

Power Electronic Systems

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

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

http://www.powerdesigners.com/InfoWeb/resources/pe_html/ch01/ch01_p1.htm

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

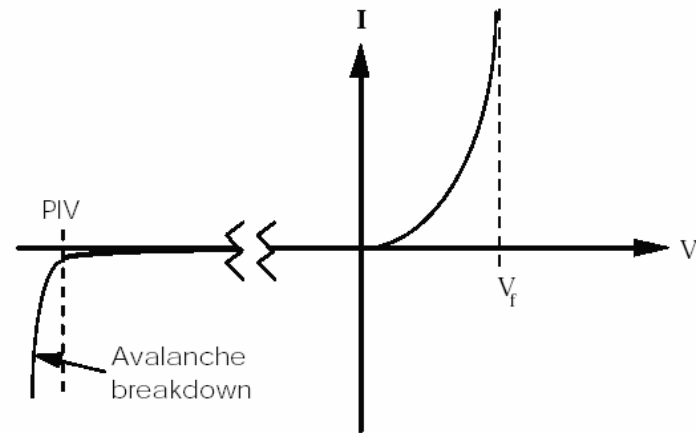
- Another universal power electronics application is the automobile's ignition system.
- Thousands of volts are required to ignite the fuel-air mixture inside a cylinder so that internal combustion can occur.
- Today's cars employ all-electronic ignition systems, which have replaced the traditional spark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

Hybrid Cars

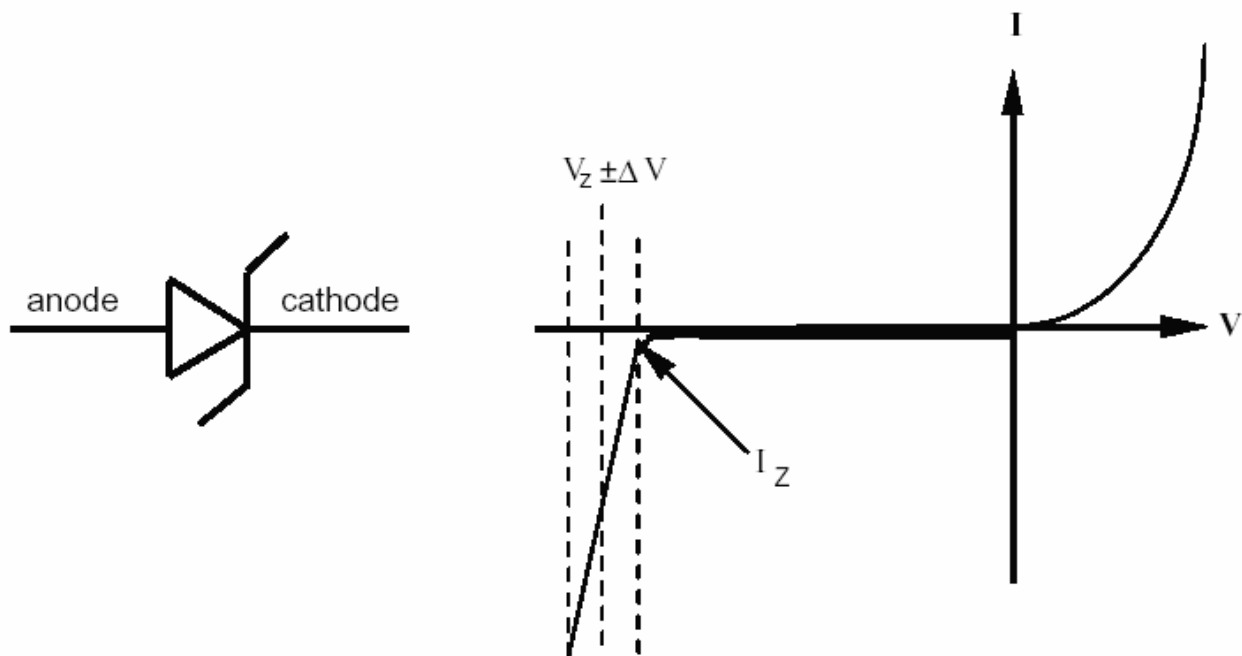
- We are curious about new electric and hybrid cars, in which the primary electrical system is dominated by power electronics. Electric cars offer high performance, zero tailpipe emissions, and low costs, but are still limited in range by the need for batteries.
- Hybrid car designs use various strategies 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

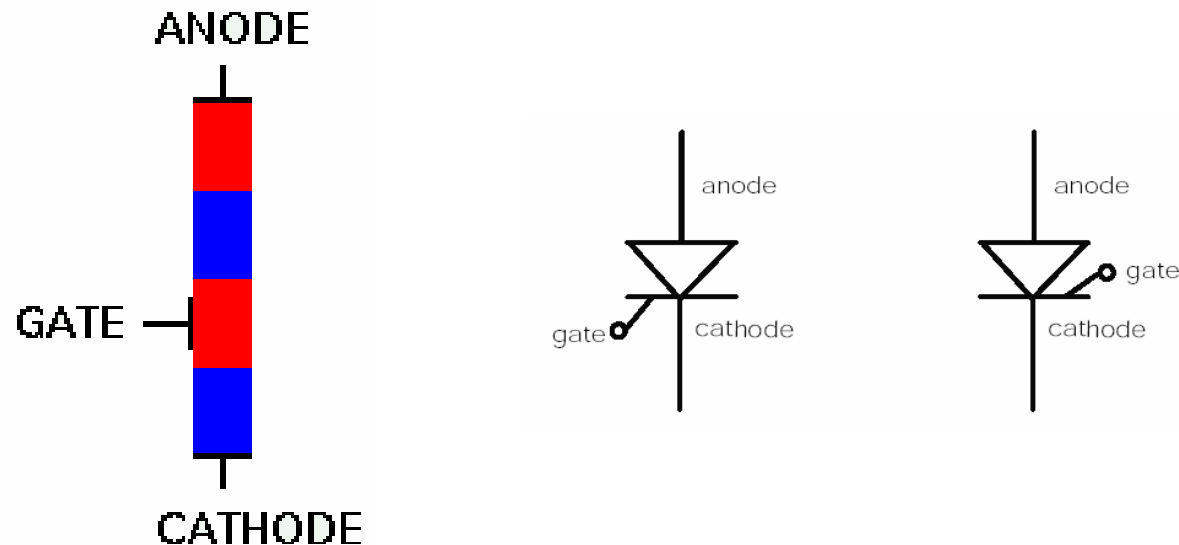


Zener Diodes



Silicon Controlled Rectifiers

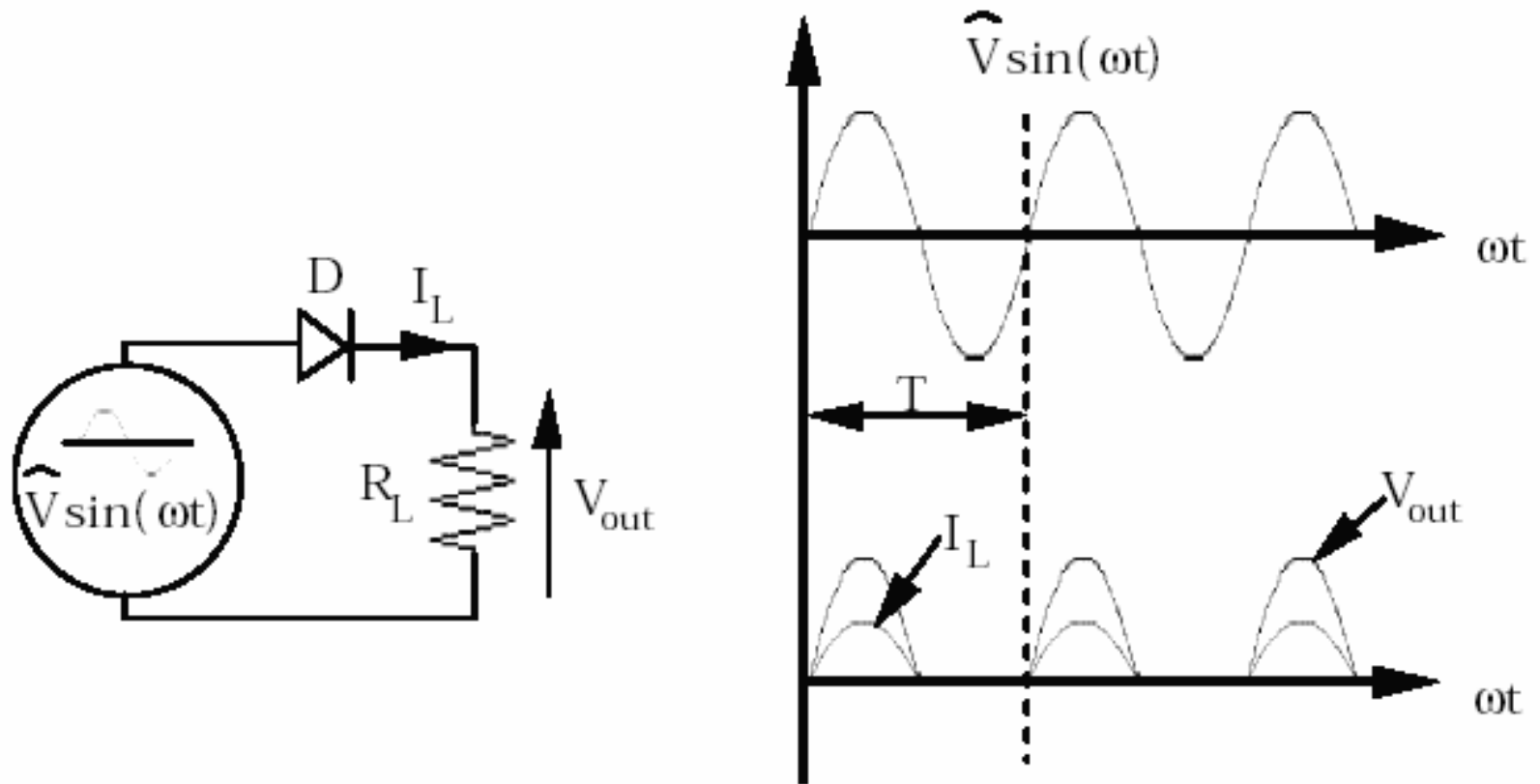
The basic purpose of the SCR is to function as a switch that can turn on or off small or large amounts of power. It performs this function with no moving parts that wear out and no points that require replacing. There can be a tremendous power gain in the SCR; in some units a very small triggering current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



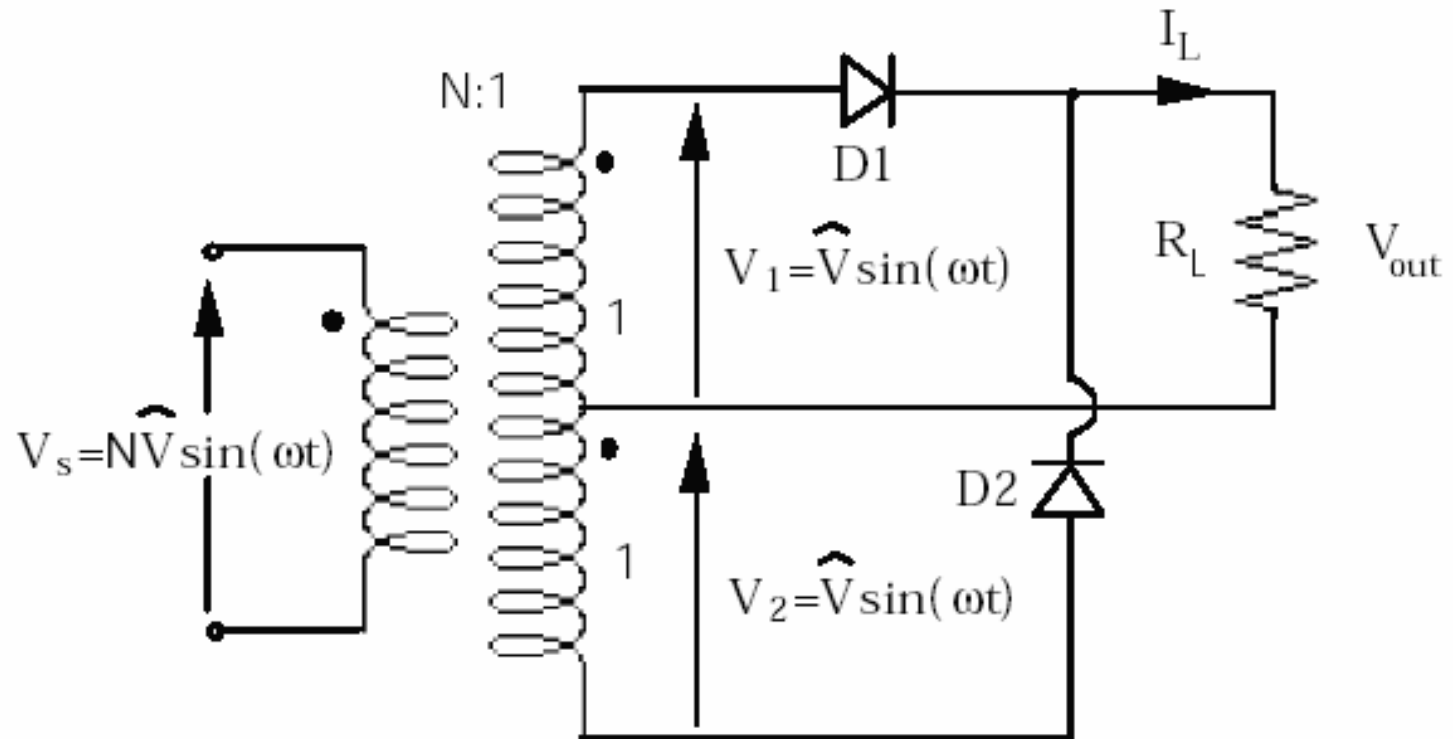
Motor Controllers



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

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

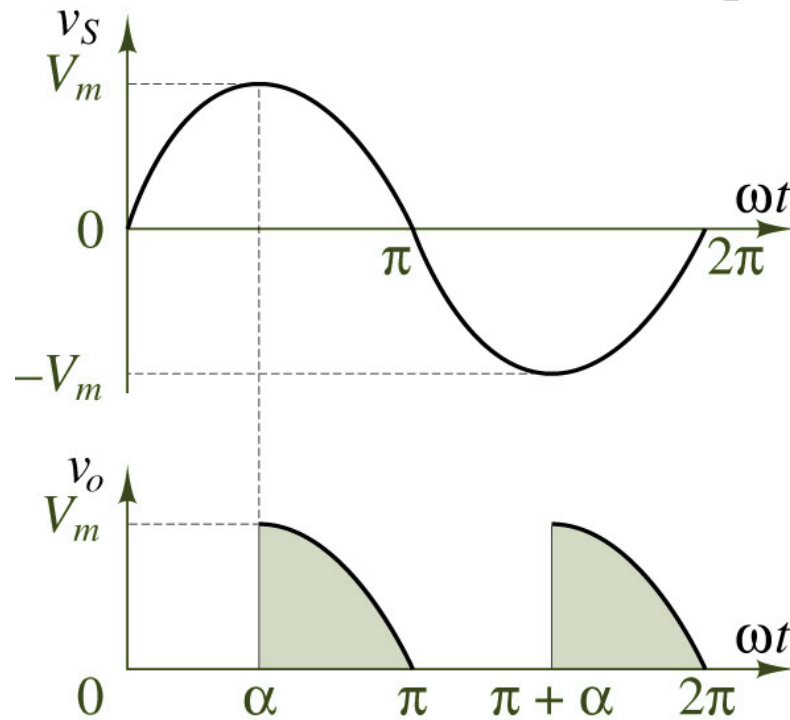
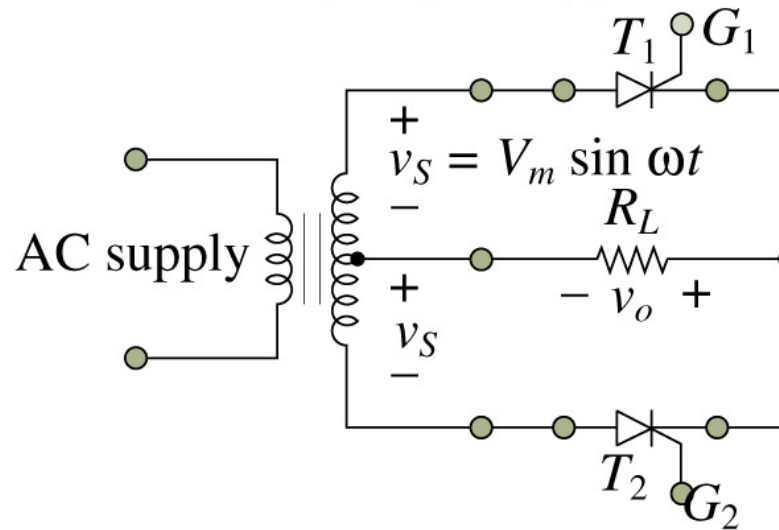
Power Electric Circuits

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| 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) |

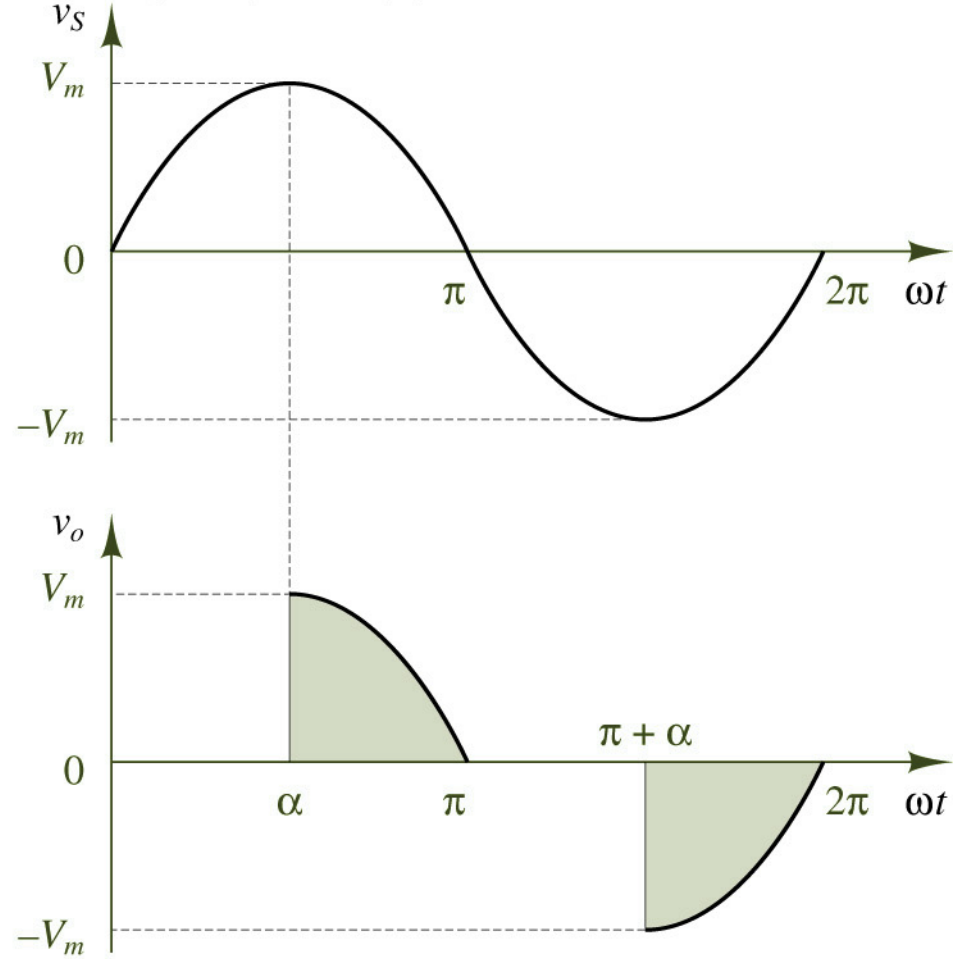
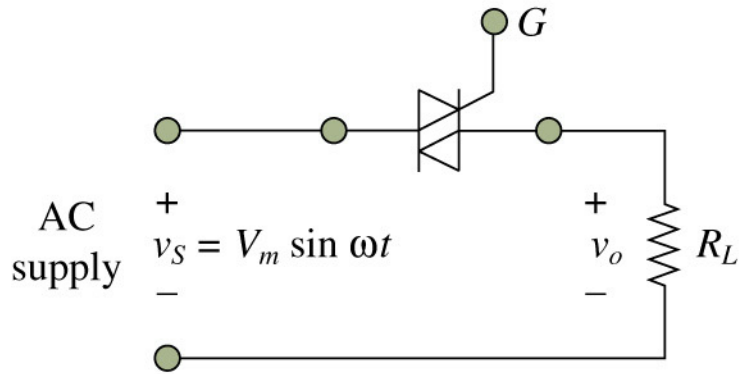
AC-DC Converter Circuit and Waveform

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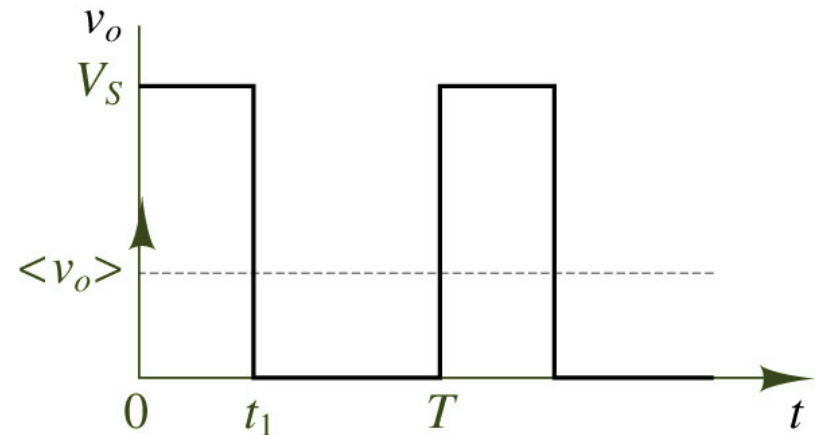
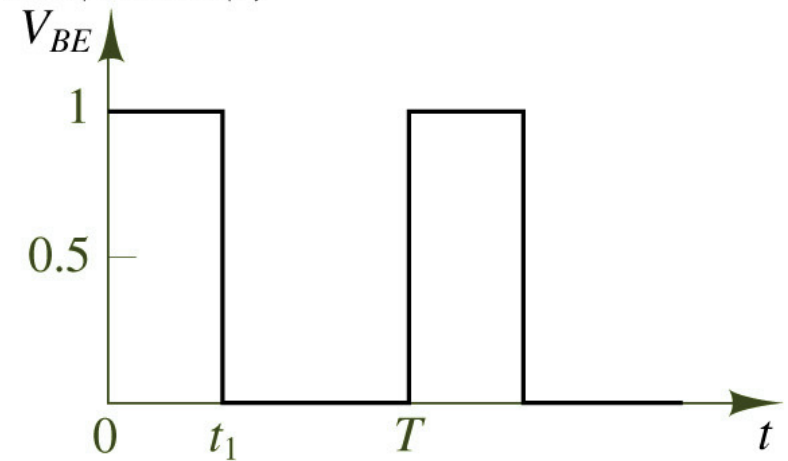
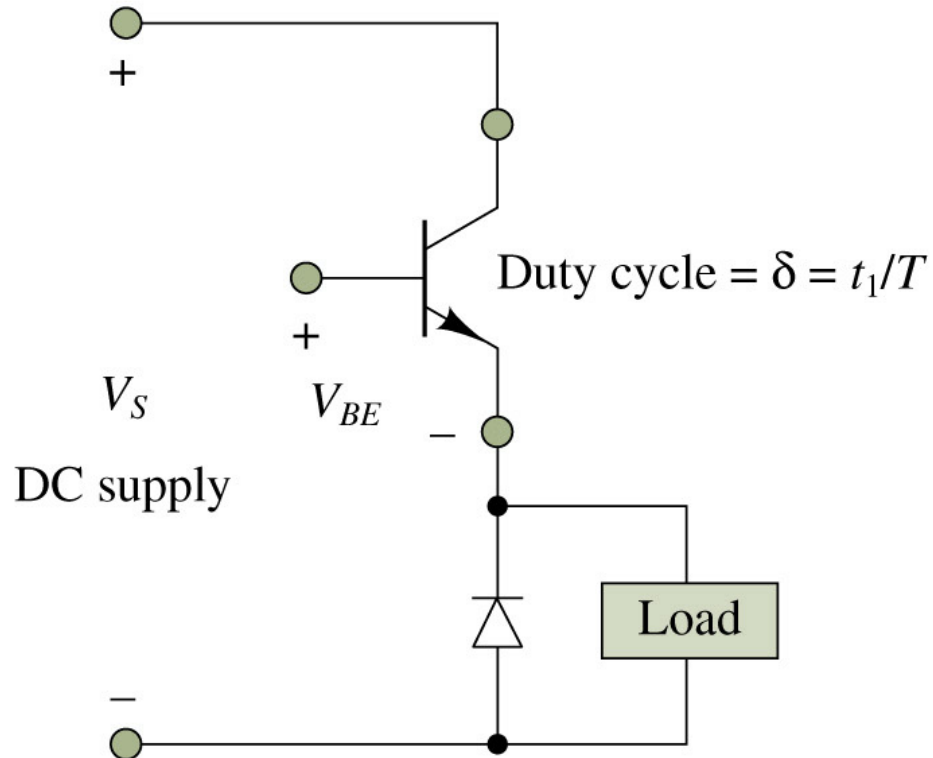
AC-AC Converter Circuit and Waveform

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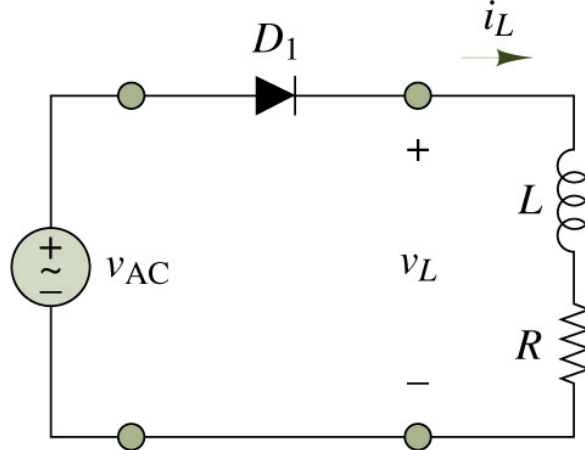
DC-DC Converter Circuit and Waveform

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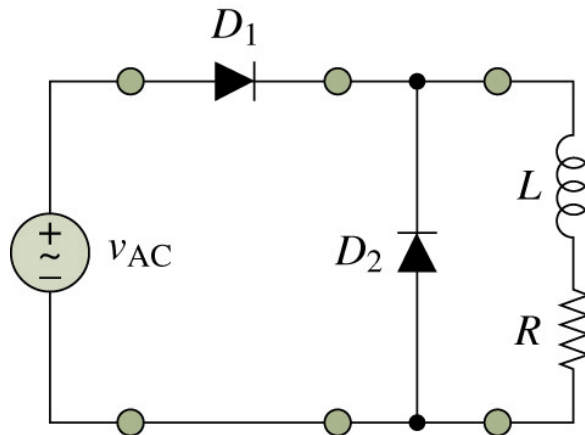


Rectifier Connected to an Inductive Load

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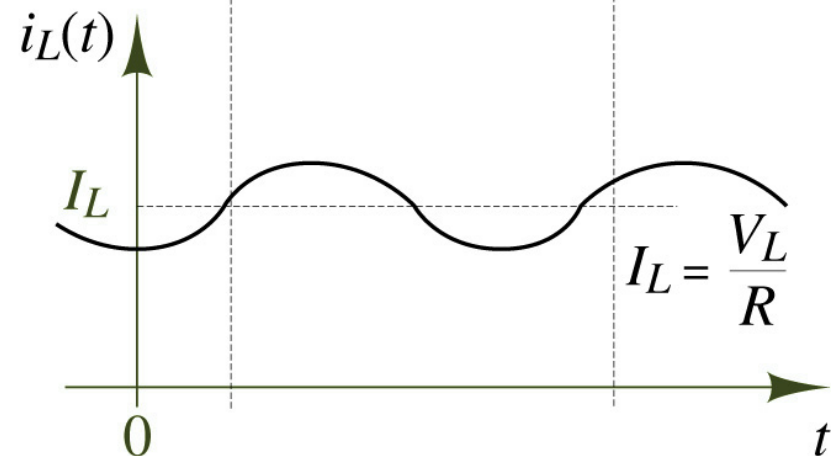
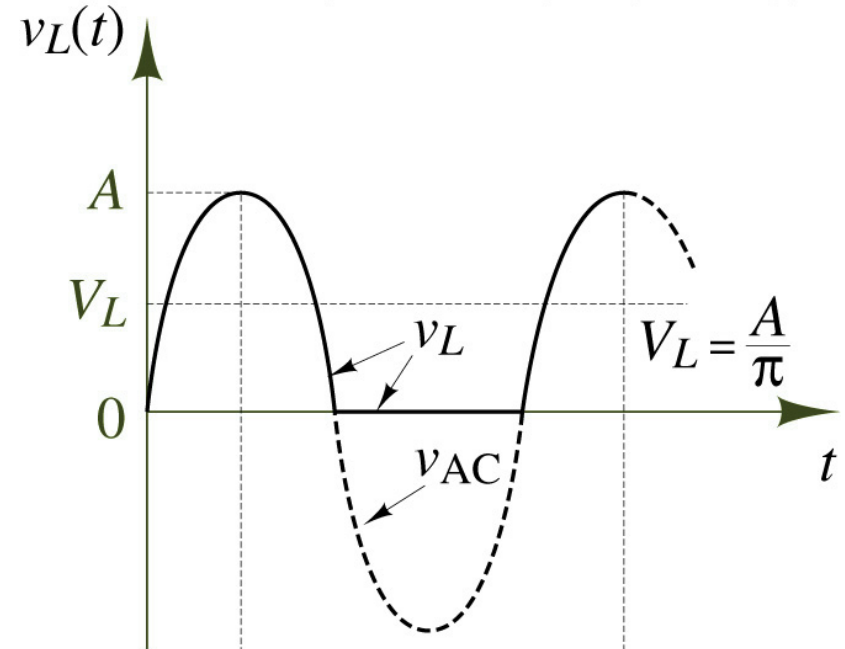
Simple half-wave rectifier



Same arrangement with freewheeling diode

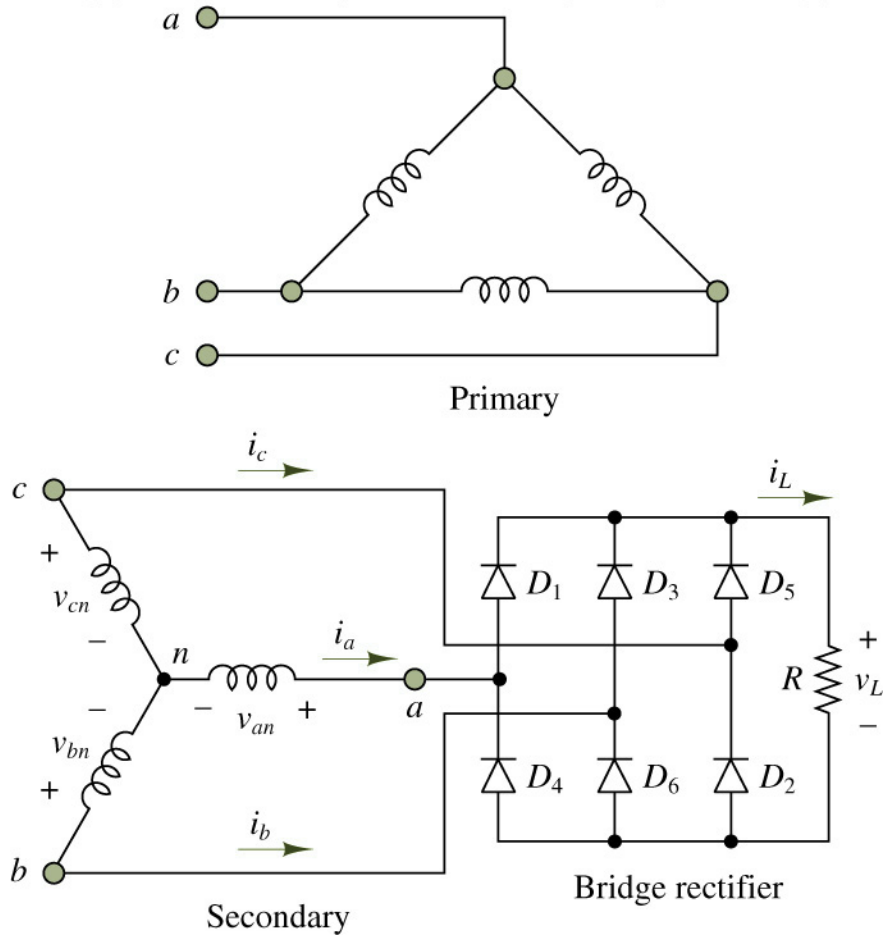
Operation of a Freewheeling Diode

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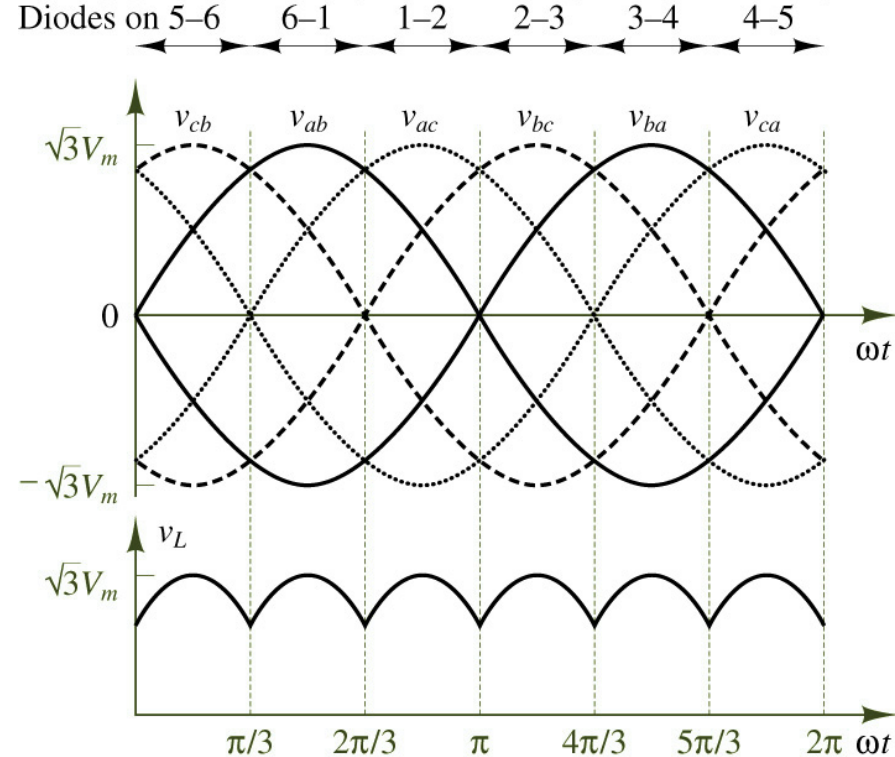
Three-Phase Diode Bridge Rectifier

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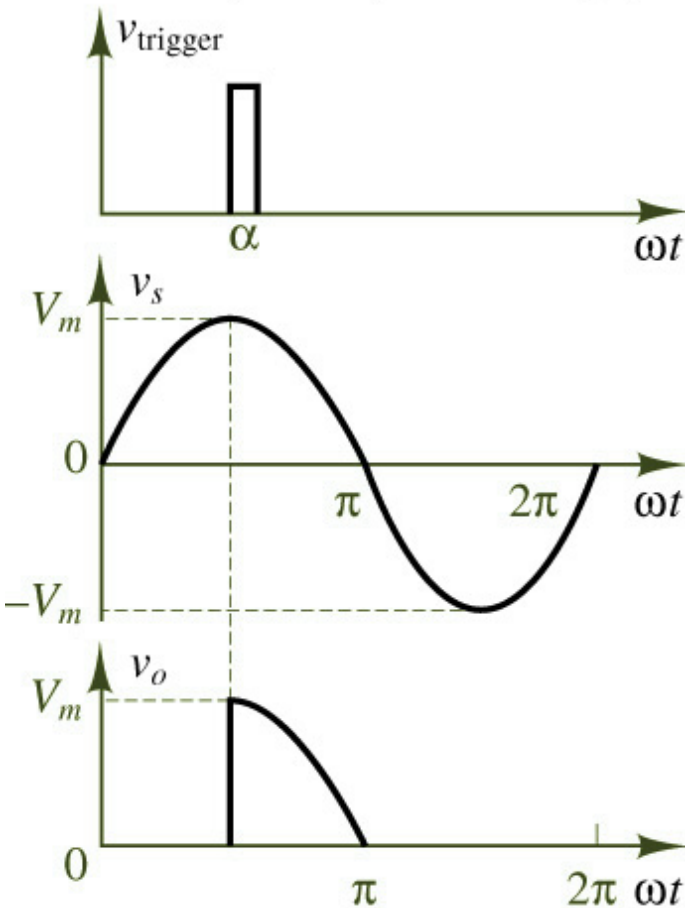
Waveforms and Conduction Times of Three-Phase Bridge Rectifier

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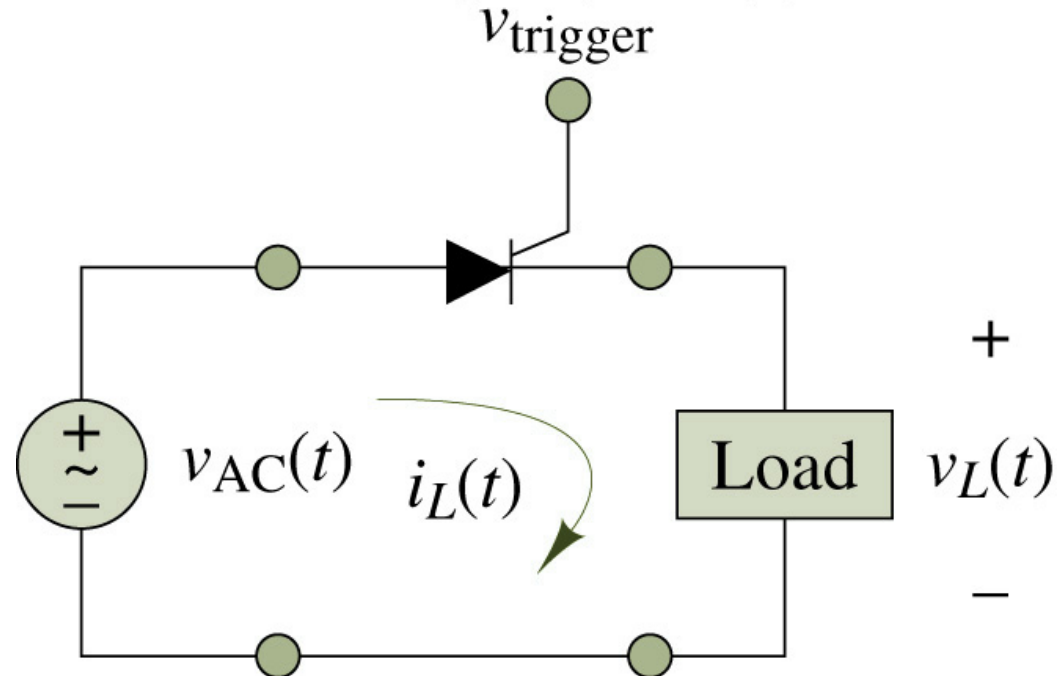
Half-Wave Controlled Rectifier Waveforms

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Controlled Rectifier Circuit

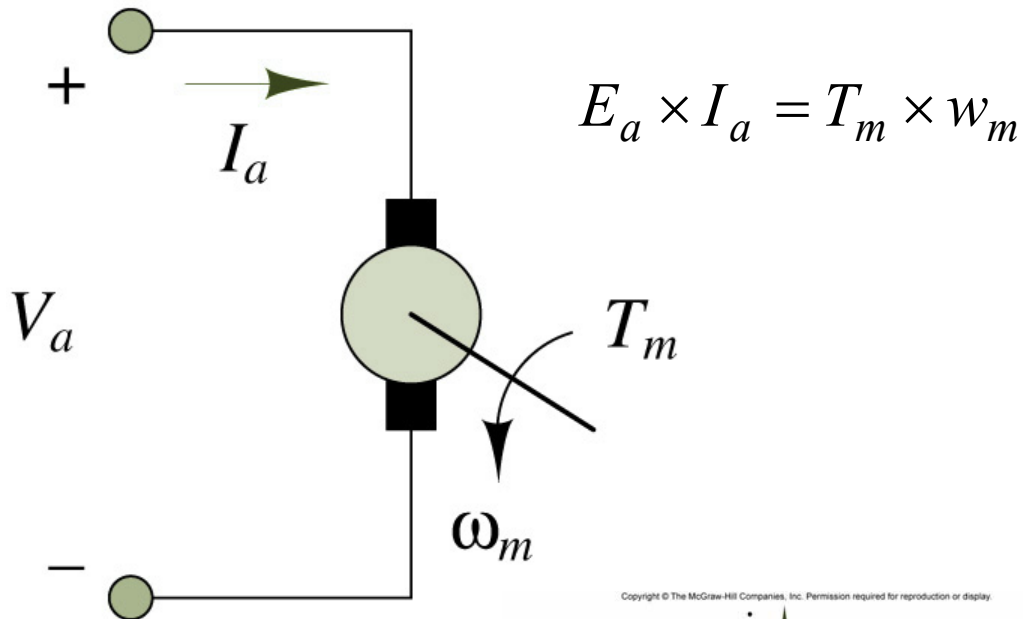
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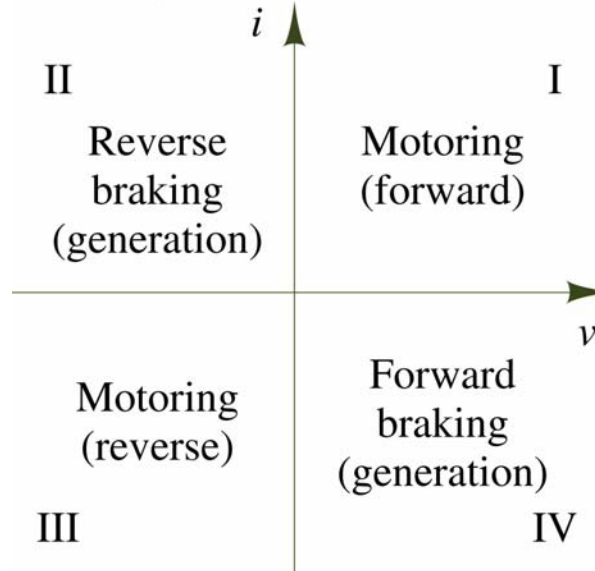
DC Motor

Step-Down Chopper (Buck Converter)

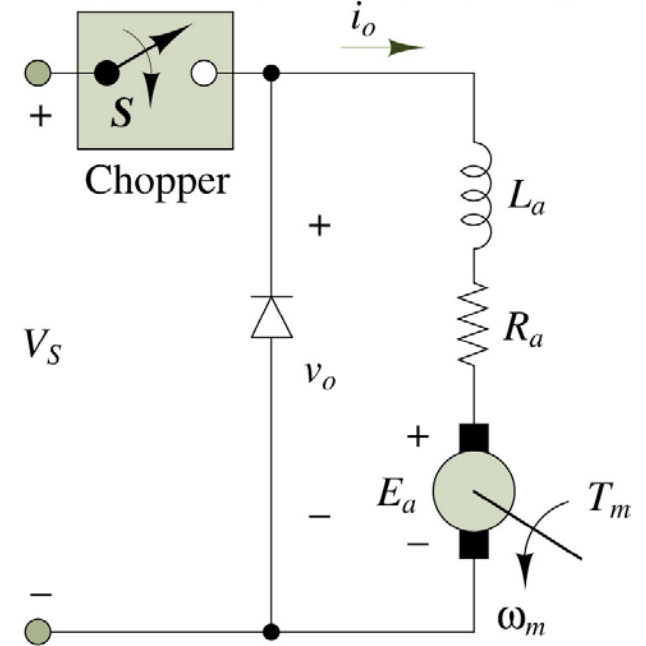
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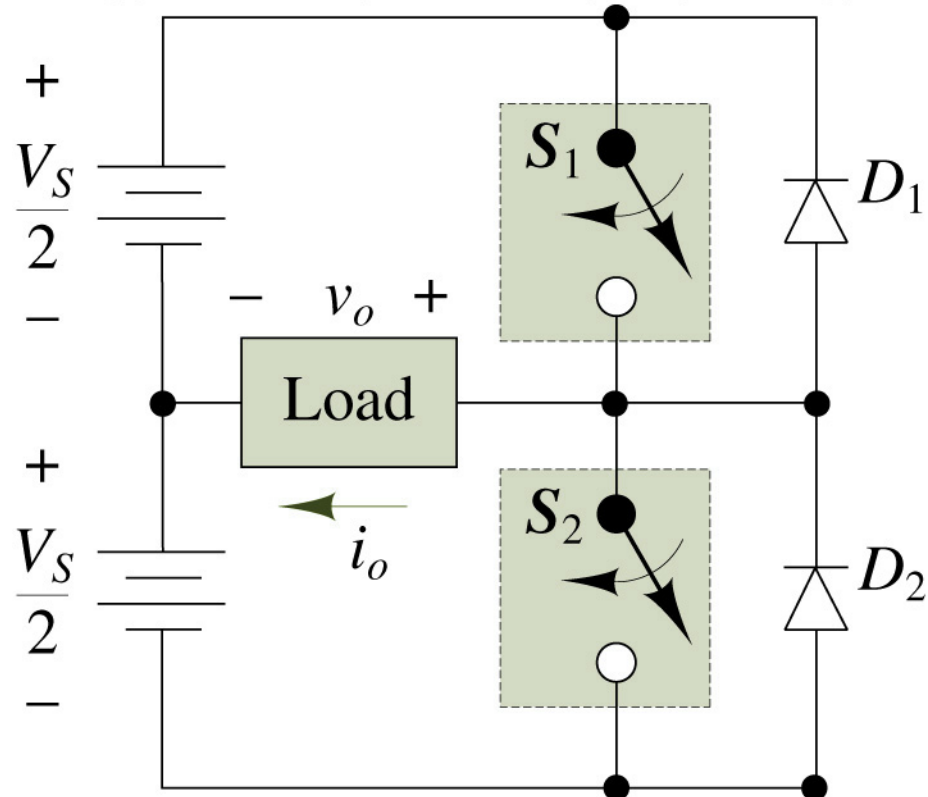


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Half-Bridge Voltage Source Inverter

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Half-Bridge Voltage Source Inverter Waveforms

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