

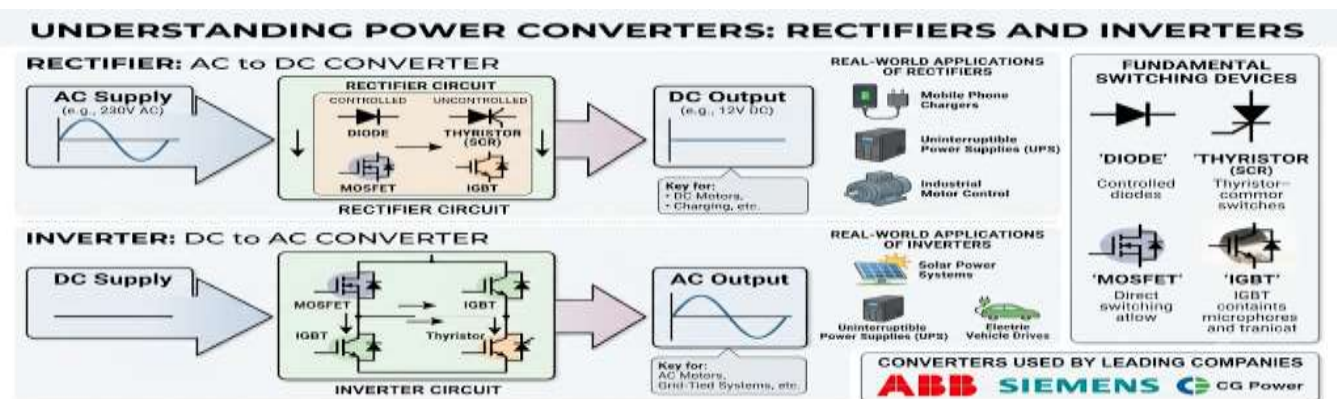
CONVERTERS

RECTIFIERS AND INVERTERS

Introduction to Power Converters

A converter is a power-electronic circuit that changes electrical energy from one form to another — in magnitude, frequency, or type (AC/DC) — using controlled or uncontrolled semiconductor switching devices such as diodes, thyristors (SCRs), MOSFETs, or IGBTs. The two most fundamental converters are:

- Rectifier — converts AC input to DC output (AC → DC).
- Inverter — converts DC input to AC output (DC → AC).

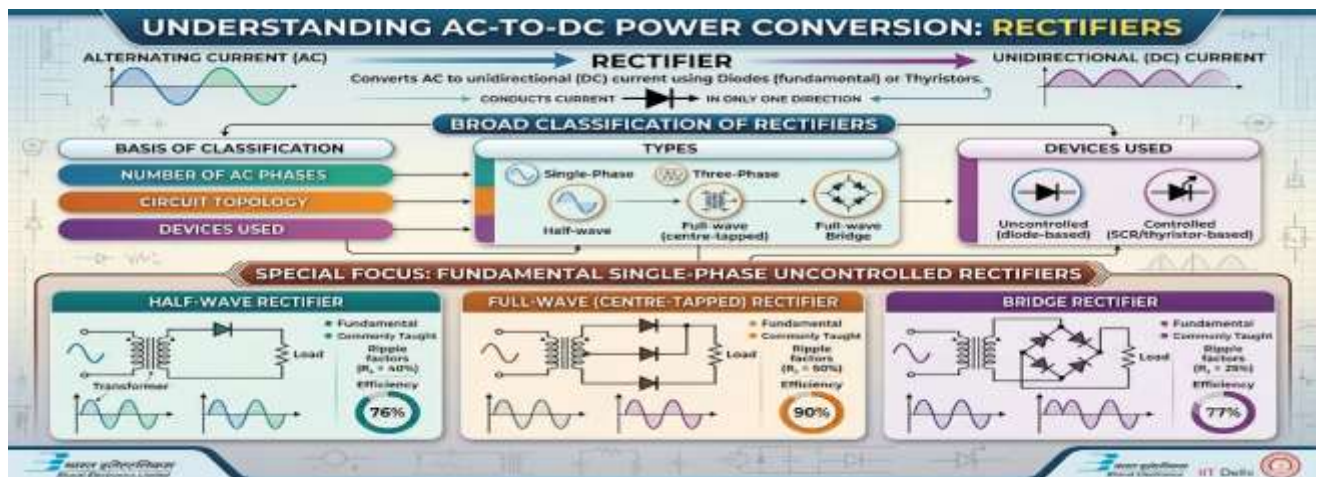


These converters form the backbone of modern power electronics, appearing in mobile phone chargers, UPS systems, solar inverters, electric vehicle drives, and industrial motor control (used by companies like ABB, Siemens, and CG Power in India).

4.2 Rectifiers — Overview and Classification

A rectifier converts alternating current (AC) into unidirectional (DC) current using diodes or thyristors, which conduct current in only one direction. Rectifiers are broadly classified as follows:

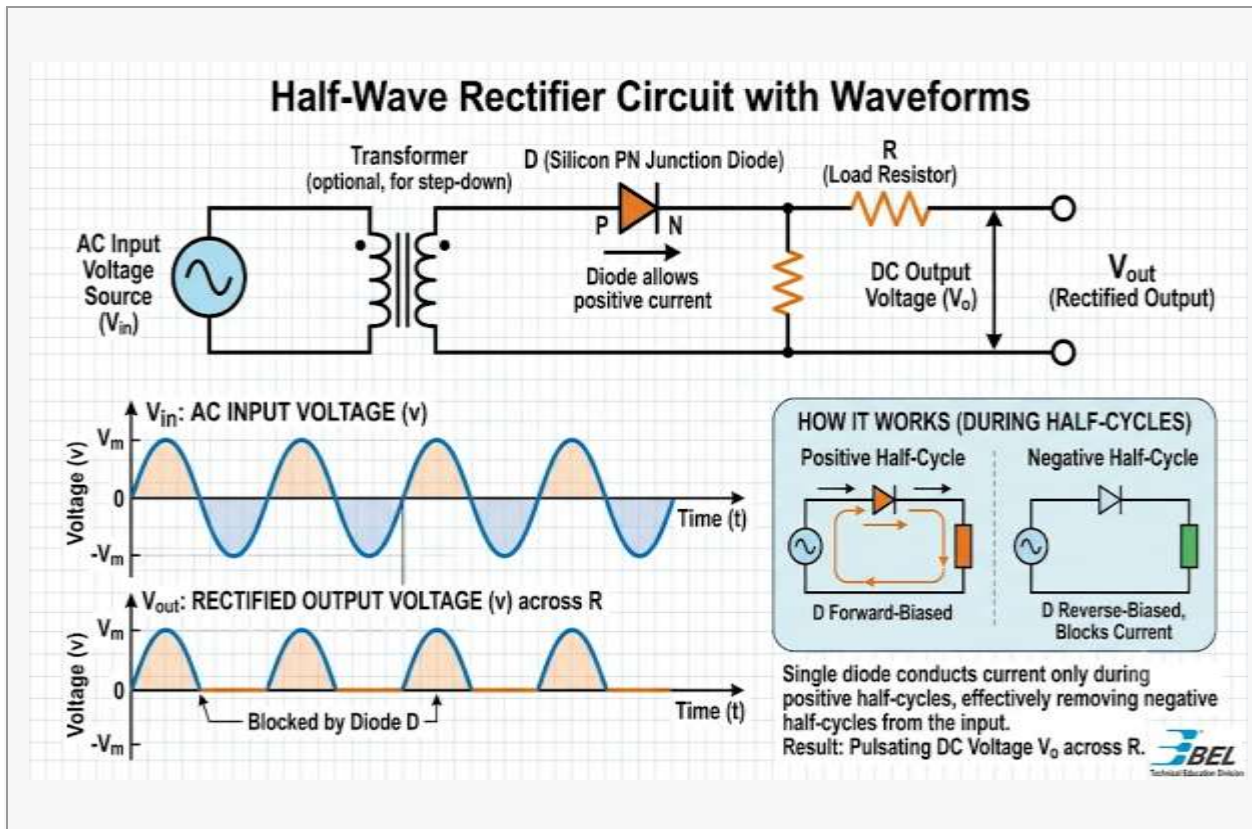
Basis of classification	
Number of AC phases	Single-phase, Three-phase
Circuit topology	Half-wave, Full-wave (centre-tapped), Full-wave bridge
Devices used	Uncontrolled (diode-based), Controlled (SCR/thyristor-based)



This chapter focuses on single-phase uncontrolled (diode) rectifiers — half-wave, centre-tapped full-wave, and bridge — which are the most fundamental and commonly taught circuits.

Half-Wave Rectifier

A half-wave rectifier uses a single diode to allow current to flow only during one half-cycle (positive or negative) of the AC input, blocking the other half completely. The output is a pulsating DC that exists only for half of each cycle.



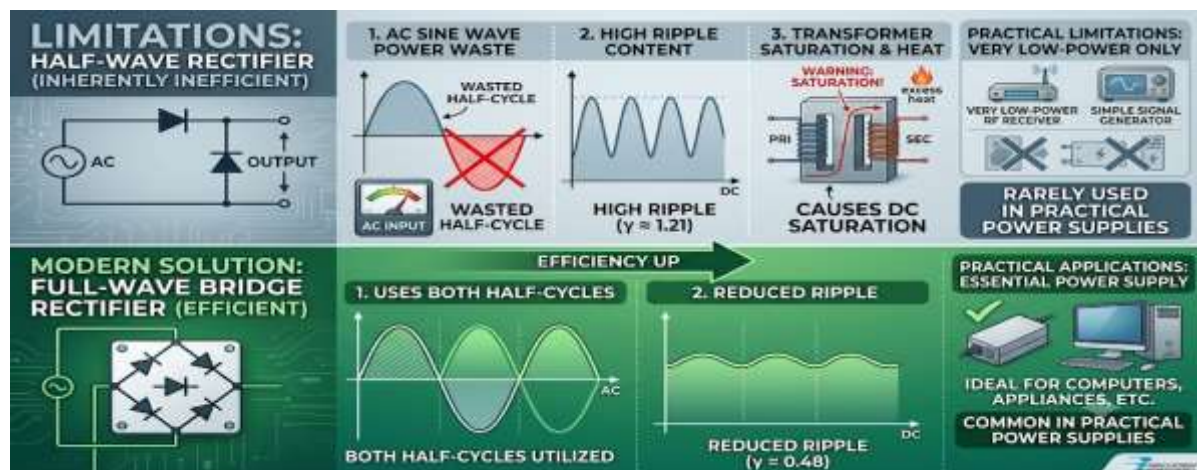
Key formulas

$$V_{dc} = V_m / \pi \approx 0.318 V_m \quad V_{rms} = V_m / 2$$

$$I_{dc} = I_m / \pi \quad \text{Ripple Factor, } \gamma = 1.21 \quad \text{Efficiency, } \eta \approx 40.6\%$$

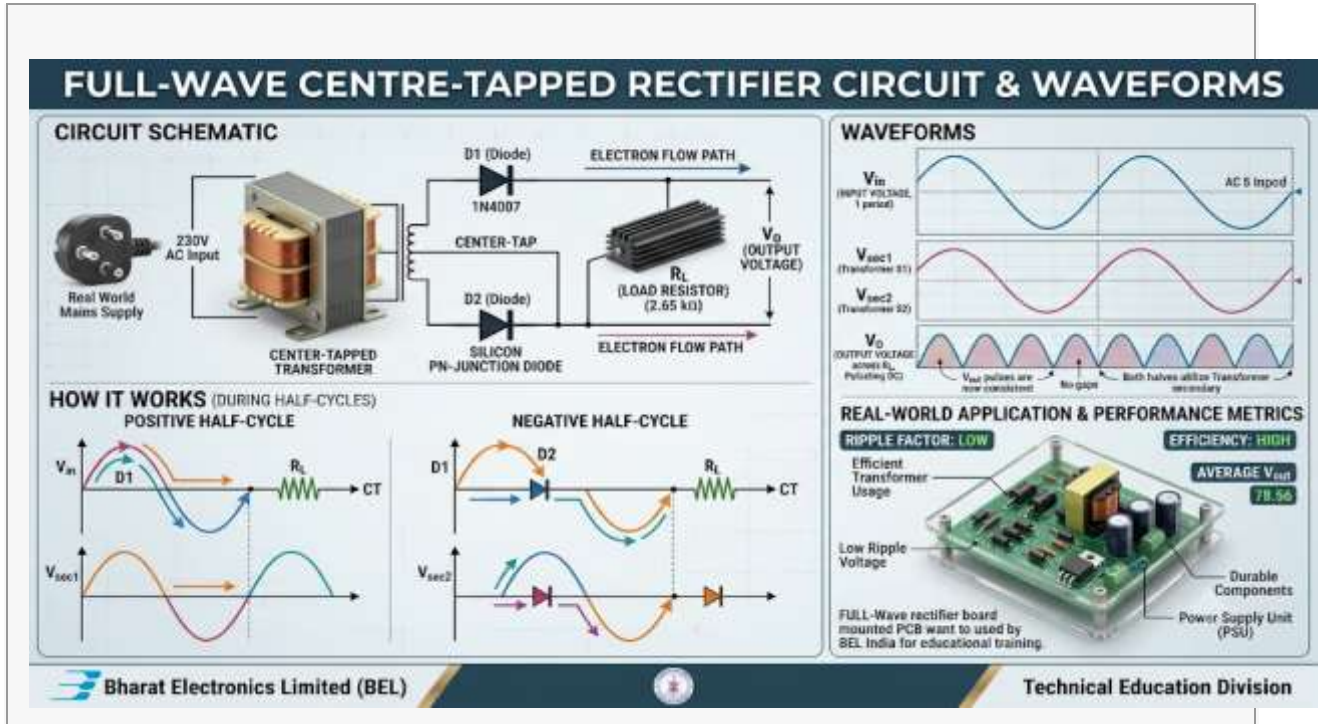
The Peak Inverse Voltage (PIV) — the maximum reverse voltage the diode must withstand — is $PIV = V_m$.

Limitation



Full-Wave Rectifier — Centre-Tapped

A centre-tapped full-wave rectifier uses a transformer with a centre-tapped secondary winding and two diodes. Each diode conducts for one half-cycle, so current flows through the load during both halves of the input cycle, but in the same direction each time.

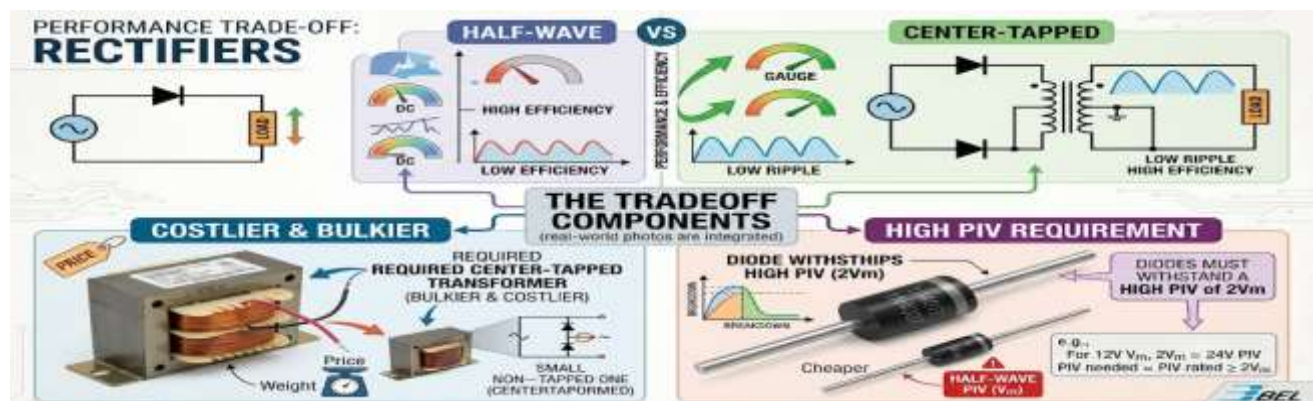


Key formulas

$$V_{dc} = \frac{2V_m}{\pi} \approx 0.636 V_m \quad V_{rms} = \frac{V_m}{\sqrt{2}}$$

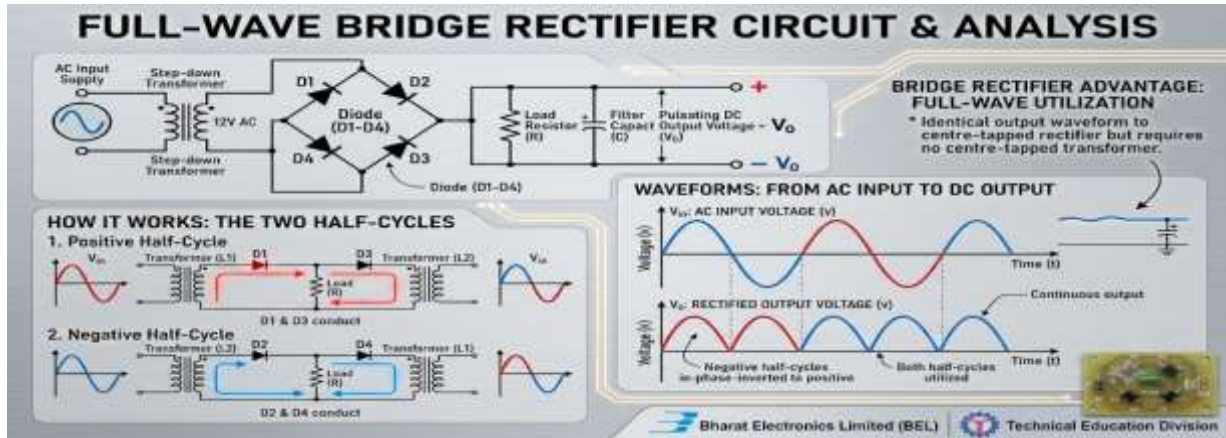
$$I_{dc} = \frac{2I_m}{\pi} \quad \text{Ripple Factor, } \gamma = 0.482 \quad \text{Efficiency, } \eta \approx 81.2\%$$

PIV for each diode = $2V_m$, since the non-conducting diode must withstand the full secondary voltage plus the conducting diode's forward portion.



Full-Wave Bridge Rectifier

The bridge rectifier uses four diodes arranged in a bridge configuration and does NOT require a centre-tapped transformer. During each half-cycle, two diagonally opposite diodes conduct, directing current through the load in the same direction for both halves of the AC input.

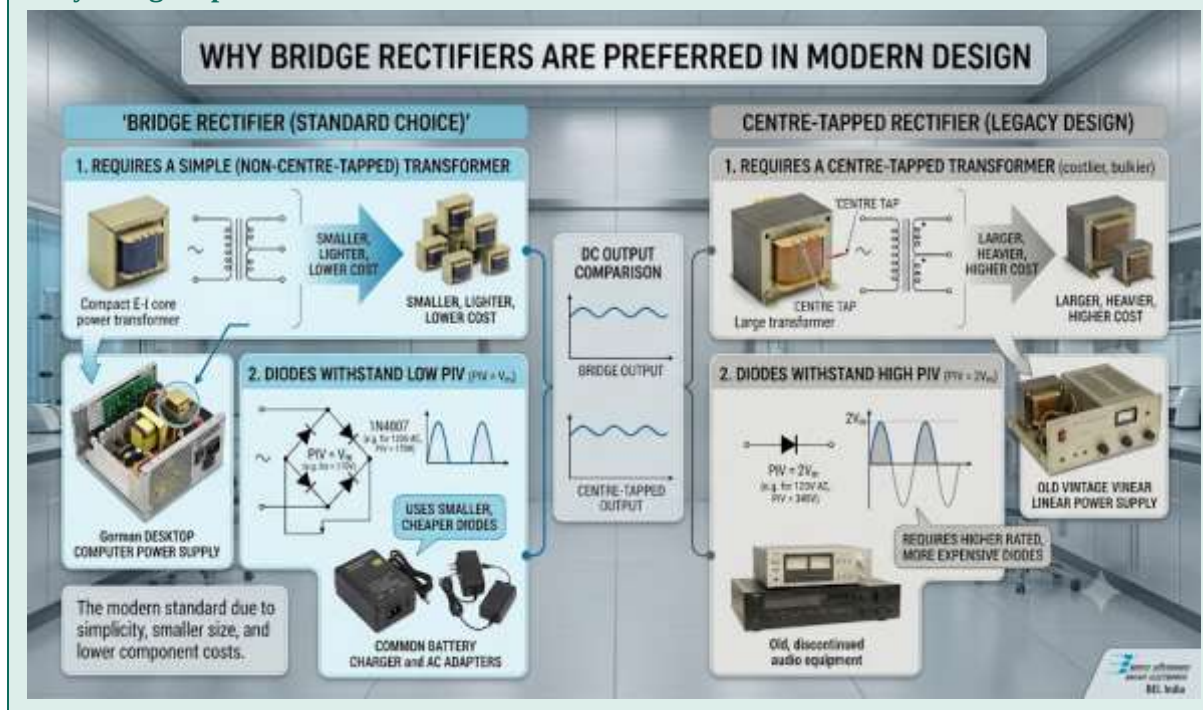


Key formulas

$$V_{dc} = \frac{2V_m}{\pi} \approx 0.636 V_m \quad V_{rms} = \frac{V_m}{\sqrt{2}}$$

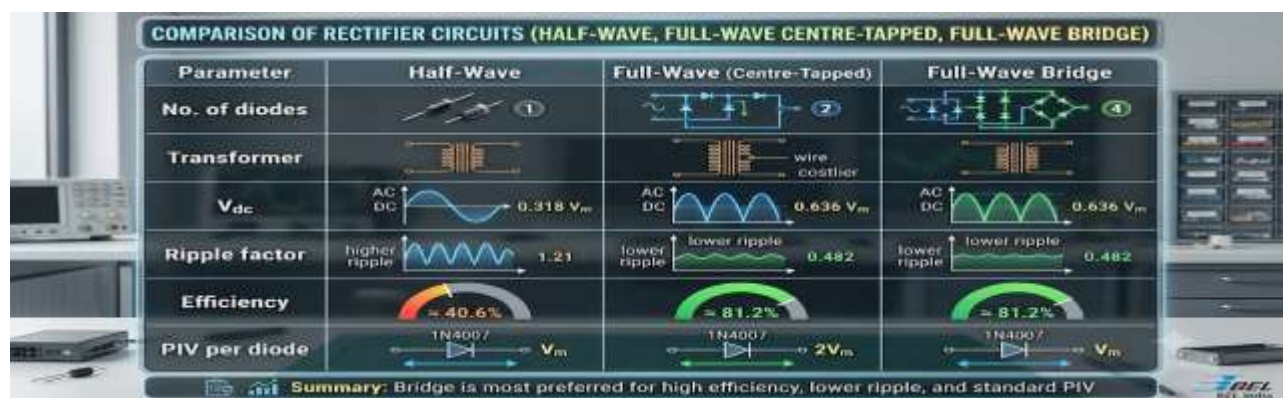
$$\text{Ripple Factor, } \gamma = 0.482 \quad \text{Efficiency, } \eta \approx 81.2\% \quad PIV = V_m \text{ (per diode)}$$

Why bridge is preferred



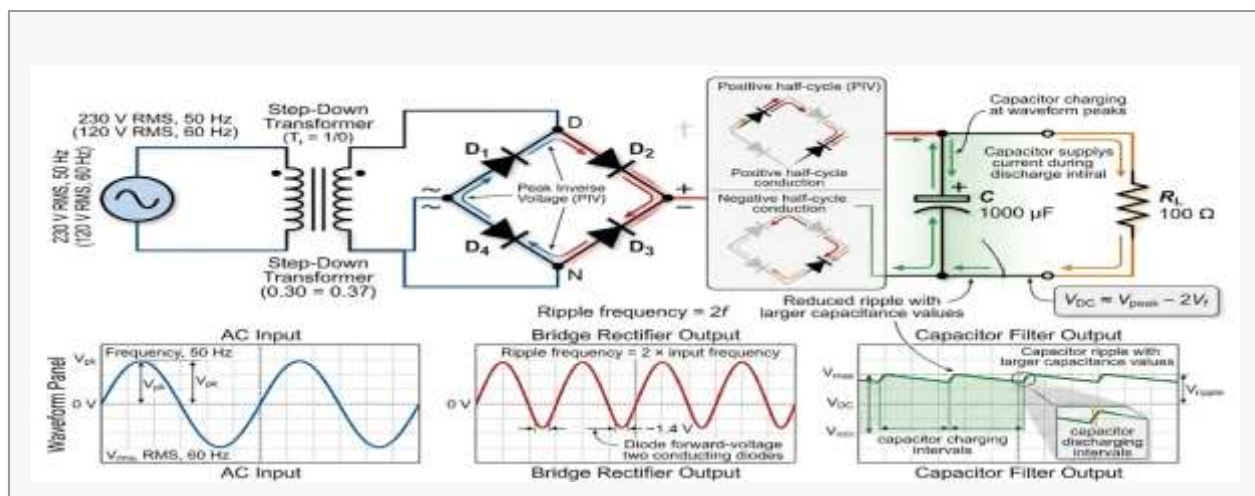
Comparison of Rectifier Circuits

Parameter	Half-Wave	Full-Wave (Centre-Tapped)	Full-Wave Bridge
No. of diodes	1	2	4
Transformer	Simple	Centre-tapped (costlier)	Simple
V _{dc}	0.318 V _m	0.636 V _m	0.636 V _m
Ripple factor	1.21	0.482	0.482
Efficiency	≈ 40.6%	≈ 81.2%	≈ 81.2%
PIV per diode	V _m	2V _m	V _m



Filters in Rectifier Circuits

The output of any rectifier is pulsating DC, containing an unwanted AC ripple component superimposed on the DC level. A filter — typically a capacitor connected across the load, sometimes combined with an inductor (LC filter) — smooths this output by storing charge during peaks and releasing it during troughs, reducing ripple significantly.



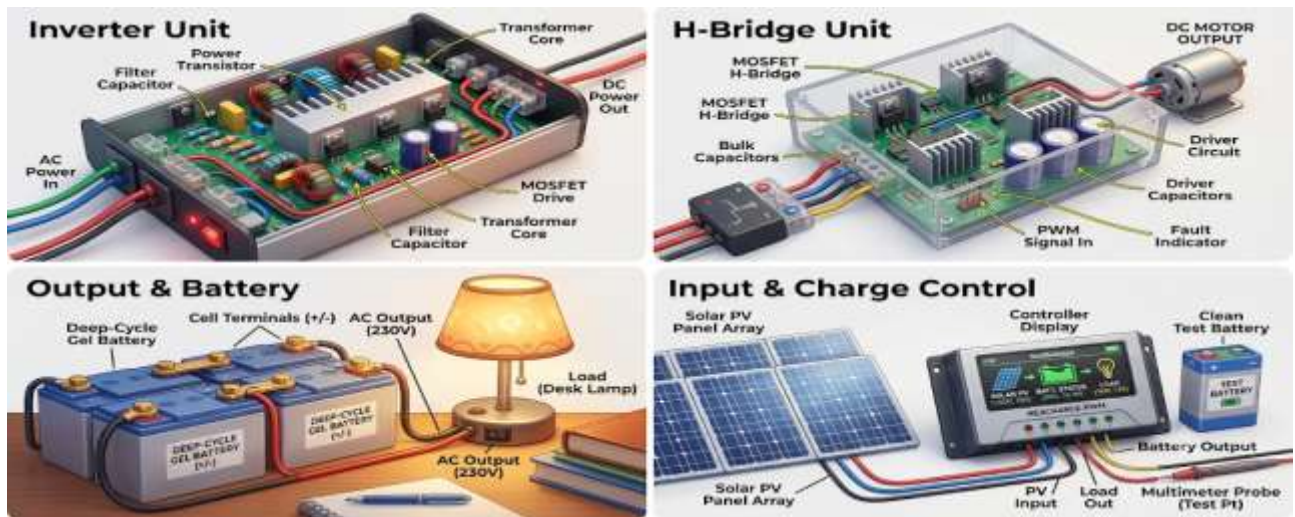
Ripple factor with capacitor filter: $\gamma \approx 1 / (2\sqrt{3} f R C)$ (approx., full-wave)

Inverters — Overview and Classification

An inverter is a power-electronic circuit that converts DC power into AC power at a desired output voltage and frequency. It uses controlled switching devices (thyristors, MOSFETs, or IGBTs) that are turned ON and OFF in a specific sequence to synthesise an alternating waveform from a constant DC source.

Classification of inverters

Basis	Types
Output phase	Single-phase inverter, Three-phase inverter
Circuit configuration	Half-bridge inverter, Full-bridge inverter
Output waveform	Square wave, Modified sine wave, Pure sine wave (PWM)

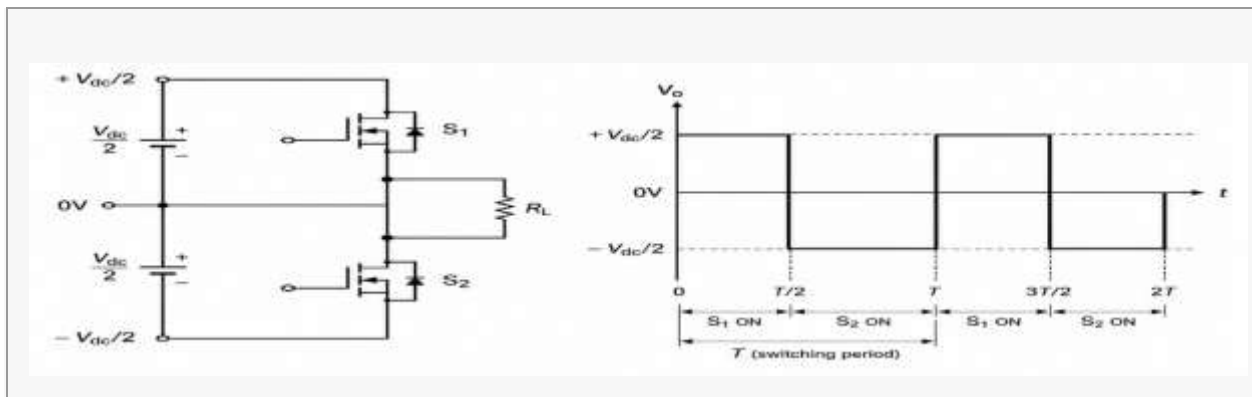


Everyday examples

Solar inverters (used by Indian companies like Luminous, Microtek, and Su-Kam) convert DC from solar panels/batteries into 230 V AC for home use; UPS systems, EV motor drives, and variable-frequency drives (VFDs) for industrial motors also rely on inverter circuits.

Single-Phase Half-Bridge Inverter

A half-bridge inverter uses two switches (S_1 , S_2) connected across a DC source with a centre-tapped supply (or two equal capacitors providing a midpoint). The switches are turned ON alternately, connecting the load first to $+V_{dc}/2$ and then to $-V_{dc}/2$, producing a square-wave AC output across the load.

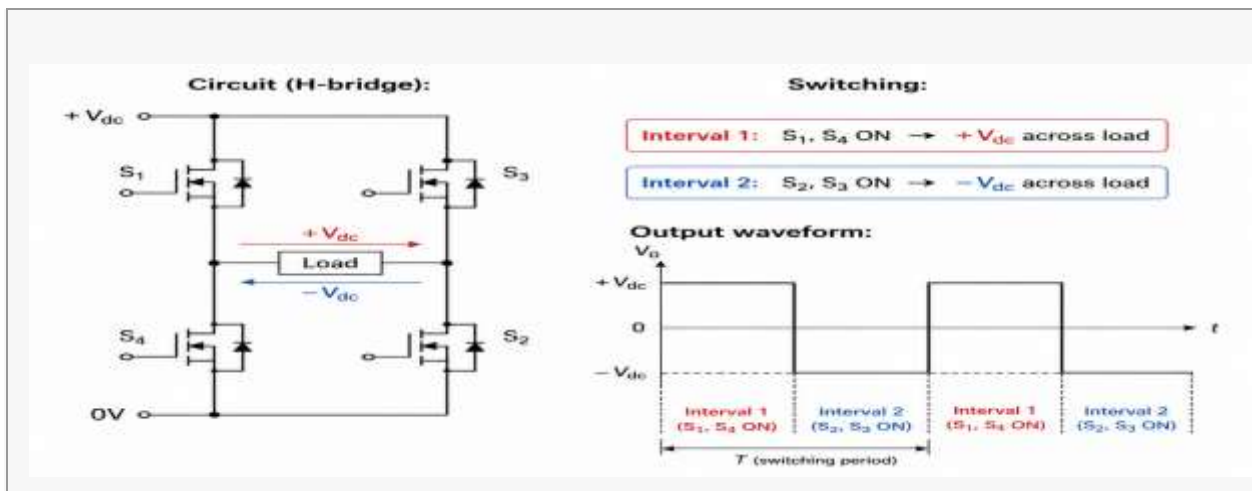


RMS output voltage: $V_o(\text{rms}) = V_{dc} / 2$

S1 and S2 are switched ON alternately, each for half the output cycle period, and must never conduct simultaneously (which would short the DC source).

Single-Phase Full-Bridge Inverter

A full-bridge inverter uses four switches (S1, S2, S3, S4) arranged in an H-bridge configuration. Diagonal pairs of switches are turned ON together, alternately reversing the polarity of voltage applied across the load, producing a square-wave AC output with full DC voltage swing.



RMS output voltage: $V_o(\text{rms}) = V_{dc}$ (full DC voltage swing, twice that of half-bridge)

Why full-bridge is preferred

The full-bridge inverter delivers twice the output voltage of a half-bridge for the same DC input and does not need a centre-tapped supply, making it the standard topology for most practical single-phase inverters, including home UPS and solar inverter systems.

In practical inverters, Pulse Width Modulation (PWM) techniques are used to control the switching of S1–S4 so that the output approximates a sine wave rather than a square wave, greatly reducing harmonic distortion for sensitive loads.

Applications of Rectifiers and Inverters

Rectifier applications
• DC power supplies for electronic devices — mobile chargers, laptop adapters. • Battery charging circuits (UPS, inverters, electric vehicles). • DC motor drives and electroplating processes. • Front-end stage of variable frequency drives (VFDs) before the inverter stage.

