

Power Electronics

BY

Sushanta kumar jena.Asst. prof.EE,SCE

Power electronics refers to control and conversion of electrical power by power semiconductor devices wherein these devices operate as switches. Advent of silicon-controlled rectifiers, abbreviated as SCRs, led to the development of a new field of application called the power electronics. Before SCRs, mercury-arc rectifiers were used for controlling electrical power, but such rectifier circuits were part of industrial electronics and the scope for applications of mercury-arc rectifiers was limited. The application spread to many fields such as drives, power supplies, aviation electronics, high

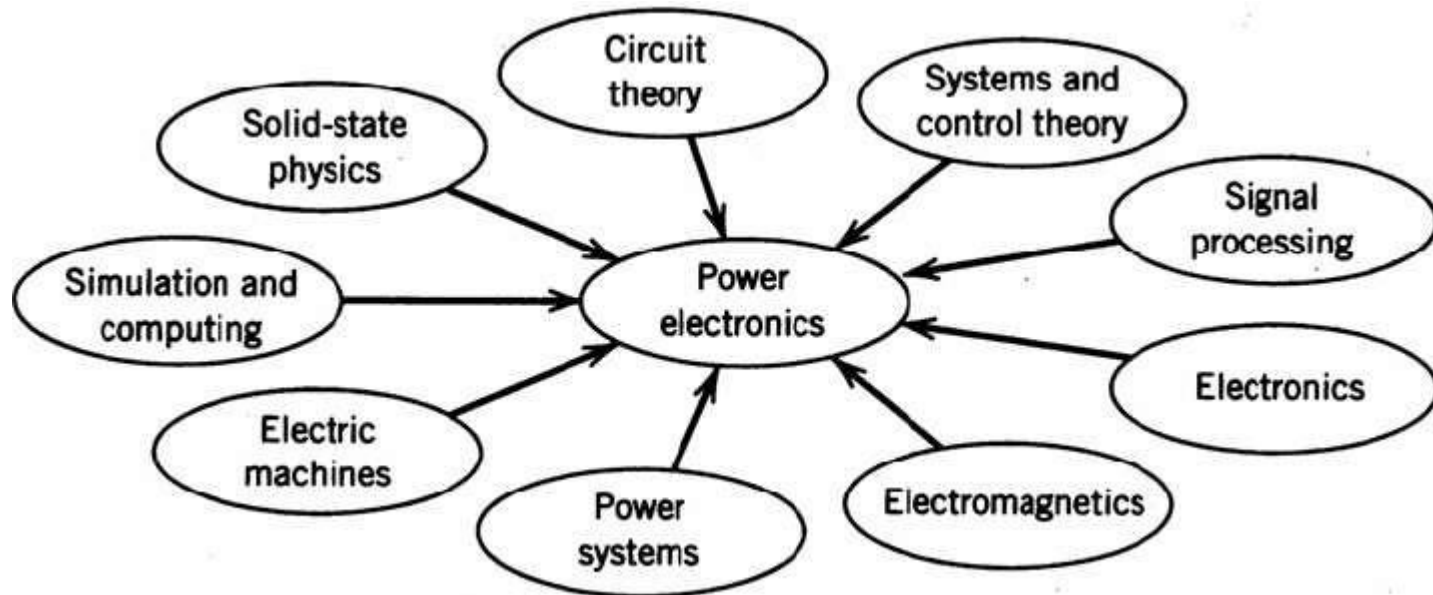
frequency inverters and power electronics.

- Power electronics relates to the control and flow of electrical energy.
- Control is done using electronic switches, capacitors, magnetics, and control systems.
- Scope of power electronics: milliWatts \Rightarrow gigaWatts
- Power electronics is a growing field due to the improvement in switching technologies and the need for more and more efficient switching circuits.

Scope of Power Electronics

<i>Power Level (Watts)</i>	<i>System</i>
0.1-10	<ul style="list-style-type: none">• Battery-operated equipment• Flashes/strobes
10-100	<ul style="list-style-type: none">• Satellite power systems• Typical offline flyback supply
100 – 1kW	<ul style="list-style-type: none">• Computer power supply• Blender
1 – 10 kW	<ul style="list-style-type: none">• Hot tub
10 – 100 kW	<ul style="list-style-type: none">• Electric car• Eddy current braking
100 kW –1 MW	<ul style="list-style-type: none">• Bus• micro-SMES
1 MW – 10 MW	<ul style="list-style-type: none">• SMES
10 MW – 100 MW	<ul style="list-style-type: none">• Magnetic aircraft launch• Big locomotives
100 MW – 1 GW	<ul style="list-style-type: none">• Power plant
> 1 GW	<ul style="list-style-type: none">• Sandy Pond substation (2.2 GW)

Interdisciplinary Nature of Power Electronics



Applications

- Heating and lighting control
- Induction heating
- Uninterruptible power supplies (UPS)
- Fluorescent lamp ballasts: Passive; Active
- Electric power transmission
- Automotive electronics
- Electronic ignitions
- Motor drives
- Battery chargers
- Alternators
- Energy storage
- Electric vehicles
- Alternative power sources: Solar; Wind; Fuel Cells
- And more!

Tasks of Power Electronics

Rectification referring to conversion of ac voltage to dc voltage

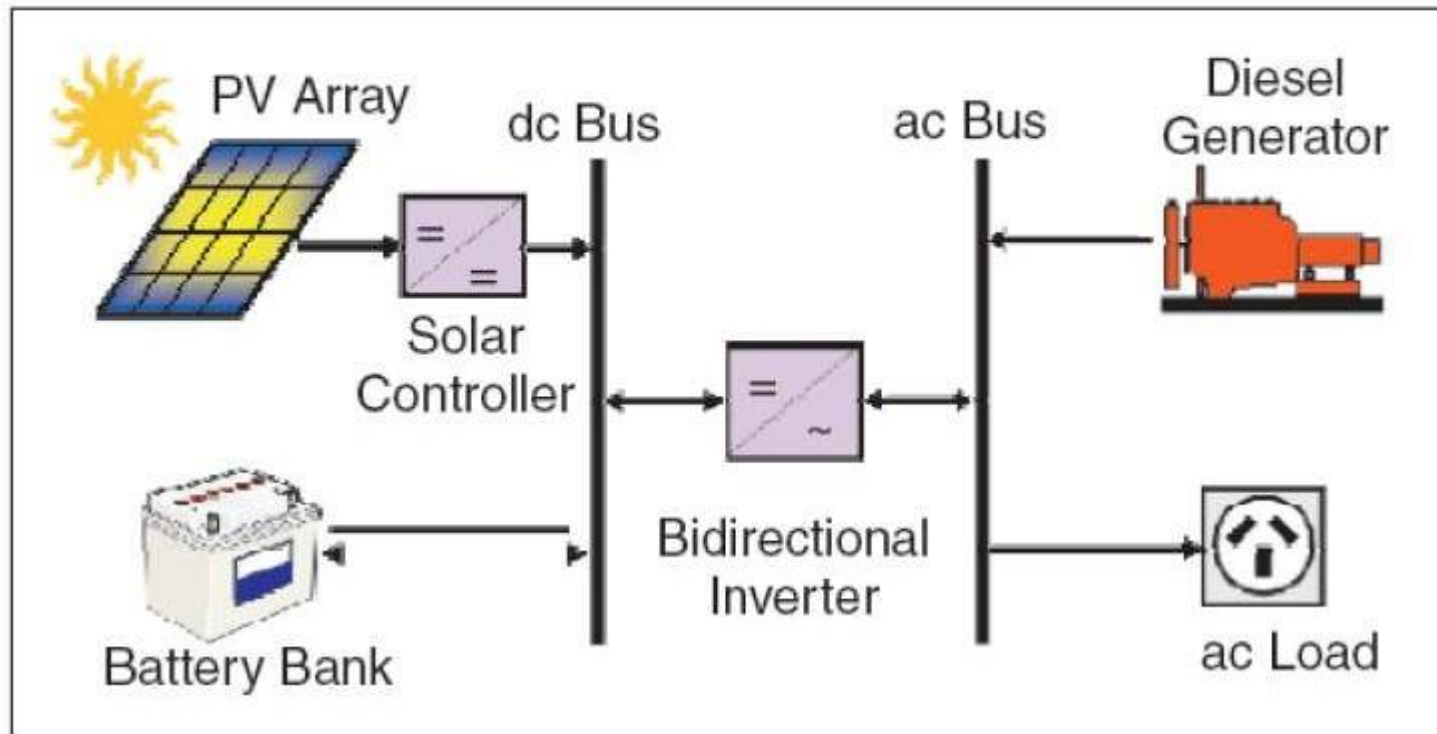
DC-to-AC conversion

DC-to DC conversion

AC-to-AC conversion

Example

Photovoltaics



Converters

Electronic power converter is the term that is used to refer to a power electronic circuit that converts voltage and current from one form to another.

- Rectifier converting an ac voltage to a dc voltage
- Inverter converting a dc voltage to an ac voltage
- Chopper or a switch-mode power supply that converts a dc voltage to another dc voltage
- Cycloconverter and cycloinverter converting an ac voltage to another ac voltage.

Rectifiers

Rectifiers may be classified as uncontrolled and controlled rectifiers. Controlled rectifiers can be further divided into semi-controlled and fully-controlled rectifiers. Uncontrolled rectifier circuits are built with diodes, and fully-controlled rectifier circuits are built with SCRs.

Both diodes and SCRs are used in semi-controlled rectifier circuits.

- Single-phase semi-controlled bridge rectifier
- Single-phase fully-controlled bridge rectifier
- Three-phase three-pulse, star-connected rectifier
- Double three-phase, three-pulse star-connected rectifiers with inter-phase transformer (IPT)
- Three-phase semi-controlled bridge rectifier
- Three-phase fully-controlled bridge rectifier
- Double three-phase fully-controlled bridge rectifiers with IPT.

DC to AC Conversion

The converter that changes a DC to AC is called an inverter. Earlier inverters were built with SCRs. Since the circuitry required to turn the SCR off tends to be complex, other power semiconductor devices such as bipolar junction transistors, power MOSFETs, insulated gate bipolar transistors (IGBT) and MOS-controlled thyristors (MCTs) are used nowadays. Currently only the inverters with a high power rating, such as 500 kW or higher.

- Emergency lighting systems
- AC variable speed drives
- Uninterrupted power supplies
- Frequency converters.

DC to DC Conversion

When the SCR came into use, a dc-to-dc converter circuit was called a chopper. Nowadays, an SCR is rarely used in a dc-to-dc converter. Either a power BJT or a power MOSFET is normally used in such a converter and this converter is called a switch-mode power supply.

- Step-down switch-mode power supply
- Step-up chopper
- Fly-back converter
- Resonant converter.

AC to AC Converter

- A cycloconverter or a cycloinverter converts an ac voltage, such as the mains supply, to another ac voltage. The amplitude and the frequency of input voltage to a cycloconverter tend to be fixed values, whereas both the amplitude and the frequency of output voltage of a cycloconverter tend to be variable.
- The circuit that converts an ac voltage to another ac voltage at the same frequency is known as an AC-chopper. A typical application of a cycloconverter is to use it for controlling the speed of an ac traction motor and most of these cycloconverters have a high power output, of the order a few megawatts and SCRs are used in these circuits. In contrast, low cost, low power cycloconverters for low power ac motors are also in use and many of these circuit tend to use TRIACS in place of SCRs.
- Unlike an SCR which conducts in only one direction, a TRIACS is capable of conducting in either direction and like an SCR, it is also a three terminal device. It may be noted that the use of a cycloconverter is not as common as that of an inverter and a cycloinverter is rarely used.

Applications of Power Electronics

- In a conventional car, power electronics applications are a major area of future expansion.
- Look inside the audio system, for example; the amplifiers in today's car stereos are usually capable of delivering 40 W or more. But a 12 V supply applied to an 8 Ohm speaker produces 18 W output at best.
- To solve this power supply problem, designers use a boost converter (DC to DC Converter) to provide higher voltage power to the amplifier circuit. This allows car amplifiers to generate the same audio output power as home stereos.

Automobile's Ignition System

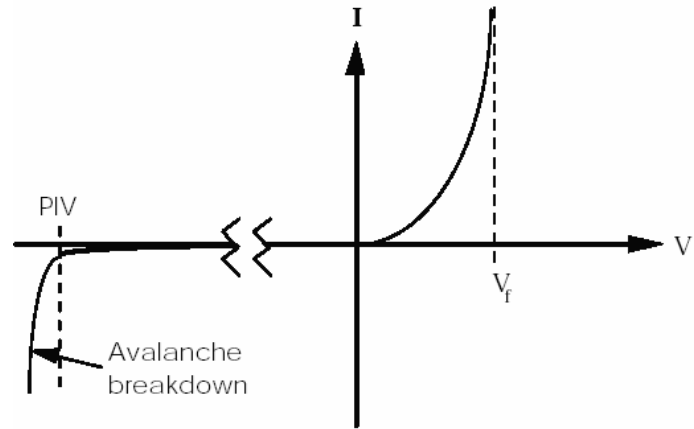
- Another universal power electronics application is the automobile's ignition system.
- Thousands of volts are required to ignite the fuel-air mixture inside a cylinder so that internal combustion can occur.
- Today's cars employ all-electronic ignition systems, which have replaced the traditional spark plugs with boost converters coupled to transformers.

Hybrid Cars

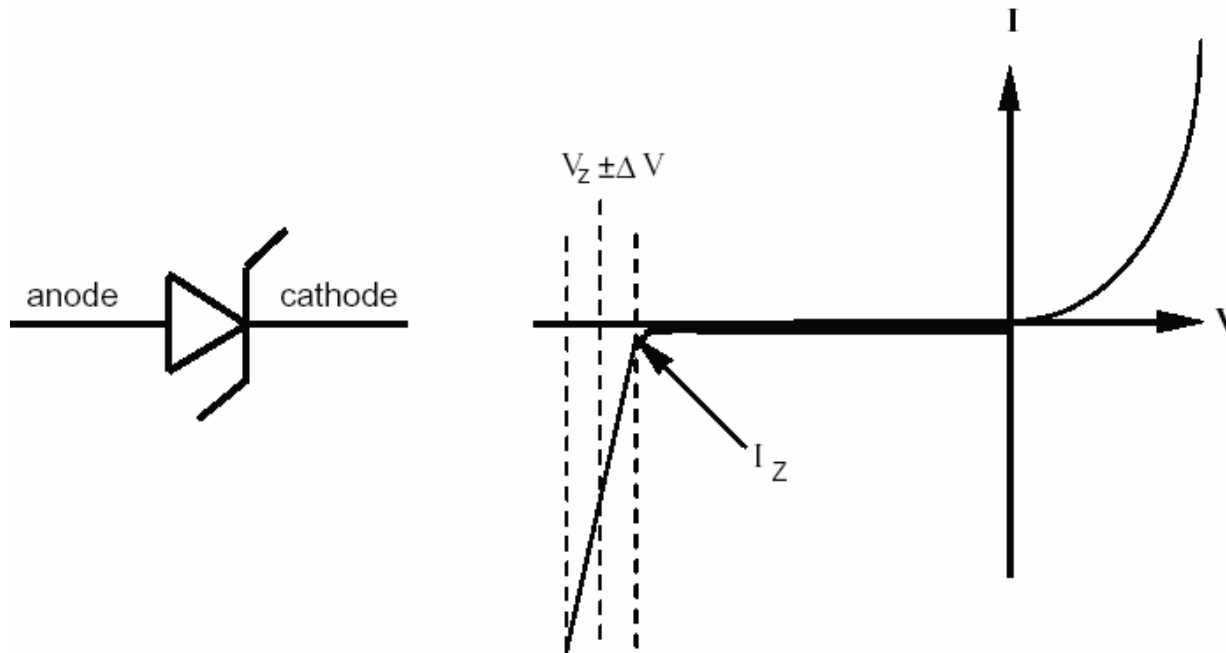
- We are curious about new electric and hybrid cars, in which the primary electrical system is dominated by power electronics. Electric cars offer high performance, zero tailpipe emissions, and low costs, but are still limited in range by the need for batteries.
- Hybrid car designs use various strategies to combine both an engine and electrical elements to gain advantages of each.
- Inverters and DC-DC converters rated for many kilowatts serve as primary energy control blocks. See <http://www.howstuffworks.com/hybrid-car2.htm>.



Diodes

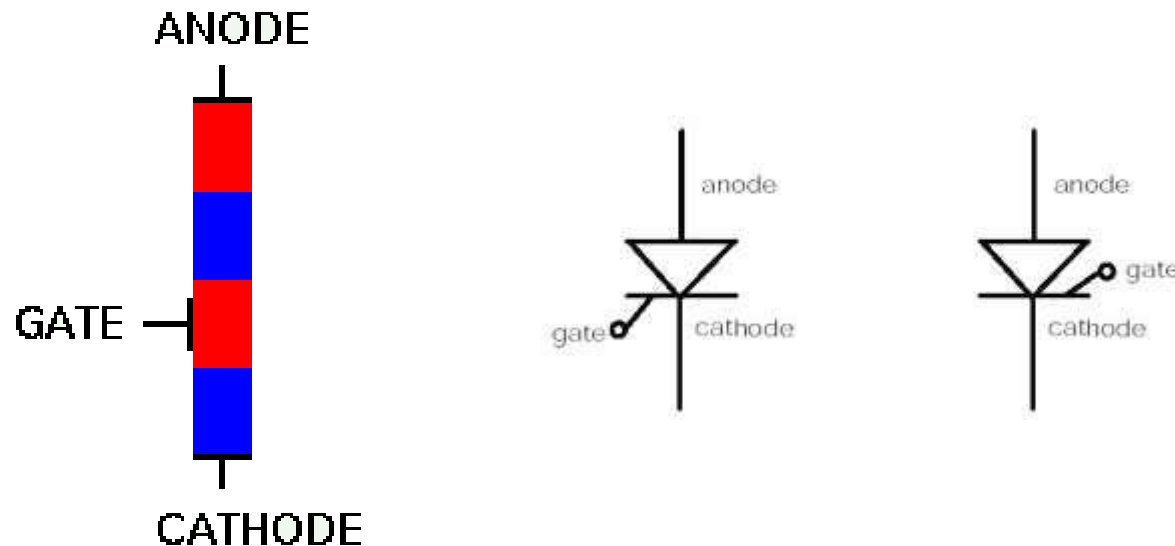


Zener Diodes



Silicon Controlled Rectifiers

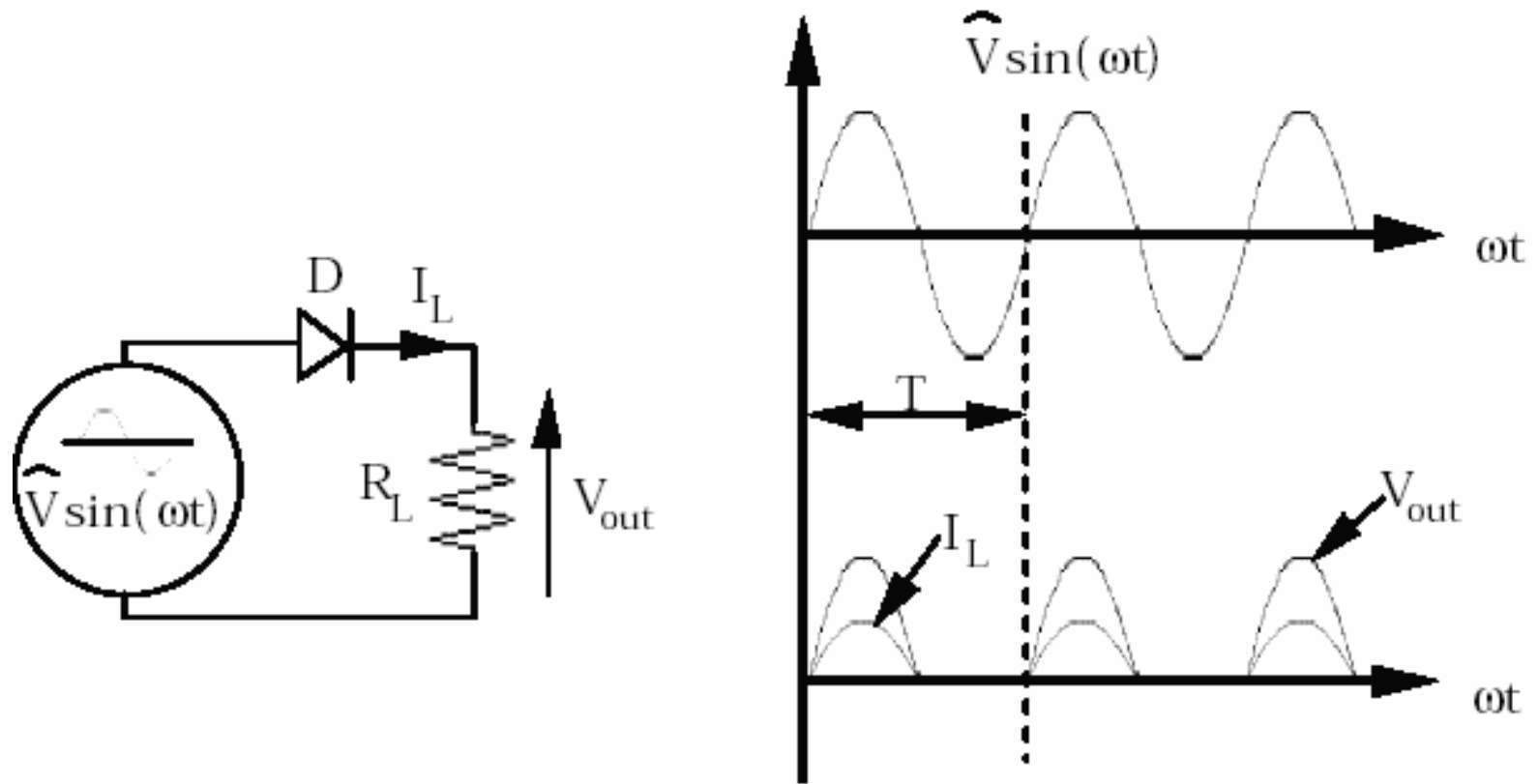
The basic purpose of the SCR is to function as a switch that can turn on or off small or large amounts of power. It performs this function with no moving parts that wear out and no points that require replacing. There can be a tremendous power gain in the SCR; in some units a very small triggering current is able to switch several hundred amperes without exceeding its rated abilities. The SCR can often replace much slower and larger mechanical switches.



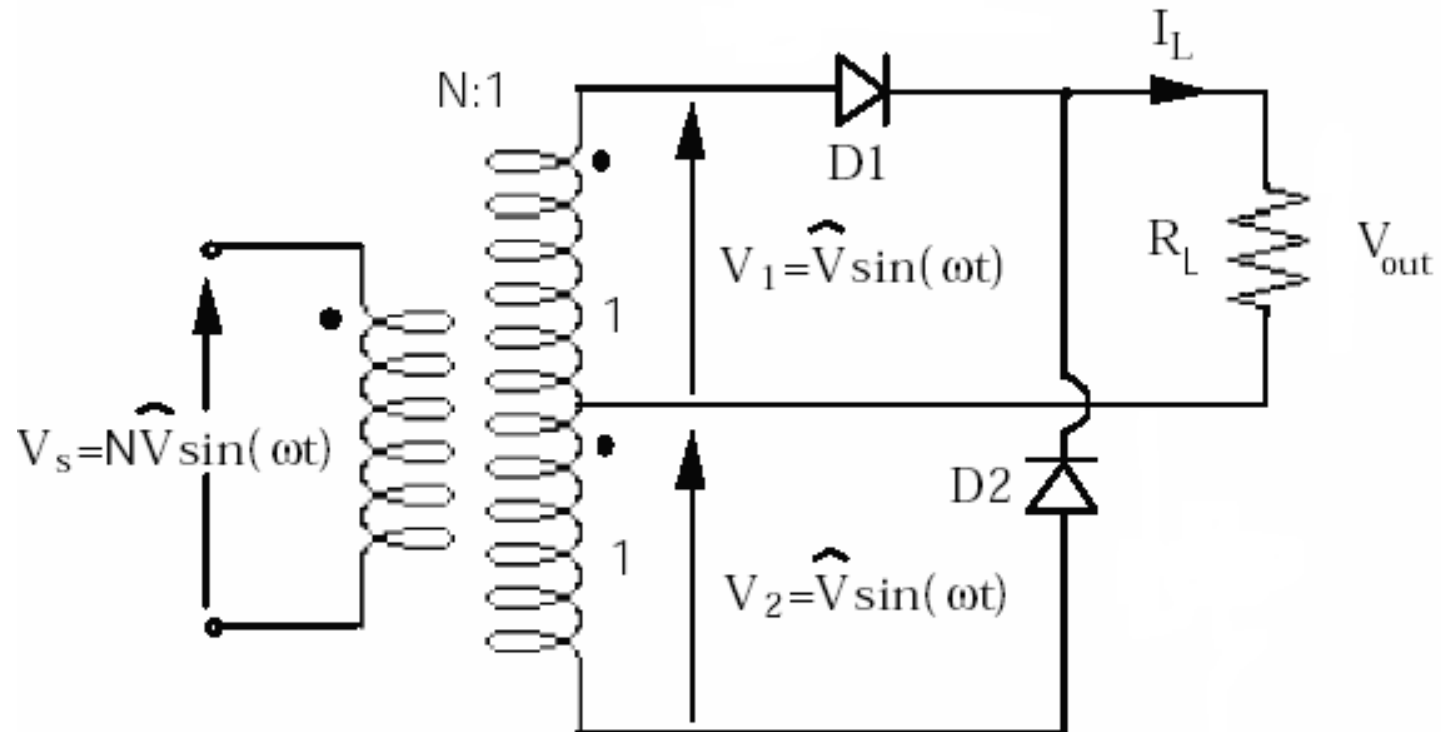
Motor Controllers



AC to DC Conversion: Half-Wave Rectifier



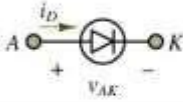
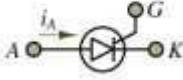
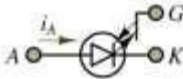
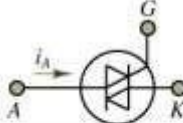
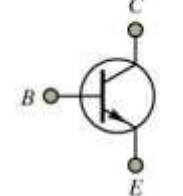
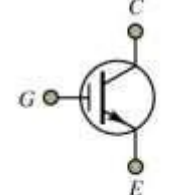
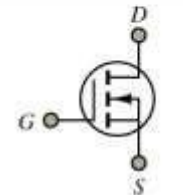
Full Wave Rectifier



Classification of Power Electronic Devices

The following is taken from Principles and Applications of Electrical Engineering by G. Rizzoni, McGraw Hill

Copyright © The McGraw-Hill Companies, Inc.
Permission required for reproduction or display.

Device	Device symbol
Diode	
Thyristor	
Gate turnoff thyristor (GTO)	
Triac	
<i>npn</i> BJT	
IGBT	
<i>n</i> -channel MOSFET	

Power Electric Circuits

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Circuit type

Essential features

Voltage regulators

Regulate a DC supply to a fixed voltage output

Power amplifiers

Large-signal amplification of voltages and currents

Switches

Electronic switches (e.g., transistor switches)

Diode rectifier

Converts fixed AC voltage (single- or multiphase) to fixed DC voltage

AC-DC converter (controlled rectifier)

Converts fixed AC voltage (single- or multiphase) to variable DC voltage

AC-AC converter (AC voltage controller)

Converts fixed AC voltage to variable AC voltage (single- or multiphase)

DC-DC converter (chopper)

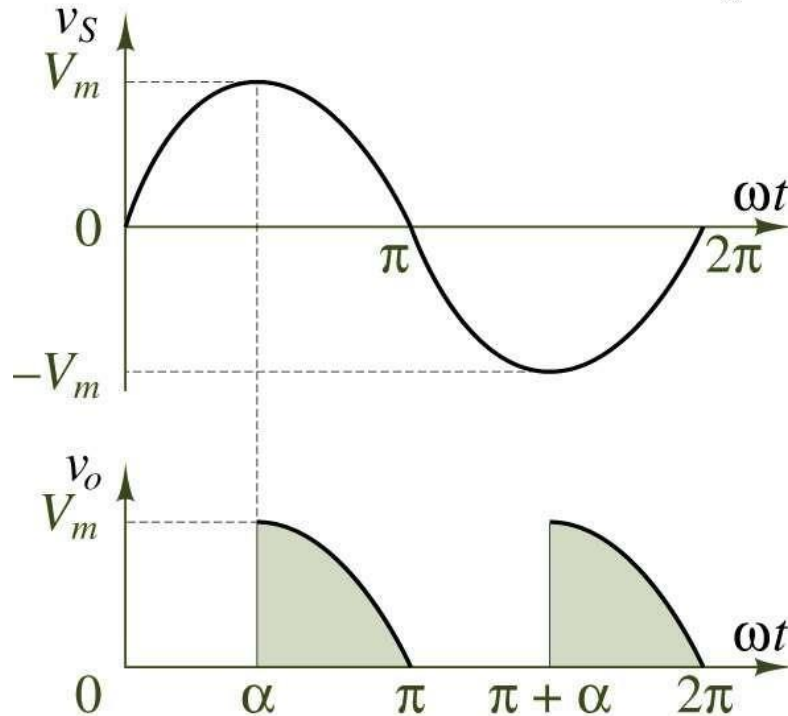
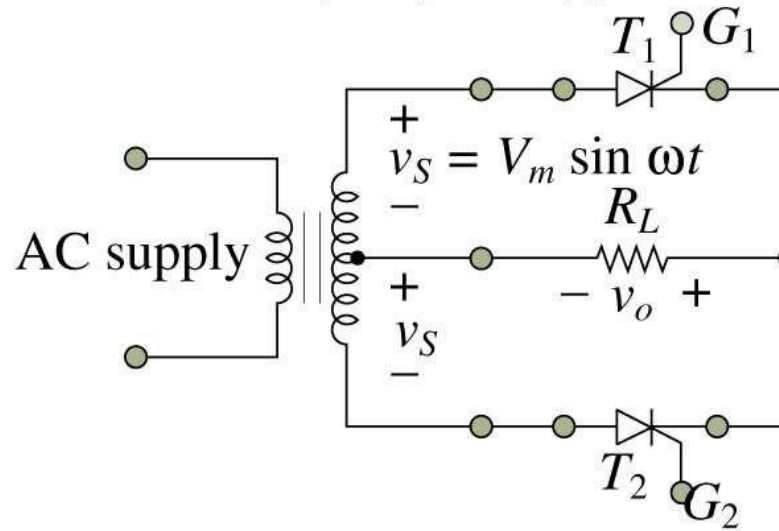
Converts fixed DC voltage to variable DC voltage

DC-AC converter (inverter)

Converts fixed DC voltage to variable AC voltage (single- or multiphase)

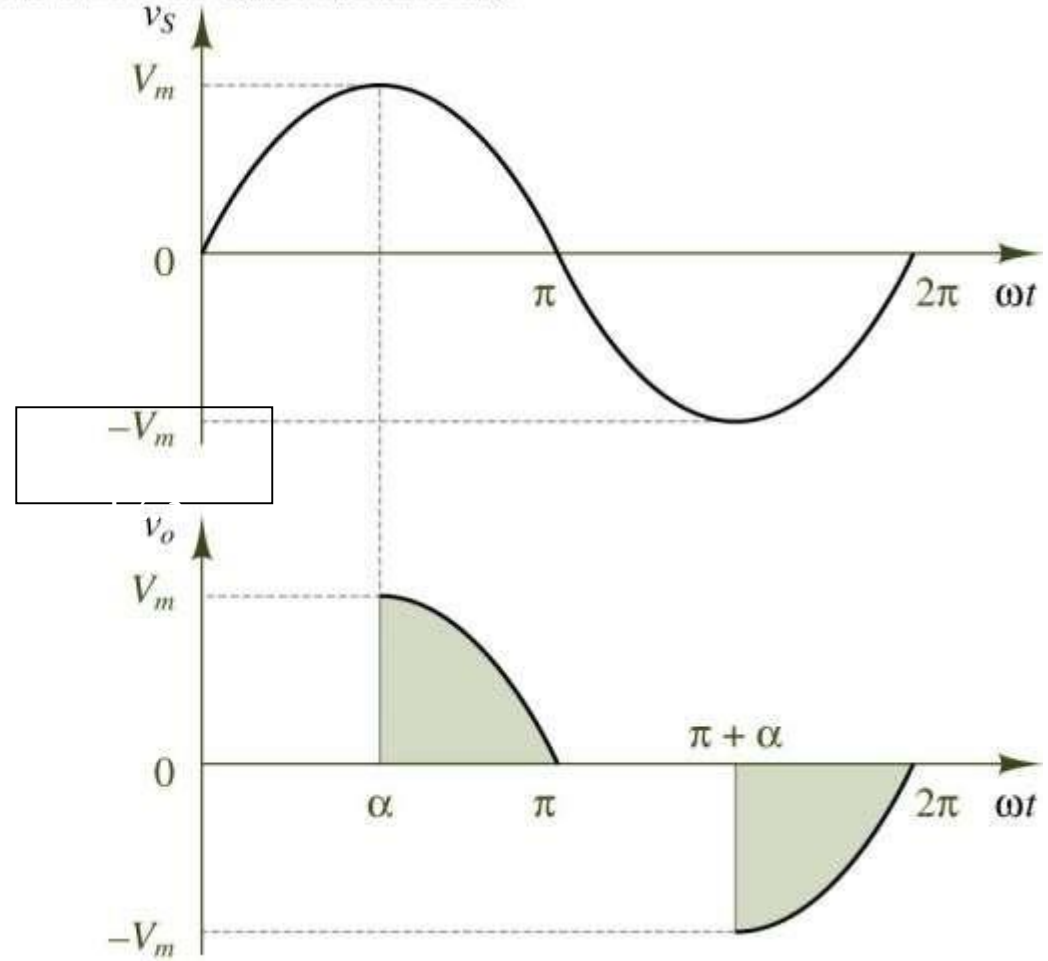
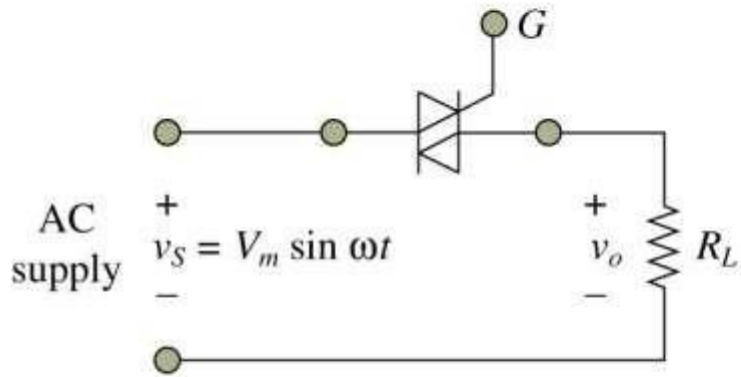
AC-DC Converter Circuit and Waveform

Copyright © The McGraw-Hill Companies, Inc.
Permission required for reproduction or display.



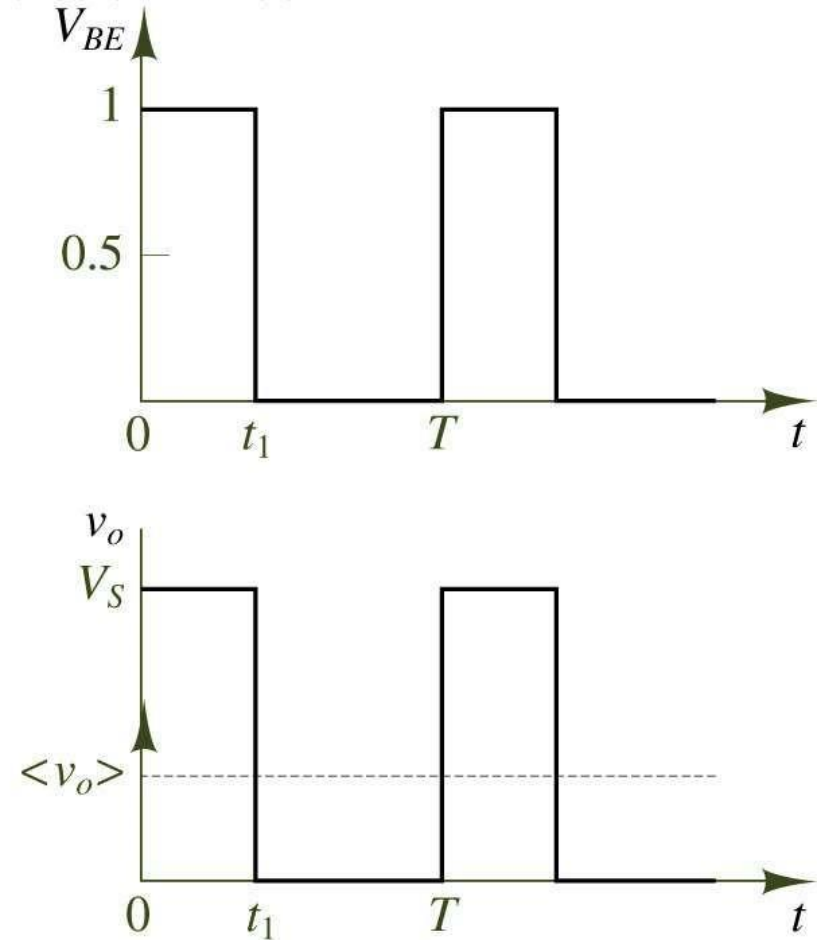
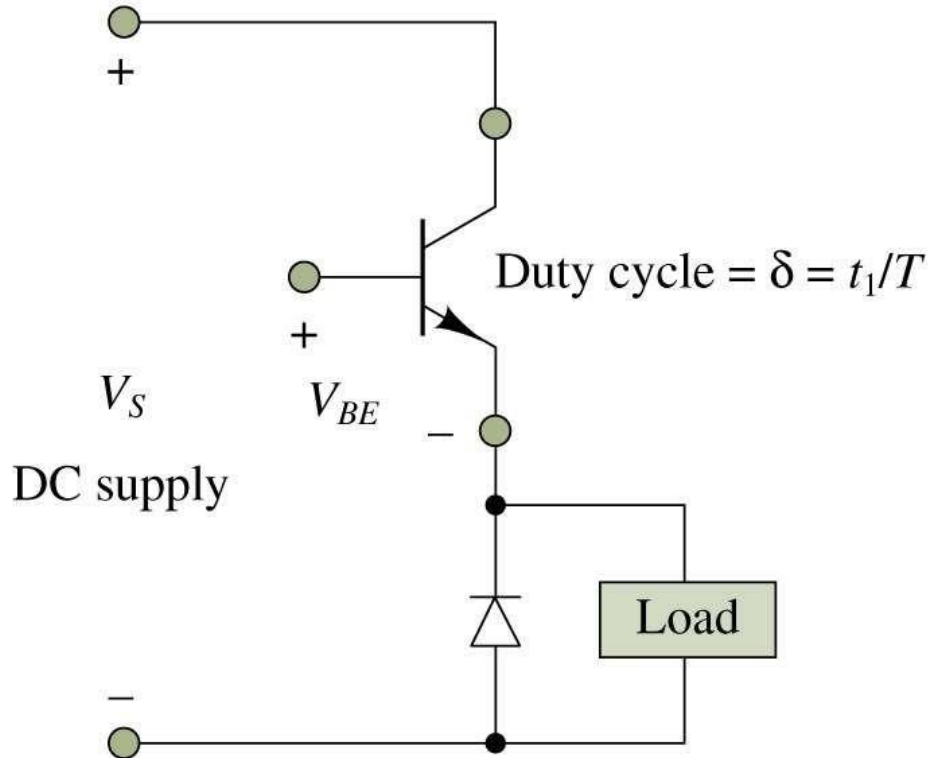
AC-AC Converter Circuit and Waveform

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



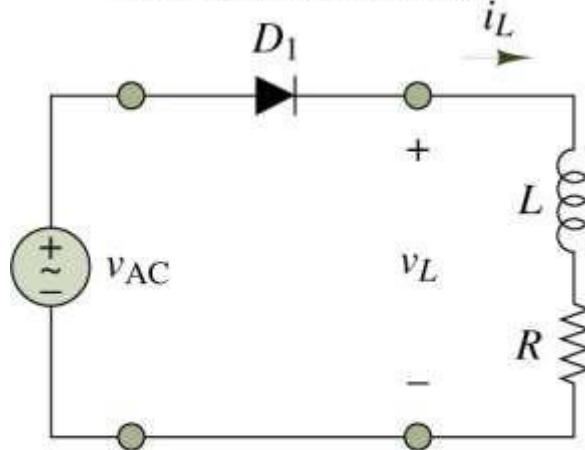
DC-DC Converter Circuit and Waveform

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

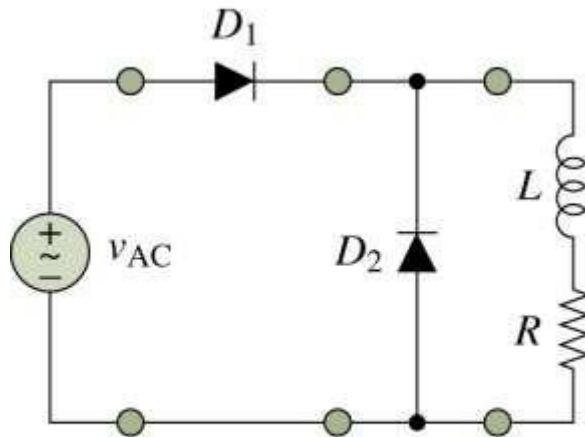


Rectifier Connected to an Inductive Load

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



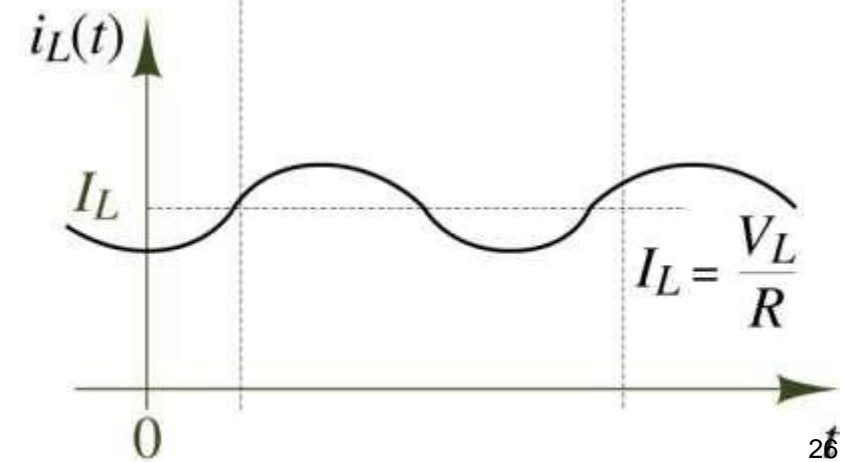
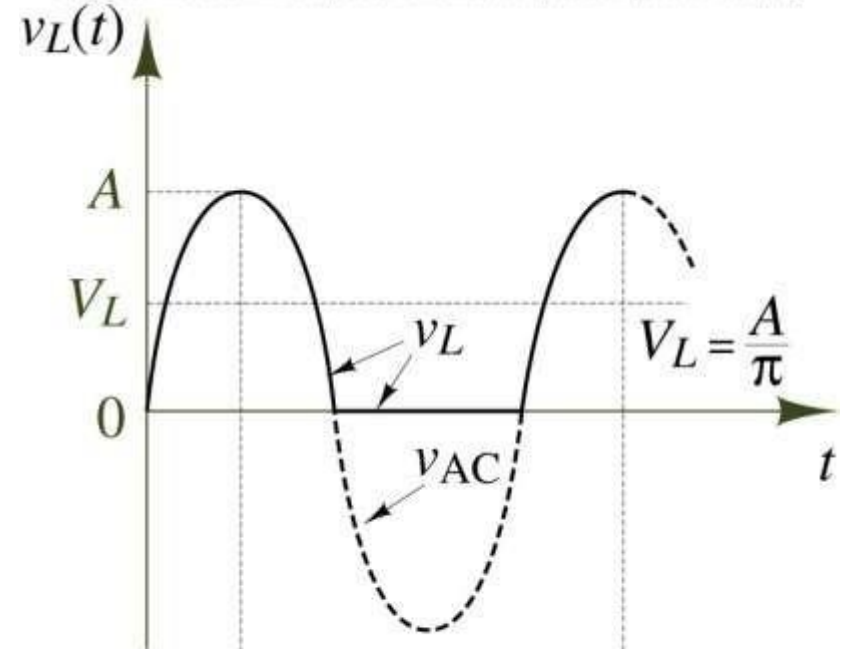
Simple half-wave rectifier



Same arrangement with freewheeling diode

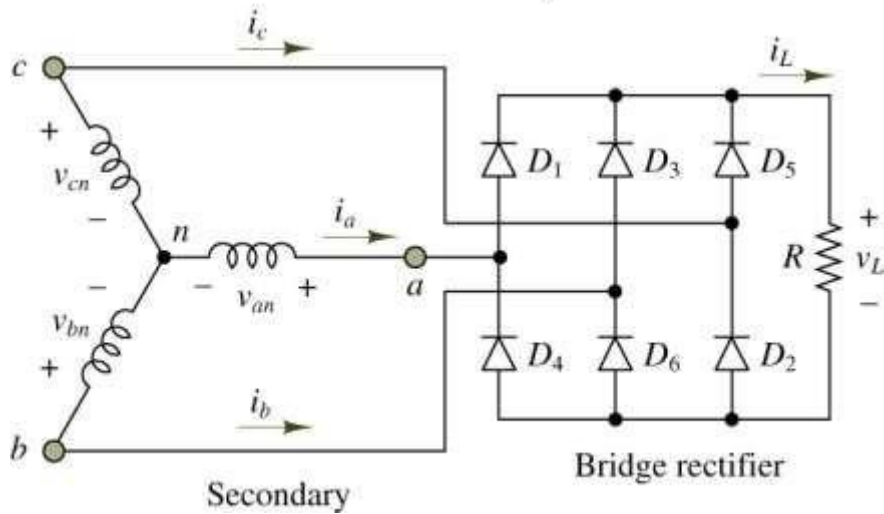
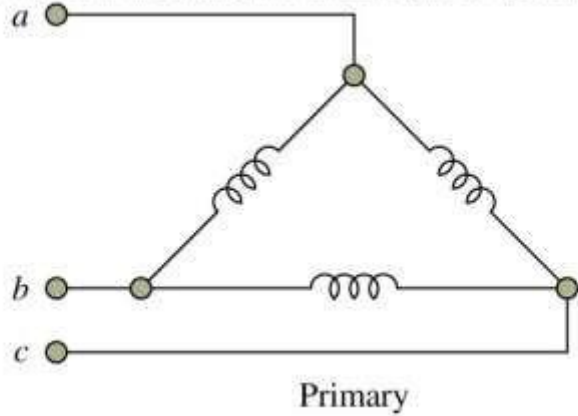
Operation of a Freewheeling Diode

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



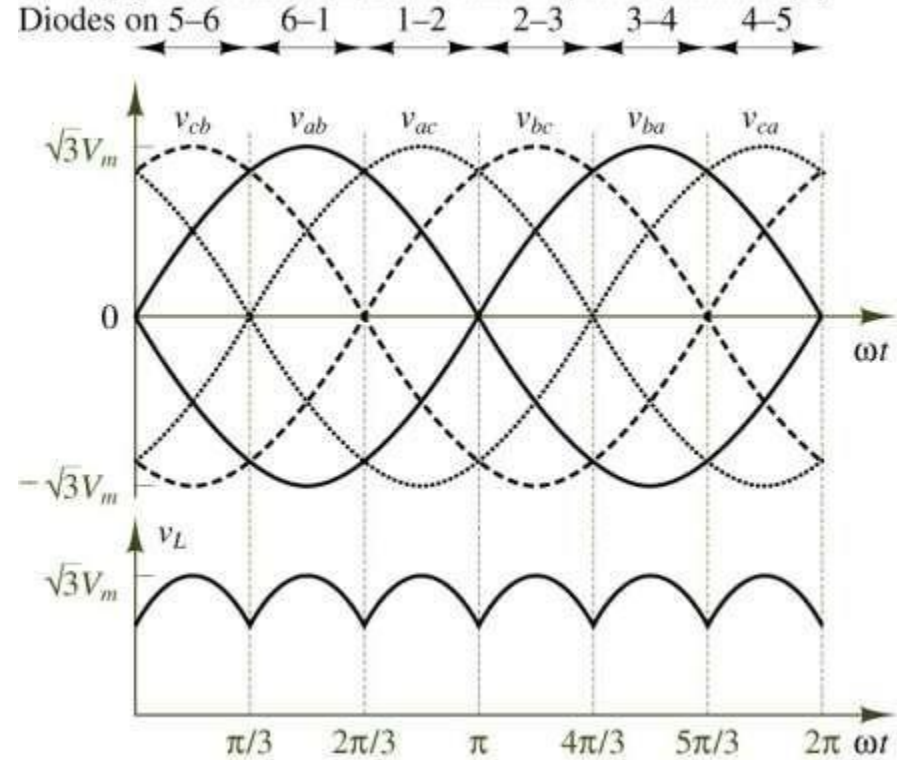
Three-Phase Diode Bridge Rectifier

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



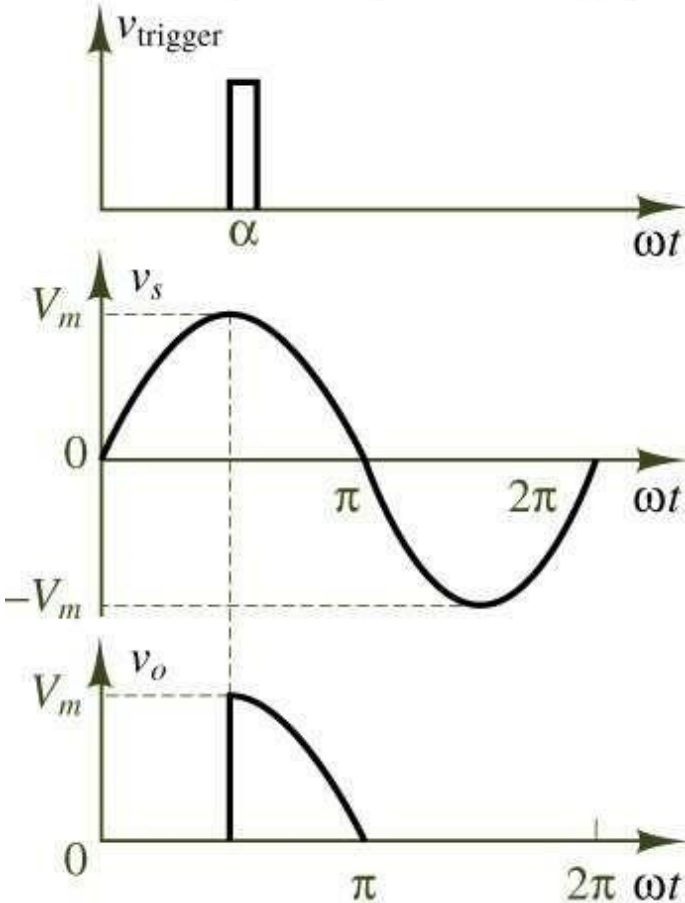
Waveforms and Conduction Times of Three-Phase Bridge Rectifier

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



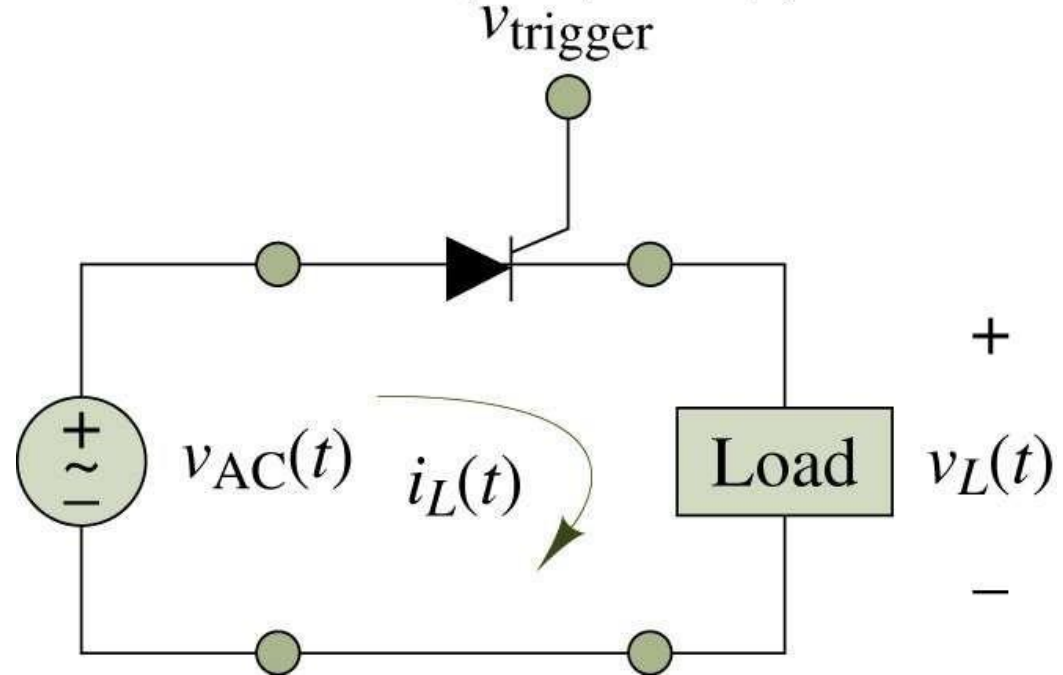
Half-Wave Controlled Rectifier Waveforms

Copyright © The McGraw-Hill Companies, Inc.
Permission required for reproduction or display.



Controlled Rectifier Circuit

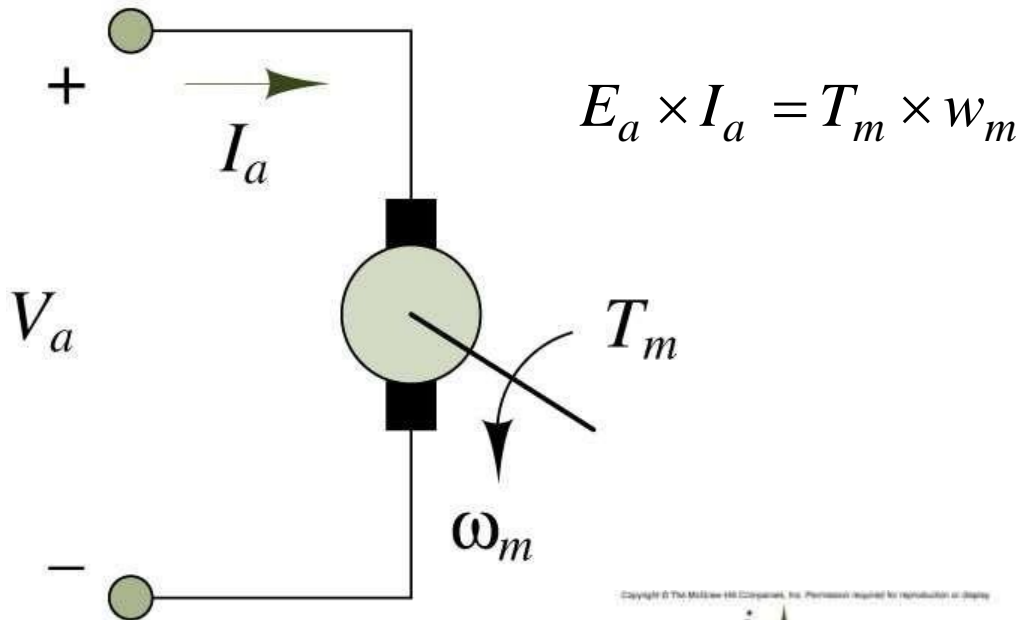
Copyright © The McGraw-Hill Companies, Inc.
Permission required for reproduction or display.



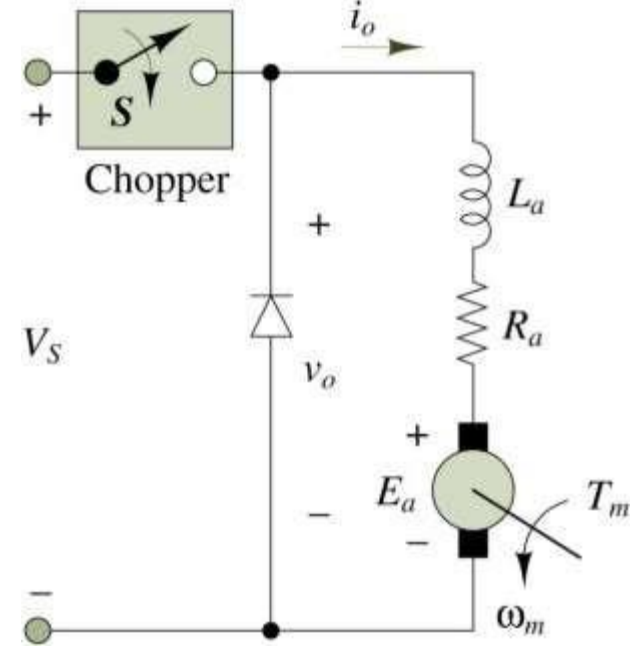
DC Motor

Step-Down Chopper (Buck Converter)

Copyright © The McGraw-Hill Companies, Inc.
Permission required for reproduction or display.



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

