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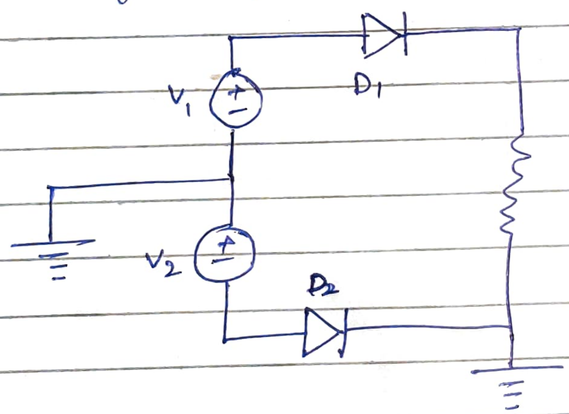
EC160 : Experiment 5
Full Wave Rectification

Objective :- (i) Explain Rectification.
(ii) Explain center tapped full wave rectification
(iii) Explain Bridge full wave rectification

Theory :- **Full wave Rectifier** :- A full wave rectifier allows unidirectional current through the load during the entire sinusoidal cycle. A full-wave rectifier converts the whole of the input waveform to one of constant polarity

The circuit for a full wave rectifier is



So, the rectifier circuit consists of two sources which have a phase difference along with two diodes. When V_1 is positive, V_2 is negative. Hence, the top diode (D_1) will be a short and bottom diode (D_2) will be an open. On the other hand, when V_1 is negative V_2 is positive. Hence, the bottom diode (D_2) will be short and the top diode (D_1) will be an open circuit.

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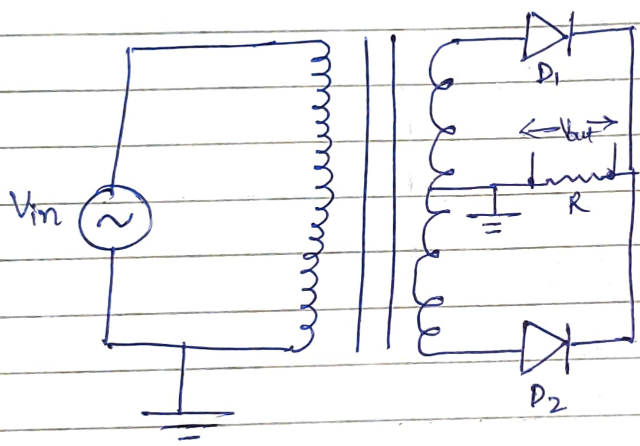
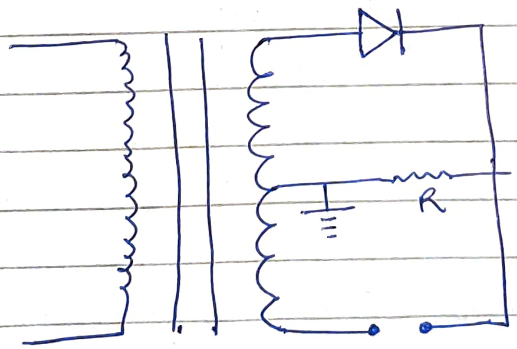
Full Wave Rectifier - Center Tapped Transformer:-

A full wave rectifier can be constructed using center-tapped transformer which gives us two shifted sinusoids so that exactly one of the waveforms is positive at one time. At any point of time, only one of the diodes is forward biased. This allows for continuous conduction through load.

The circuit for such a full-wave rectifier is



In positive cycle, the equivalent circuit is



Diode D_1 is forward biased hence it will short and diode D_2 is reverse biased hence it will be open-circuited.

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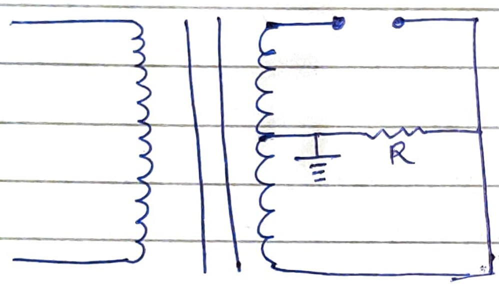
Applying KVL

$$V_{in} - V_{out} = 0$$
$$\therefore V_{out} = V_{in}$$

In negative cycle, diode D_1 is reverse biased and diode D_2 is forward biased, hence the equivalent circuit is



$$\therefore V_{in} - V_{out} = 0$$
$$V_{out} = V_{in}$$

Full-Wave Rectifier - Bridge Rectifier

Bridge rectifier uses 4 rectifying diodes connected in a "bridged" configuration to produce the desired output but does not require a special centre tapped transformer, thereby reducing its size and cost. The single secondary winding is connected to one side of the diode bridge network and the load to other side

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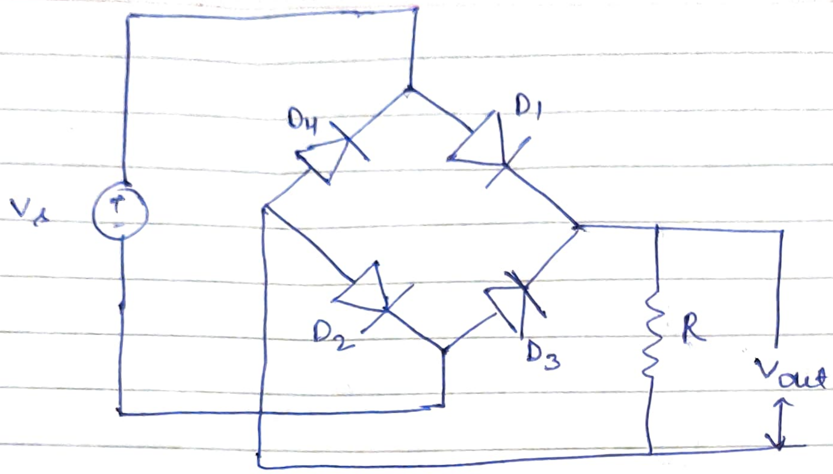
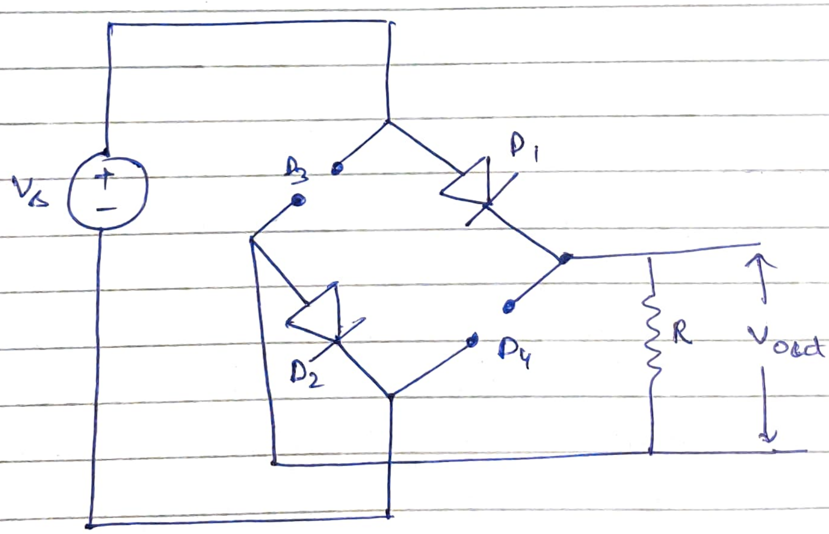


During the positive half cycle, the diodes D_1 and D_2 conduct in series while diodes D_3 and D_4 are reverse biased. The equivalent circuit is, therefore



$\therefore$ $V_{in} - V_{out} = 0$

$V_{out} = V_{in}$

V_{in} is input voltage

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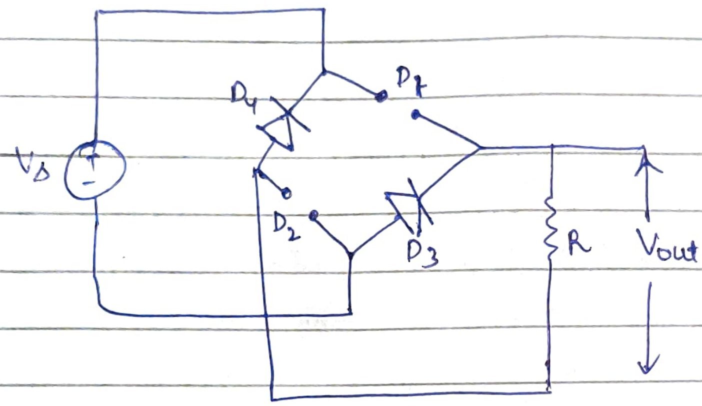
During the negative half-cycle, diodes D_3 and D_4 conduct in series, but diodes D_1 and D_2 switch off as they are now reverse biased. The current flowing through the load is in same direction as before.

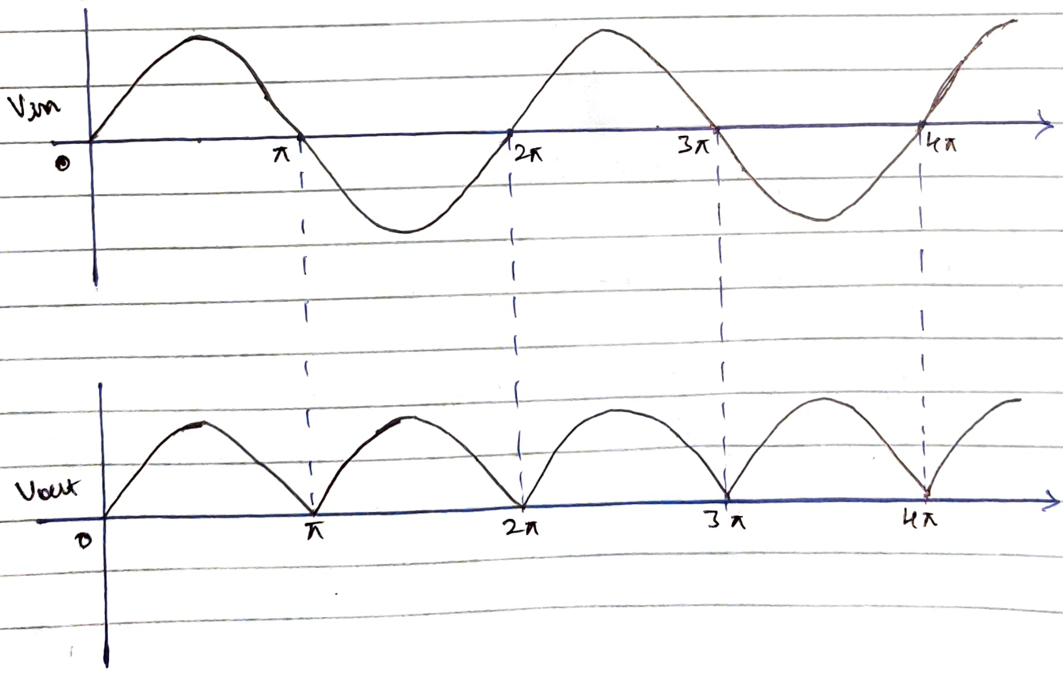


For negative cycle again

$$V_{out} - V_{in} = 0$$

$$\therefore V_{out} = V_{in}$$

Waveforms in case of an full-wave rectifier are given below.



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Mathematical Expressions

For an ideal full wave rectifier

$$V_{output} = \begin{cases} V_{input} & \text{for positive half-cycle} \\ -V_{input} & \text{for negative half-cycle} \end{cases}$$

$$V_{output} = \begin{cases} V \sin \omega t & \text{for positive half cycle} \\ -V \sin \omega t & \text{for negative half cycle} \end{cases}$$

- Average Output Voltage :- It is the average voltage across the load for one cycle.

$$\therefore \quad V_{avg} = \frac{\int_0^{\pi} V \sin\theta \, d\theta + \int_{\pi}^{2\pi} -V \sin\theta \, d\theta}{2\pi}$$

$$V_{avg} = \frac{-V\left[(\cos\theta)\right]_0^{\pi} + V\left[(\cos\theta)\right]_{\pi}^{2\pi}}{2\pi}$$

$$= \frac{2V + 2V}{2\pi}$$

$$= \frac{2V}{\pi}$$

$$V_{avg} = 0.636\,V$$

- RMS load Voltage :-

$$V_{rms} = \sqrt{\frac{\int_0^{\pi} V^2 \sin^2\theta \, d\theta + \int_{\pi}^{2\pi} V^2 \sin^2\theta \, d\theta}{2\pi}}$$

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$$V_{rms} = \sqrt{\frac{\frac{V^2}{2}\int_0^{\pi}(1+\cos 2\theta)\,d\theta + \frac{V^2}{2}\int_{\pi}^{2\pi}(1+\cos 2\theta)\,d\theta}{2\pi}}$$

$$= \sqrt{\frac{V^2}{4\pi}\left\{\left(\theta + \frac{\sin 2\theta}{2}\right)\Bigg|_0^{\pi} + \left(\theta + \frac{\sin 2\theta}{2}\right)\Bigg|_{\pi}^{2\pi}\right.}$$

$$= \sqrt{\frac{V^2\cancel{\pi}}{2\cancel{\pi}}}$$

$$V_{rms} = \frac{V}{\sqrt{2}}$$

- Average Load Current

$$I_{avg} = \frac{V_{avg}}{R}$$

$$= \frac{0.636\,V}{R}$$

- RMS load current →

$$I_{RMS} = \frac{V_{rms}}{R}$$

$$= \frac{V}{\sqrt{2}R}$$

- Form Factor :- It is defined as ratio of rms load voltage and average load voltage.

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$$\text{Form Factor (FF)} = \frac{V_{rms}}{V_{avg}}$$

$$= \frac{\frac{V}{\sqrt{2}}}{\frac{2V}{\pi}}$$

$$= \frac{\pi}{2\sqrt{2}}$$

$$\text{Form factor} = 1.11$$

Hence, form factor for full wave rectifier is 1.11.

- **Ripple Factor :-** Ripple factor is the ratio of RMS value of AC voltage (input voltage) and the DC voltage (output voltage) of the rectifier

$$\text{Ripple factor } (\gamma) = \sqrt{\left(\frac{V_{rms}}{V_{avg}}\right)^2 - 1}$$

$$= \sqrt{(1.11)^2 - 1}$$

$$= \sqrt{0.2321}$$

$$\gamma = 0.4817$$

Hence, ripple factor for full wave rectifier is 0.4817.

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- Efficiency :- Defined as ratio of output DC power and input AC power.

$$\text{Efficiency } (\eta) = \frac{\text{Output power}}{\text{Input power}} \times 100\%$$

$$\eta = \frac{\frac{4 I^2}{\pi^2} \cdot R}{\frac{I^2}{2} R} \times 100\%$$

$$\eta = \frac{8}{\pi^2} \times 100\%$$

$$\eta = 81.2\%$$

Hence, efficiency of full wave rectifier is 81.2 %.

- Peak Inverse Voltage :- It is the maximum voltage that the diode can withstand during reverse bias condition.

For Centre Tapped transformer full wave rectifier

$$(PIV) \geq 2V$$

But for bridge rectifier,

$$(PIV) \geq V$$

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Procedure for the experiment :-

Step 1 : Set the resistor R_L.
Step 2 : Click on 'ON' button to start the experiment.
Step 3 : Click on 'sine wave' button to generate input waveform.
Step 4 : Click on 'Osulloscope' button to get rectified output.
Step 5 : Vary amplitude, frequency, volt/div using the controllers.
Step 6 : Click on 'Dual' button to observe both waveforms. (Chanel 1 shows input waveform while chanel 2 shows output waveform).

~~Step~~

Simulation Results

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Full Wave Rectifier

INSTRUCTION

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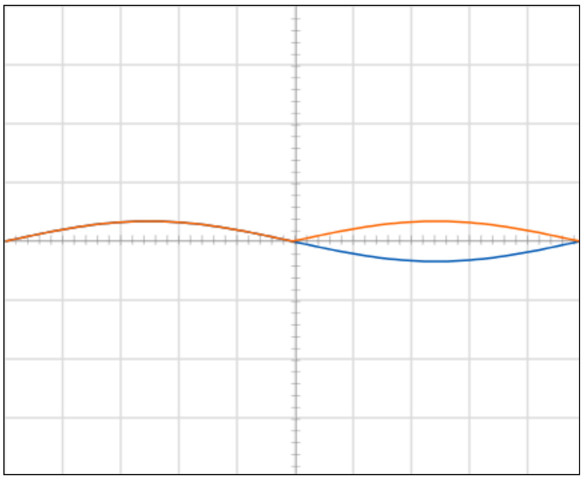


Channel 1 Channel 2 Ground Dual

1000
Frequency(Hz)

1.5
Amplitude(Volt)

CALCULATION

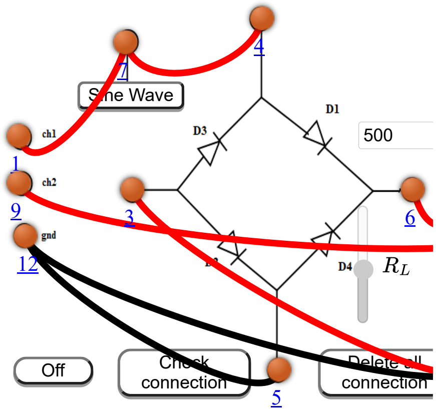
$V_{rms} = \frac{V_m}{\sqrt{2}}$, V_m is the peak voltage

$V_{dc} = \frac{2 \times V_m}{\pi}$

Ripple Factor$=\frac{V_{ac}}{V_{dc}}$ Since, $V_{ac} = \sqrt{(V_{rms}^2 - V_{dc}^2)}$

Peak Current: 0.5999999978538282 mA

CIRCUIT



CONTROLS

2.1
Volt(V)/div

Position-Y Channel 1 Position-Y

Position-X

0.1
Time(ms)/div

Full Wave Rectifier

INSTRUCTION

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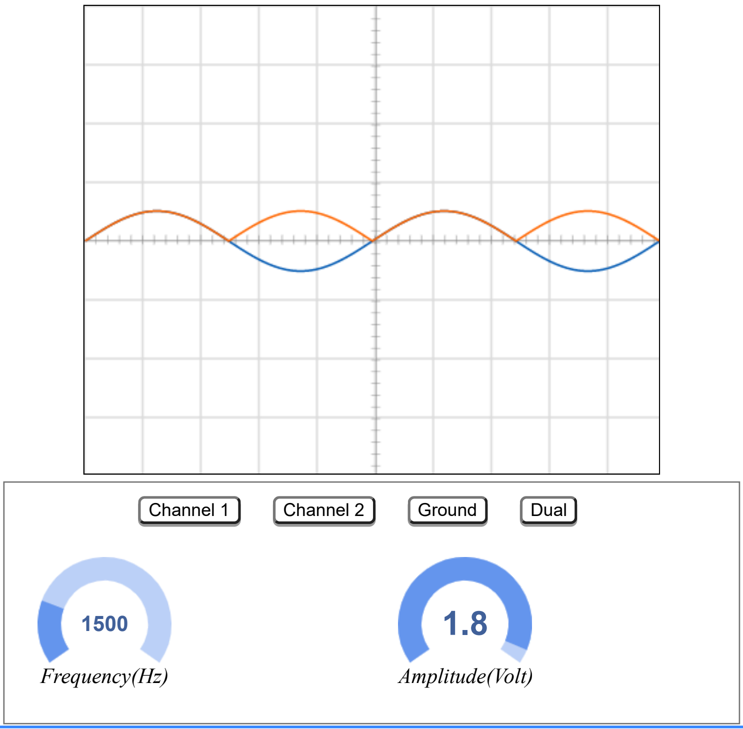
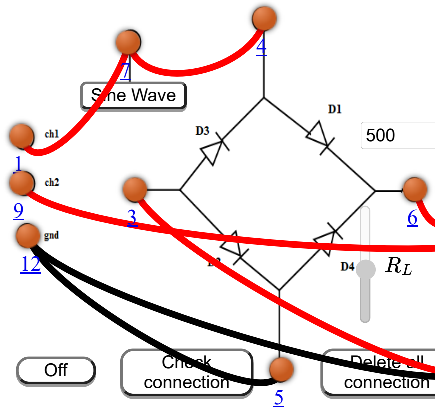
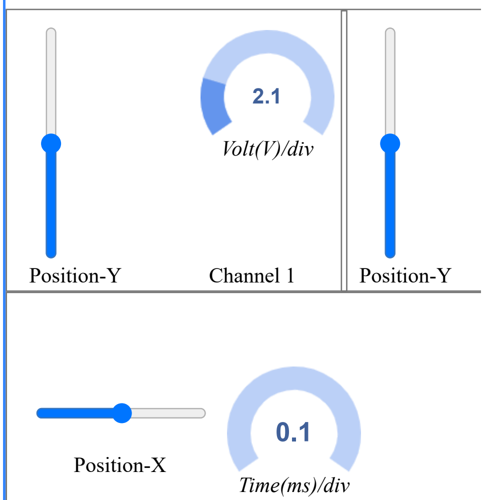


CIRCUIT



CONTROLS



CALCULATION

$V_{rms} = \frac{V_m}{\sqrt{2}}$, V_m is the peak voltage

$V_{dc} = \frac{2 \times V_m}{\pi}$

Ripple Factor=$\frac{V_{ac}}{V_{dc}}$ Since, $V_{ac} = \sqrt{(V_{rms}^2 - V_{dc}^2)}$

Peak Current: 0.5999999978538282 mA

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Full Wave Rectifier

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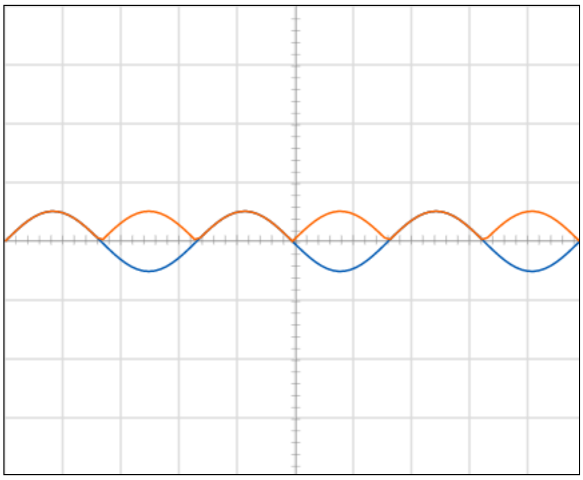

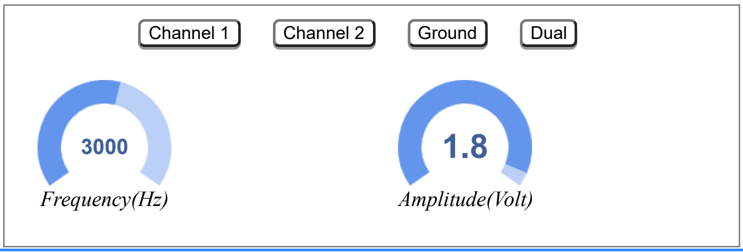

CALCULATION

$V_{rms} = \frac{V_m}{\sqrt{2}}$, V_m is the peak voltage

$V_{dc} = \frac{2 \times V_m}{\pi}$

Ripple Factor=$\frac{V_{ac}}{V_{dc}}$ Since, $V_{ac} = \sqrt{(V_{rms}^2 - V_{dc}^2)}$

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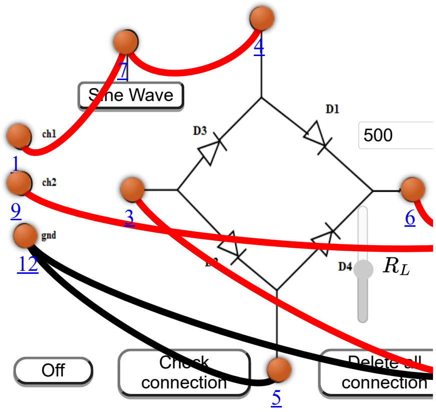
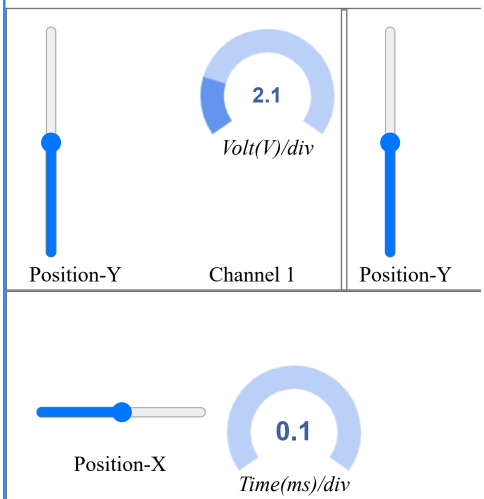
CIRCUIT



CONTROLS



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Full Wave Rectifier

INSTRUCTION

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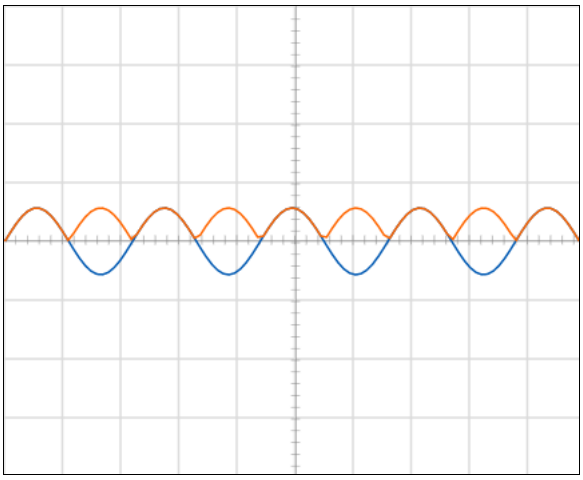


Channel 1 Channel 2 Ground Dual

4500 Frequency(Hz)

2 Amplitude(Volt)

CALCULATION

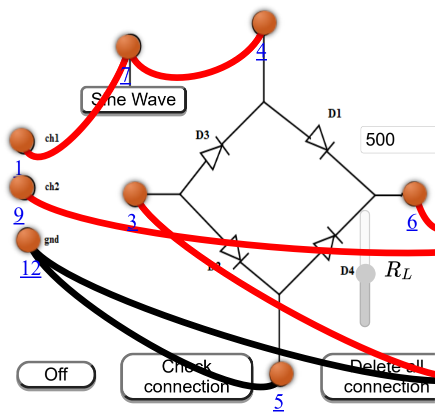
$V_{rms} = \frac{V_m}{\sqrt{2}}$, V_m is the peak voltage

$V_{dc} = \frac{2 \times V_m}{\pi}$

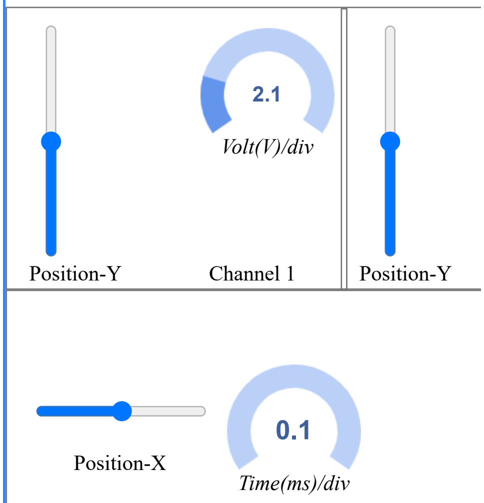
Ripple Factor=$\frac{V_{ac}}{V_{dc}}$ Since, $V_{ac} = \sqrt{(V_{rms}^2 - V_{dc}^2)}$

Peak Current: 0.5999999978538282 mA

CIRCUIT



CONTROLS



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Conclusion:- Performing the above experiment, following conclusions can be drawn,.

i) A full wave rectifier converts the input AC signal to output DC signal during all the positive and negative half-cycles.

ii) The form factor and ripple factor of a full wave rectifier are 1.11 and 0.48 respectively.

(iii) The efficiency of a full wave rectifier is 81.2%.

Quiz Performance

Full Wave Rectification

Quiz

Test Your Knowledge!!

✓ 1. What is the Ripple factor of a fullwave rectifier ?

- ○ 0.31
- ● 0.48
- ○ 0.707
- ○ 1.21

✓ 2. If the peak applied signal voltage is V_m, then for a full wave rectifier circuit(not bridge) the PIV of the diodes should be

- ● $\geq 2V_m$
- ○ $< 2V_m$
- ○ $\geq V_m$
- ○ $< V_m$

✓ 3. In a full wave rectifier if the input signal frequency is 50Hz, then the output frequency is

- ○ 25 Hz
- ○ 50 Hz
- ● 100 Hz

✓ 4. Ripple factor of a bridge rectifier is

- ○ 0.31
- ● 0.48
- ○ 0.707
- ○ 1.21

✓ 5. If the peak applied signal voltage is Vm then for a bridge rectifier circuit the PIV of the diodes will be

- [x] $\geq V_m$
- [ ] $< 2V_m$
- [ ] $\geq 2V_m$
- [ ] $< V_m$

✓ 6. Four ideal Si diodes [VT = 0.7V] are used in a bridge rectifier circuit which has a peak input sinusoidal signal amplitude of 5V [Vm = 5V]. The average DC voltage is

- [ ] <2.54
- [x] $=2.74$
- [ ] >3.74

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