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EC160: Experiment 4
Half-Wave Rectification

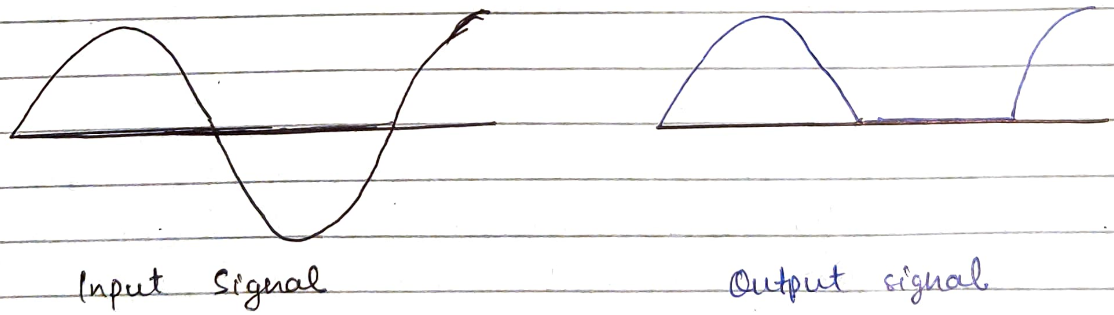
Objective :- To understand rectification and to study the working of a half-wave rectifier.

Theory :- A rectifier is a device that converts an oscillating two-directional alternating current (AC) into a single-directional direct current (DC.

Rectifiers are essentially of two types:-
(i) Half-Wave Rectifier
(ii) Full-wave Rectifier

Half-Wave Rectifier

The diagram below illustrates the basic principle of a half-wave rectifier.



Half-wave rectifiers allow only one half of AC voltage through and will block the other half-cycle.

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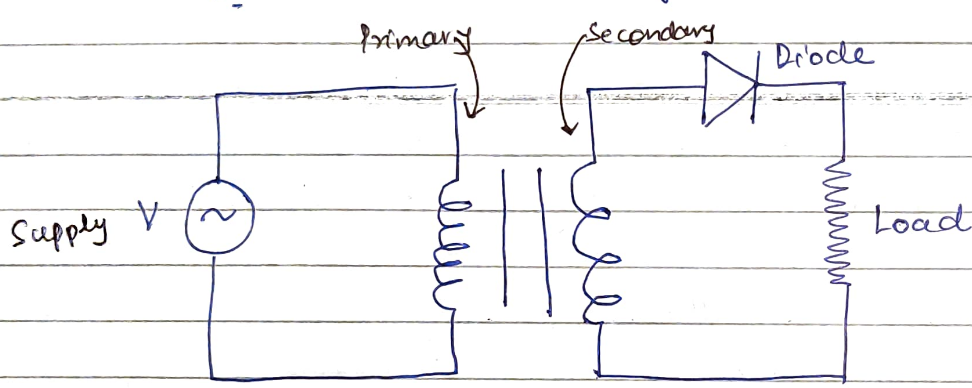
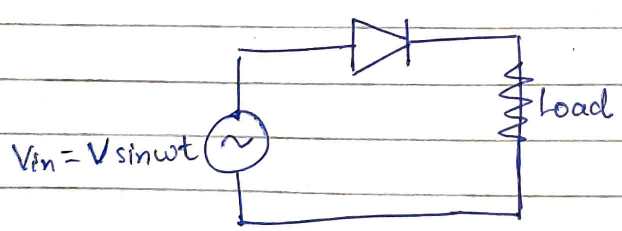
A half-wave rectifier consists of three main parts
i) A transformer
ii) A diode
iii) A resistive load

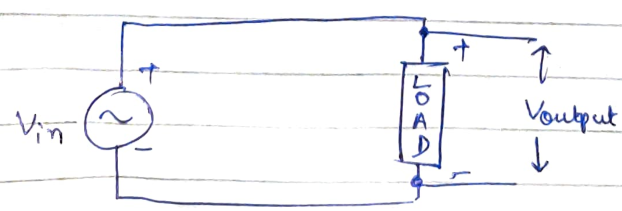
A half-wave circuit diagram looks like this:



An AC voltage is applied to the primary of transformer and an AC voltage Vin is available across the diode. Therefore, the circuit can be redrawn as



For the positive half-cycle of the AC source voltage, the equivalent circuit effectively becomes



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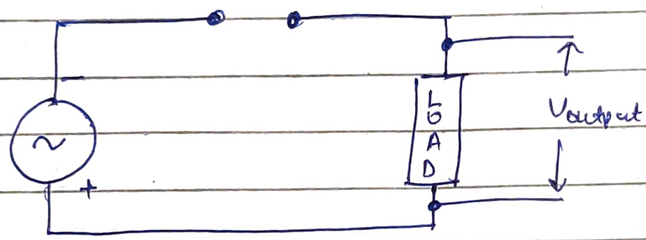
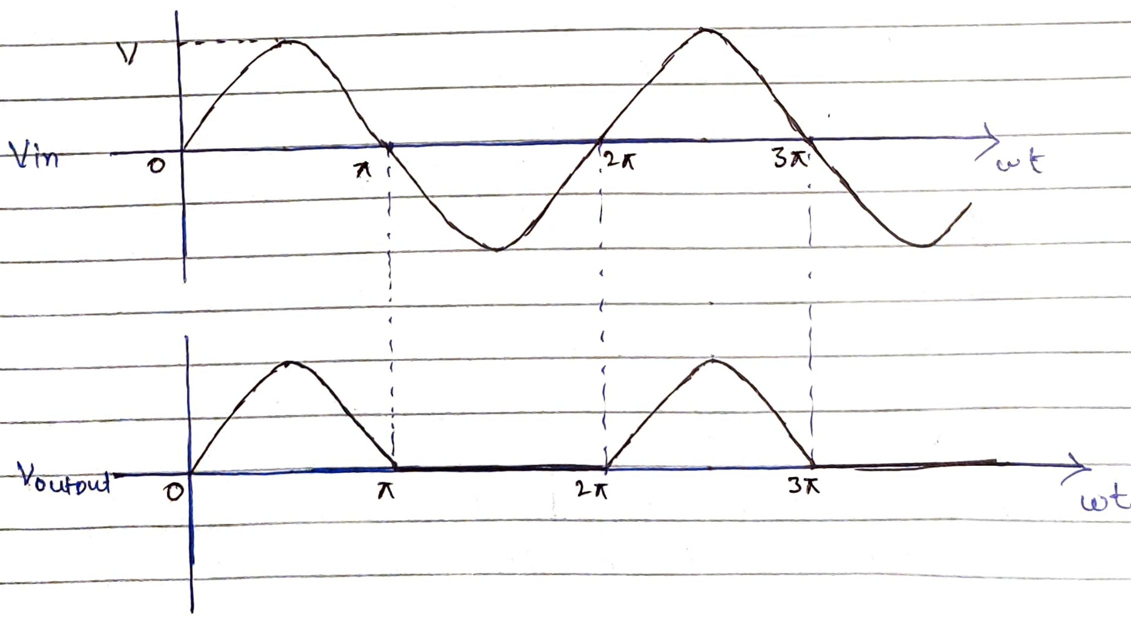
This is because the diode is forward biased and hence allowing current to pass through. Therefore, for positive half cycle the output voltage across the load (V_{output}) is equal to input voltage.

But for the negative half-cycle of AC source voltage, the equivalent circuit becomes



this is because the diode is now reverse biased and hence no current flows through it. Therefore, for negative half-cycle the output voltage across the load (V_{output}) is zero.

The waveform of input and output voltage is drawn below



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The waveform drawn is of a positive half-wave rectifier. A positive half-wave allows only positive half-cycles to flow through the diode while a negative half-wave rectifier allows only negative half-cycles to flow through the diode.

Mathematical Expressions

For an ideal half-wave rectifier,

output voltage (V_{output}) in positive half-cycle = V_{in}
output voltage (V_{output}) in negative half-cycle = 0

$$V_{output} = \begin{cases} V \sin\omega t & : \text{for positive half-cycles} \\ 0 & : \text{for negative half-cycles} \end{cases}$$

- **Average output voltage** :- It is the average voltage across the load for one cycle.

$$\text{average output voltage} = \frac{\int_0^{\pi} V \sin\theta \, d\theta + \int_{\pi}^{2\pi} 0 \, d\theta}{2\pi}$$

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

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

$$V_{avg} = 0.318\ V$$

Hence, the average output voltage is 0.318 times of the maximum voltage V.

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- RMS Load Voltage :-

$$V_{rms} = \sqrt{\frac{\int_0^{\pi} V^2 \sin^2\theta \, d\theta + \int_{\pi}^{2\pi} 0 \, d\theta}{2\pi}}$$

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

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

$$= \sqrt{\frac{V^2}{4\pi}(\pi)}$$

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

$$\therefore \quad V_{rms} = \frac{V}{2}$$

- Average load current :-

$$I_{avg} = V_{avg}/R$$

where R is resistance of load.

$$\therefore \quad I_{avg} = 0.318\, V/R$$

- RMS load current :-

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

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

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- Form factor of Half Wave Rectifier

Form factor (F.F.) is the ratio between RMS value and average value (either of voltage or current)

$$\therefore \quad F.F. = \frac{V_{rms}}{V_{avg}}$$

$$= \frac{0.5V}{0.318 V} = 1.57$$

Hence, FF for a half-wave rectifier is 1.57.

- Ripple Factor: The ripple is the ratio between the RMS value of AC voltage (on the input side) and the DC voltage (on the output side) of the rectifier.

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$$

The ripple factor for half-wave rectifier is 1.21.

- Efficiency: Rectifier efficiency is the ratio between output DC power and input AC power.

$$\text{Efficiency } (\eta) = \frac{\text{Output Power}}{\text{Input power}}$$

The efficiency of a half-wave rectifier is equal to 40.6 %.

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- Peak Inverse Voltage -: Peak inverse Voltage (PIV) is the maxium voltage that the diode can withstand during reverse bias condition.

Peak Inverse Voltage (PIV) $\geqslant V$

Procedure for the Experiment -:

Step 1 : Set the resistance 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 'Oscilloscope' button to get rectified output.
Step 5 : Vary the amplitude, frequency, volt/div using the controllers.
Step 6 : Click on 'dual' to observe both waveforms. (Chanel 1 shows input waveform and channel 2 shows output rectified waveform)

Simulation Results

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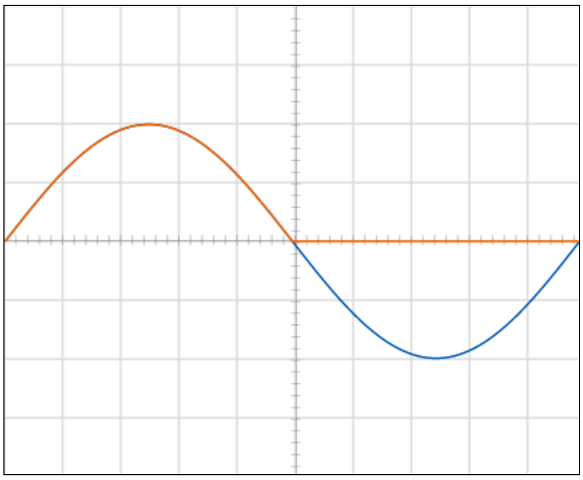
Half Wave Rectifier

INSTRUCTION

OSCILLOSCOPE



Channel 1 | Channel 2 | Ground | Dual

1000
Frequency(Hz)

2
Amplitude(Volt)

CALCULATION

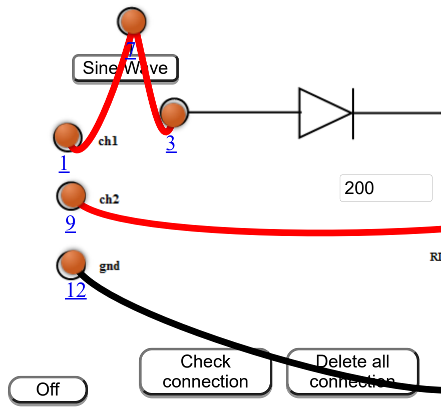
$V_{rms} = \frac{V_m}{2}$, V_m is the peak voltage

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

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

Peak Current: 6.499999989269141 mA

CIRCUIT



CONTROLS

2.4
Volt(V)/div

Position-Y Channel 1 Position-Y

Position-X

0.1
Time(ms)/div

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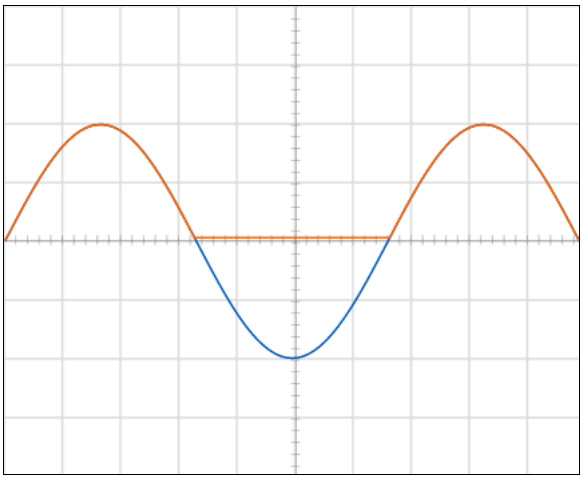
Half Wave Rectifier

INSTRUCTION

OSCILLOSCOPE



Channel 1 Channel 2 Ground Dual

1500
Frequency(Hz)

2
Amplitude(Volt)

CALCULATION

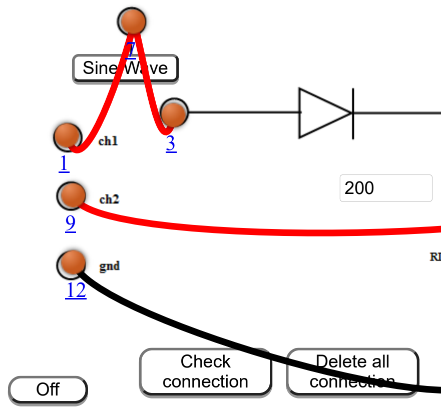
$V_{rms} = \frac{V_m}{2}$, V_m is the peak voltage

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

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

Peak Current: 6.499999989269141 mA

CIRCUIT



CONTROLS

2.4
Volt(V)/div

Position-Y Channel 1 Position-Y

Position-X

0.1
Time(ms)/div

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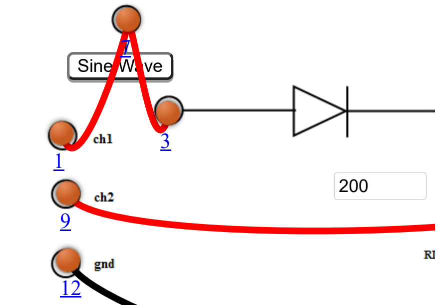
Half Wave Rectifier

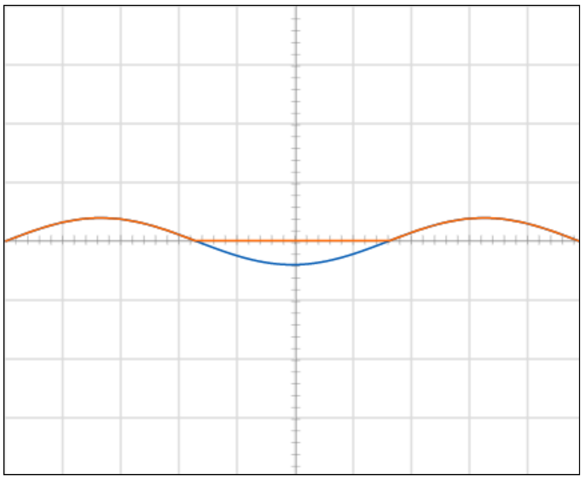
INSTRUCTION

CIRCUIT



Off | Check connection | Delete all connection

OSCILLOSCOPE



Channel 1 | Channel 2 | Ground | Dual

1500 *Frequency(Hz)*

0.5 *Amplitude(Volt)*

CONTROLS

Position-Y

2.4 *Volt(V)/div*

Channel 1

Position-Y

Position-X

0.1 *Time(ms)/div*

CALCULATION

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

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

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

Peak Current: 6.499999989269141 mA

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Half Wave Rectifier

INSTRUCTION

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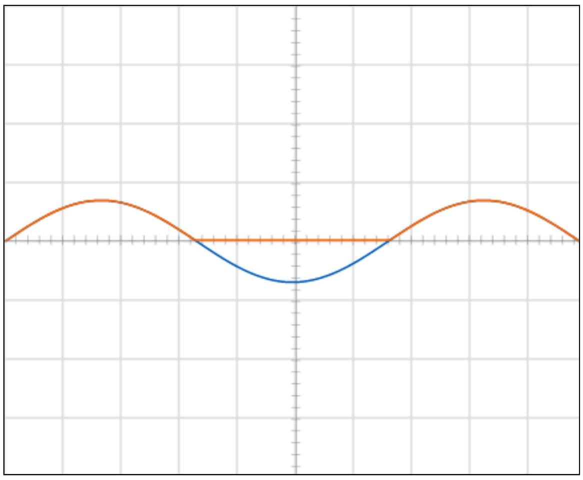


Channel 1 | Channel 2 | Ground | Dual

1500 *Frequency(Hz)*

1 *Amplitude(Volt)*

CALCULATION

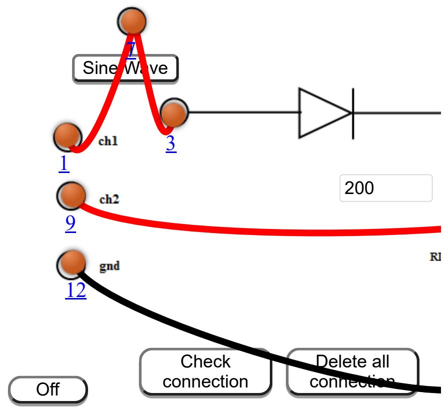
$V_{rms} = \frac{V_m}{2}$, V_m is the peak voltage

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

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

Peak Current: 6.499999989269141 mA

CIRCUIT



CONTROLS

Position-Y

2.4 *Volt(V)/div*

Channel 1

Position-Y

Position-X

0.1 *Time(ms)/div*

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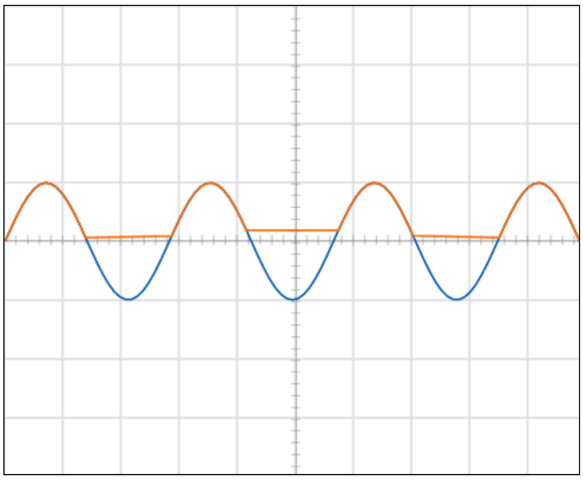
Half Wave Rectifier

INSTRUCTION

OSCILLOSCOPE



Channel 1 Channel 2 Ground Dual

3500
Frequency(Hz)

1
Amplitude(Volt)

CALCULATION

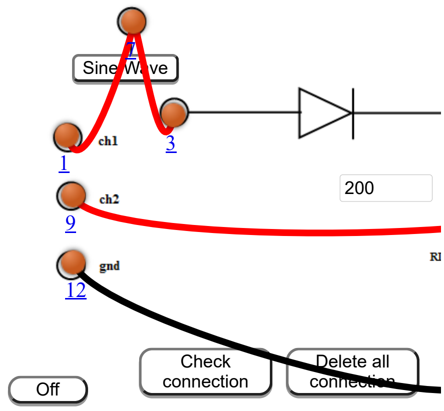
$V_{rms} = \frac{V_m}{2}$, V_m is the peak voltage

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

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

Peak Current: 6.499999989269141 mA

CIRCUIT



Off Check connection Delete all connection

CONTROLS

Position-Y

2.4
Volt(V)/div

Channel 1

Position-Y

Position-X

0.1
Time(ms)/div

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Conclusion :- Performing the above experiment we came to following conclusions :-

i) Rectifier is a device which converts an AC current/voltage to a DC current/voltage.

ii) Half-wave rectifier is a device which converts half of the input AC signal to an output DC signal.

(iii) The form factor and ripple factor of an ideal half-wave rectifier are 1.57 and 1.21 respectively.

(iv) The efficiency of an ideal half-wave rectifier is 40.6%.

Quiz Performance

Half Wave Rectification

Quiz

Test Your Knowledge!!

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

- ○ 0.31
- ○ 0.48
- ○ 0.707
- ● 1.21;

✓ 2. The peak applied signal voltage is V_m then for a half wave rectifier circuit the PIV(Peak Inverse Volatge) of the diode should be:

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

✓ 3. An ideal Si diode is used in a half wave rectifier circuit with peak input sinusoidal signal amplitude of 5V (V_m = 5V & V_T = 0.7V). The average dc voltage is

- ○ <1.27V
- ● =1.37V
- ○ >1.87V

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