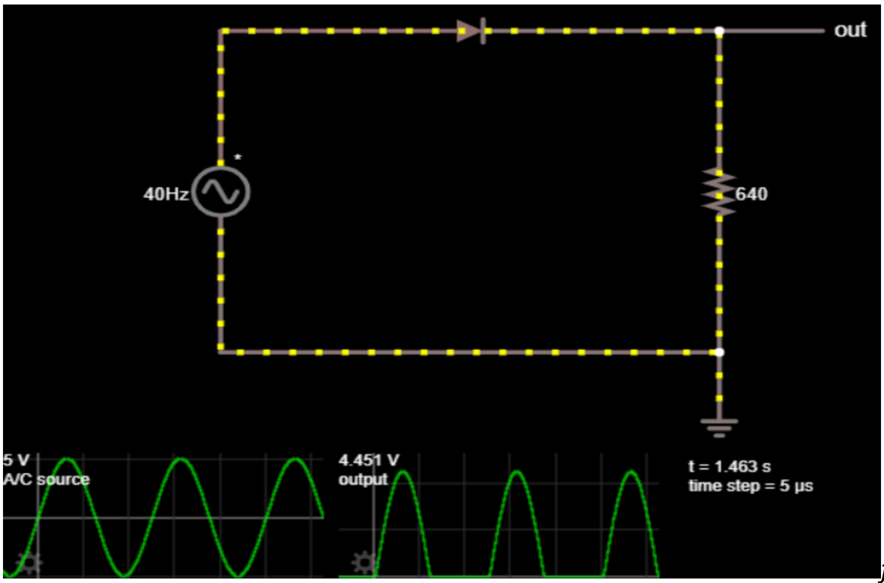

Vin
Vout
C
R


Vin
R2
Vout
C
R1
Z
R

PROCEDURE:

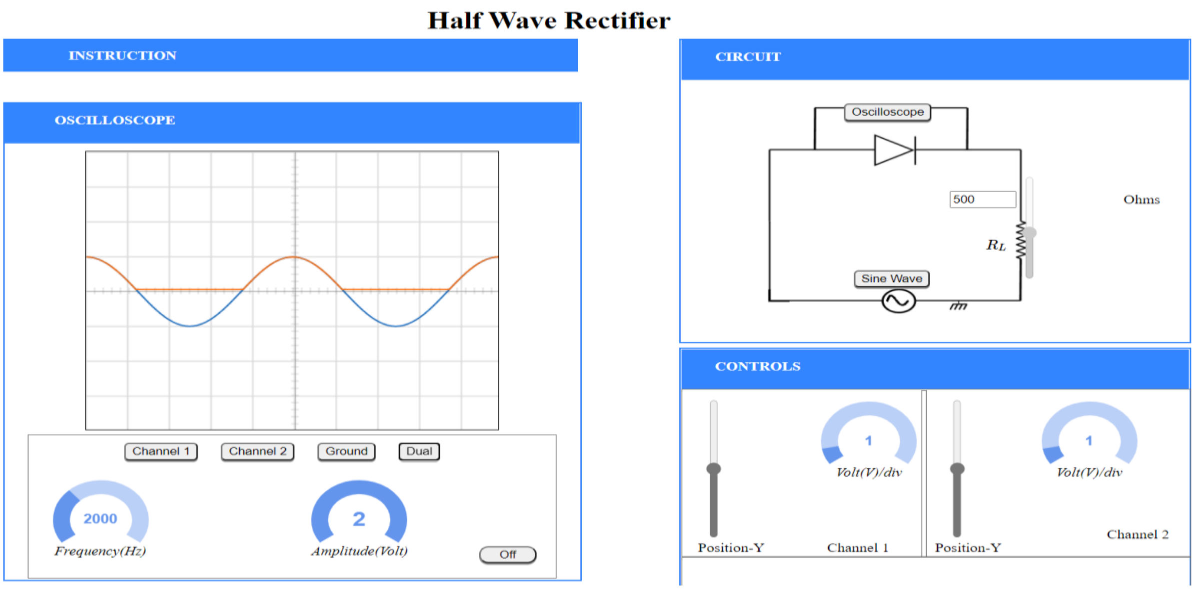
HALF WAVE RECTIFIER –

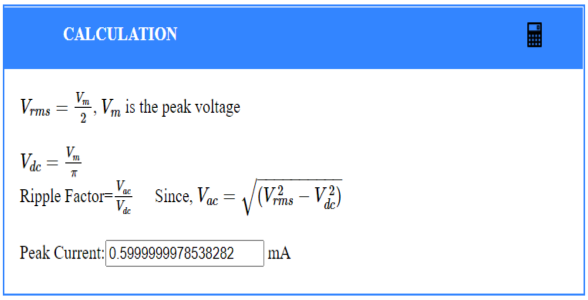
- A load resistance was connected in series with a diode with an AC voltage source as shown in the first circuit diagram.
- The drop across the load resistor was taken and the waveform of this output voltage was observed.

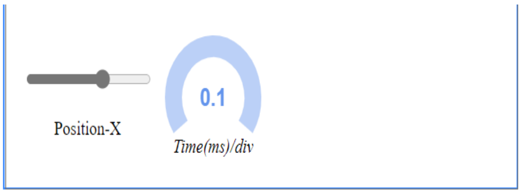


from Falstad

- The output waveform was noted as the half-rectified output of the input waveform.
- The waveform was analysed to find the values of V_γ (knee voltage of the diode) , PIV (peak inverse voltage) , V_{dc} , V_{rms} , V_{r-rms} (ripple voltage), r (ripple factor) and η (efficiency).
- The simulation on *Virtual Labs* is shown as below.

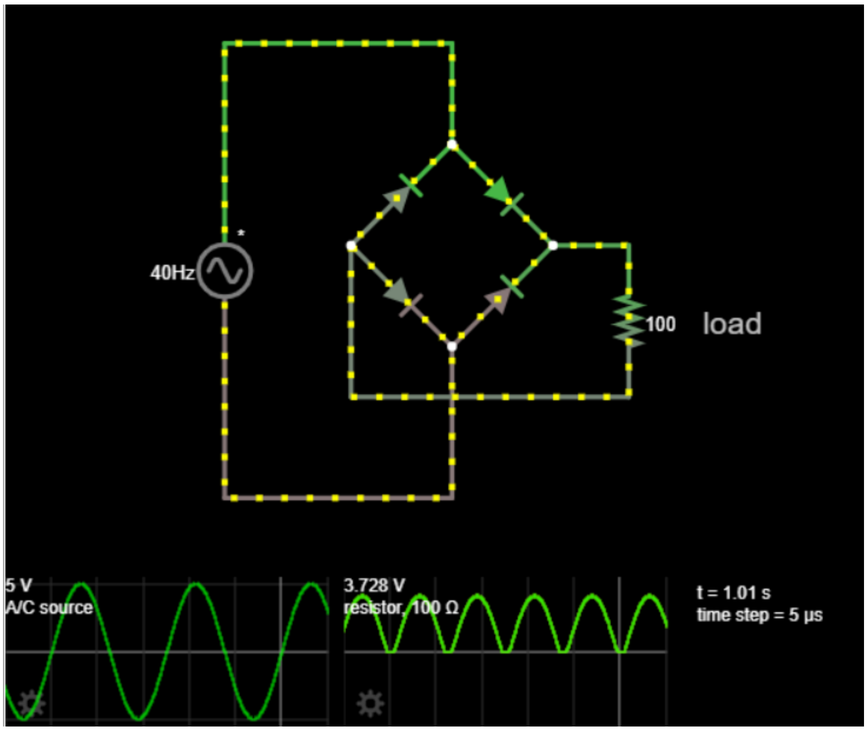






FULL WAVE RECTIFIER –

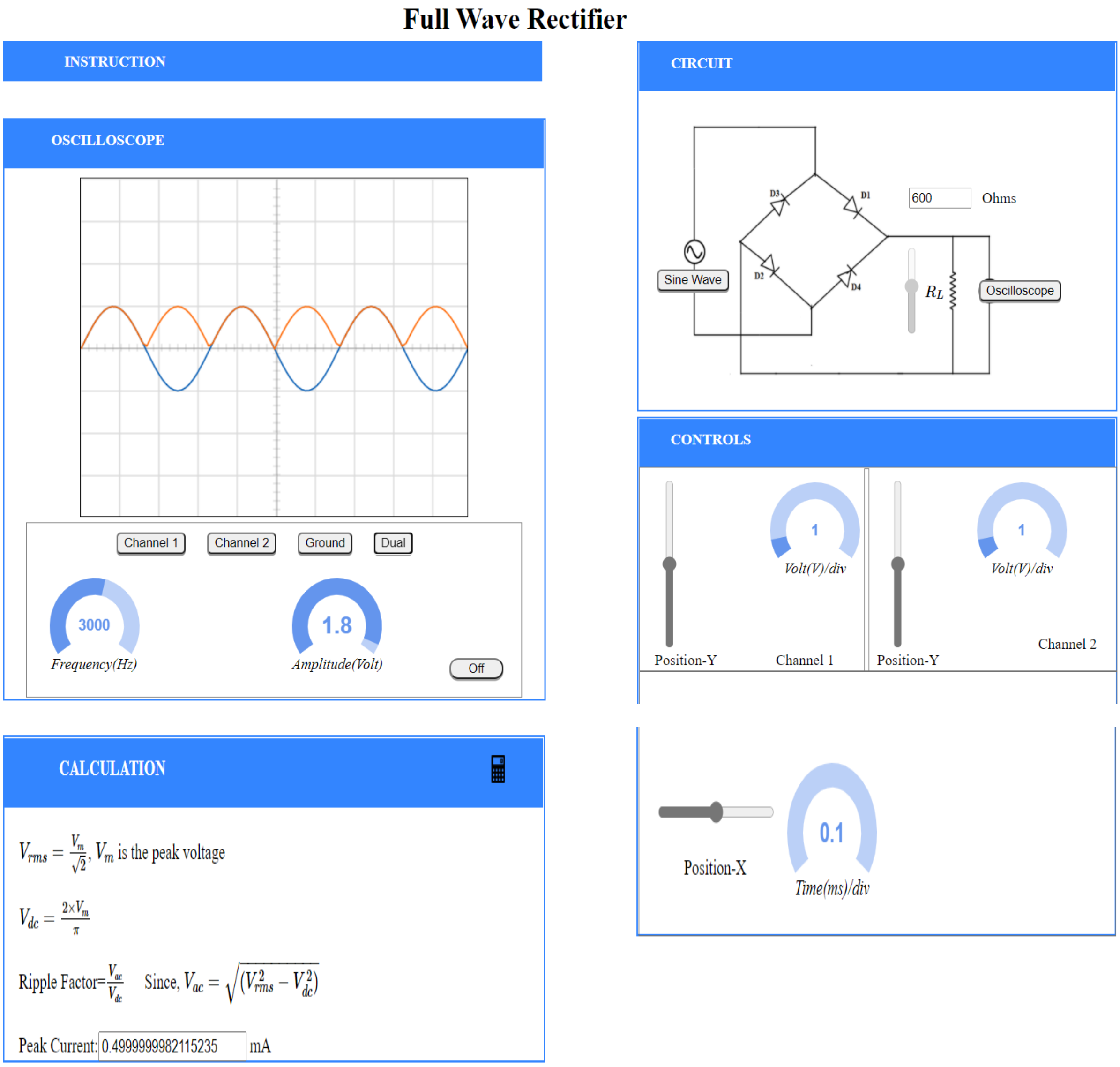
- A load resistance was connected across a bridge rectifier as shown in the second circuit diagram.
- The drop across the load resistor was taken and the waveform of this output voltage was observed.



from Falstad

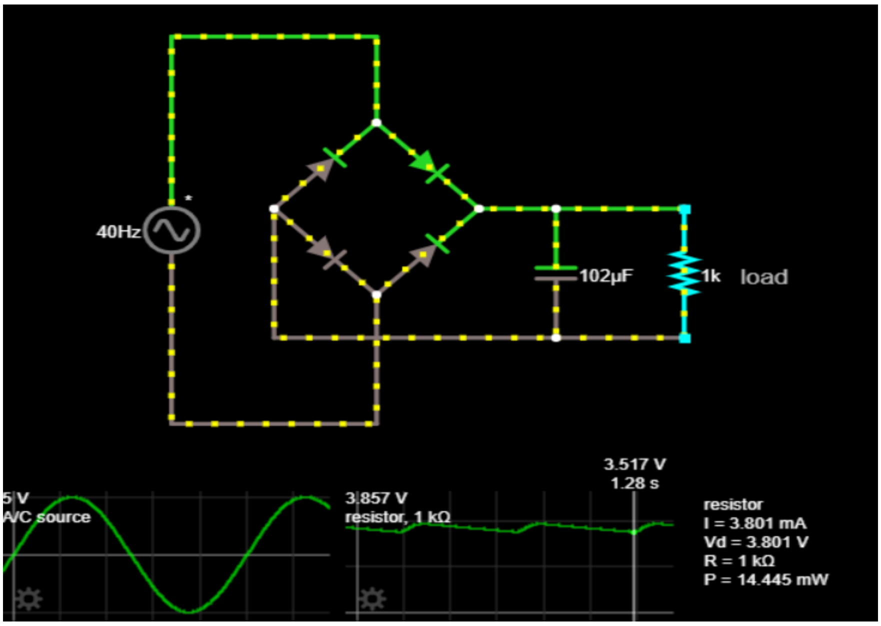
- The output waveform was noted as the full rectified output of the input waveform.
- The waveform was analysed to find the values of V_γ (knee voltage of the diode) , PIV (peak inverse voltage) , V_{dc} , V_{rms} , V_{r-rms} (ripple voltage), r (ripple factor) and η (efficiency).
- These values were compared with the values obtained for the half wave rectifier.

- The simulation on *Virtual Labs* is shown as below.



FULL WAVE RECTIFIER WITH FILTER –

- A capacitance was connected across a bridge rectifier as shown in the third circuit diagram. A load resistance was then connected in parallel with the capacitance. The product RC (product of values of resistance and capacitance connected in parallel across the bridge rectifier) was kept much higher than the time period of the full-rectified output waveform. (Here it was kept four times the time period)
- The drop across the load resistor was taken and the waveform of this output voltage was observed.



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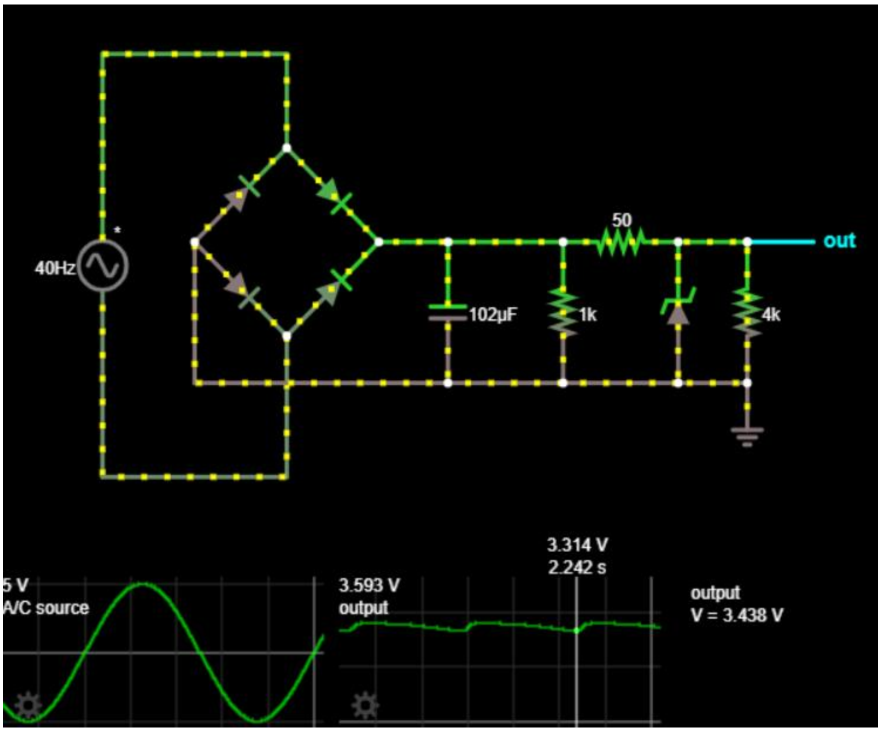
- The waveform was analysed to find the value of ripple voltage V_r. This value was then compared with the theoretically calculated value.

ZENER DIODE REGULATION –

- A capacitance was connected across a bridge rectifier as shown in the third circuit diagram. A load resistance was then connected in parallel with the capacitance. The product RC (product of values of resistance and capacitance connected in parallel across the bridge rectifier) was kept much higher than the time period of the full-rectified output waveform. (Here it was kept four times the time period)
- A Zener voltage regulator was connected in cascade with the load resistor as shown in the fourth circuit diagram. The Zener breakdown voltage was chosen to be a little less than the minimum output voltage obtained in the previous experiment.
- The potential drop across the load resistance connected in parallel to the Zener diode was taken and the output waveform was observed.
- The value of ripple voltage V_r was deduced and compared with the value obtained in the previous experiment without the Zener diode.



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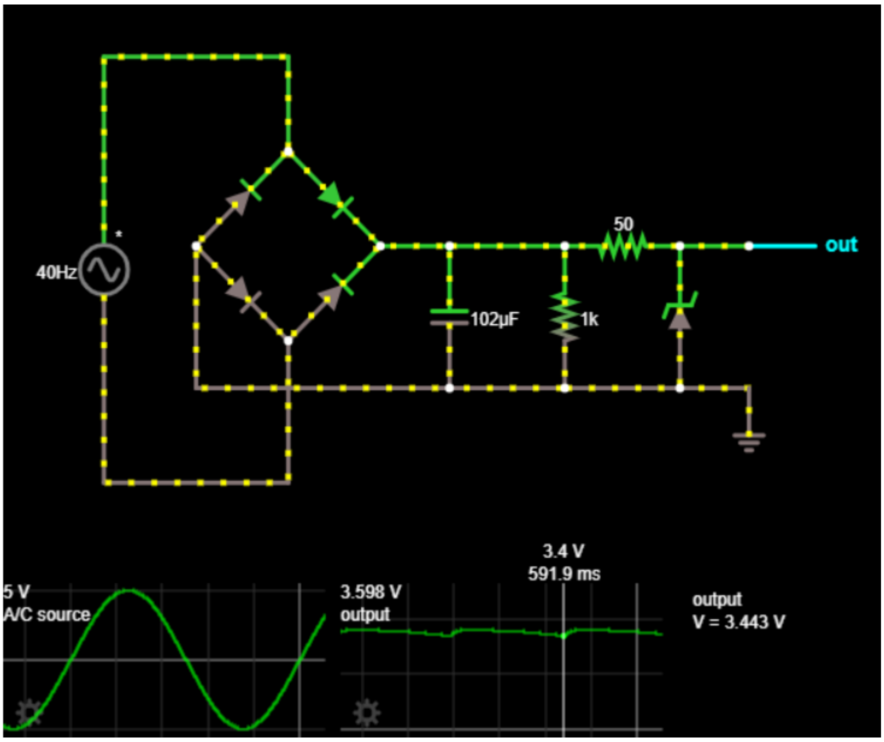
- Next, the load resistance was removed to produce a no-load condition. The values of no-load voltage V_{NL} and the full-load voltage V_{FL} were used to calculate the voltage regulation.



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CALCULATIONS AND OBSERVATIONS:

HALF WAVE RECTIFIER –

From the topology of the output waveform the following deductions can be made-

1) $V_{m-out} = 4.451V \quad for \;\; V_{m-in} = 5V$
2) $V_{out} \; is \; 0V \; for \; half \; of \; the \; time \; period$

Using Kirchhoff's Voltage Loop rule, $V_{m-out} = V_{m-in} - V_{\gamma}$, where V_{γ} is the cut-in or the knee voltage of the diode.

$$V_{\gamma} = V_{m-in} - V_{m-out} = 5 - 4.451 = 0.549\,V$$

$$PIV \; (\, peak - inverse \; voltage \,) = V_{m-in} = 5V$$

$$V_{dc} = \frac{V_{m-out}}{\pi} = \frac{4.451}{\pi} = 1.417\,V$$

$$V_{rms} = \frac{V_{m-out}}{2} = \frac{4.451}{2} = 2.225\,V$$

$$\eta \; (\, efficiency \,) = \frac{{V_{dc}}^2}{{V_{rms}}^2} = \frac{1.417^2}{2.225^2} = 40.56\,\%$$

$$V_{r-rms} = \sqrt{{V_{rms}}^2 - {V_{dc}}^2} = \sqrt{2.225^2 - 1.417^2} = 1.715V$$

$$r \; (\, ripple \; factor \,) = \frac{V_{r-rms}}{V_{dc}} = \frac{1.715}{1.417} = 1.210$$

FULL WAVE RECTIFIER –

From the topology of the output waveform the following deductions can be made-

1) $V_{m-out} = 3.728V \quad for \;\; V_{m-in} = 5V$
2) $V_{out} \; is \; positive \; throughout \; the \; time \; period$

Using Kirchhoff's Voltage Loop rule, $V_{m-out} = V_{m-in} - 2 * V_{\gamma}$, where V_{γ} is the cut-in or the knee voltage of the diode.

$$V_{\gamma} = (V_{m-in} - V_{m-out})/2 = (5 - 3.728)/2 = 0.636\,V$$

$PIV\ (\ peak - inverse\ voltage\ ) = \ V_{m-in} - \ V_{\gamma} = 5 - 0.636 = 4.364V$

$$V_{dc} = \frac{2 * V_{m-out}}{\pi} = \frac{2 * 3.728}{\pi} = 2.373\ V$$

$$V_{rms} = \frac{V_{m-out}}{\sqrt{2}} = \frac{3.728}{\sqrt{2}} = 2.636\ V$$

$$\eta\ (\ efficiency\ ) = \frac{{V_{dc}}^2}{{V_{rms}}^2} = \frac{2.373^2}{2.636^2} = \ 81.04\ \%$$

$$V_{r-rms} = \ \sqrt{{V_{rms}}^2 - \ {V_{dc}}^2} = \ \sqrt{2.636^2 - \ 2.373^2} = 1.148V$$

$$r\ (\ ripple\ factor\ ) = \frac{V_{r-rms}}{V_{dc}} = \frac{1.148}{2.373} = 0.484$$

COMPARISON BETWEEN HALF WAVE AND FULL WAVE RECTIFIER –

1) The full wave rectifier is twice as efficient as the half wave rectifier. This is because half of the input voltage in the half-wave rectifier gets wasted and is not used to produce any output voltage.
2) The ripple factor of full-wave rectifier is half that of the half-wave rectifier. This is because the full-wave rectified output is positive throughout the time period whereas the half wave rectifier is zero for half of the time period.
3) The PIV in the full wave rectifier is less than that in the half wave rectifier. This enables the full wave rectifier to be used even with the diodes that have the inverse breakdown voltage somewhat less than the maximum input voltage.

FULL WAVE RECTIFIER WITH FILTER –

From the topology of the output waveform the following deductions can be made-

1) $V_{max-out} = 3.857V$
2) $V_{min-out} = 3.517V$
3) $V_{out}\ waveform\ is\ closer\ to\ a\ DC\ voltage\ waveform$

$$V_{r-practical} = V_{max-out} - V_{min-out} = 3.857 - 3.517 = 0.340\ V$$

$$V_{r-theoretical} = \frac{V_{max-out}}{2fRC} = \frac{3.857}{2 * 40 * 10^3 * 102 * 10^{-6}} = 0.473\ V$$

$$error = \frac{V_{r-theoretical} - V_{r-practical}}{V_{r-theoretical}} = \frac{0.473 - 0.340}{0.473} = 28.12\ \%$$

ZENER DIODE REGULATION –

From the topology of the output waveform the following deductions can be made-

1) $V_{max-out}(with\ load) = V_{FL} = 3.593V$
2) $V_{min-out}(with\ load) = 3.314V$
3) $V_{max-out}(no\ load) = V_{NL} = 3.598V$
4) $V_{min-out}(no\ load) = 3.400V$
5) $V_{out}\ waveform\ is\ closer\ to\ a\ DC\ voltage\ waveform\ with\ a\ Zener\ diode.$

$$V_{r-zener}(full\ load) = V_{max-out} - V_{min-out} = 3.593 - 3.314 = 0.279\ V$$

$V_{r-zener} < V_{r-practical}(without\ Zener\ diode)$; this implies that Zener diode reduces the ripple voltage and brings the output waveform even closer to the DC voltage waveform.

$$V.R.(Voltage\ Regulation) = \frac{V_{NL} - V_{FL}}{V_{FL}} = \frac{3.598 - 3.593}{3.593} = 0.14\ \%$$

DISCUSSION:

In this experiment the conversion of AC to DC voltage was studied. The experiment was successful in verifying various results and equations formulated theoretically for rectifiers and regulators. The comparisons drawn between the half wave and the full wave rectifiers on the basis of the experimental observations are in direct congruence with the theoretical facts. The ripple voltage is seen to decrease significantly upon filtration and regulation. Moreover, the value of voltage regulation figure of merit for the Zener diode regulation comes out to be very small establishing the nearly DC behaviour of the output voltage.