



## **Chapter One**

# **Introduction**

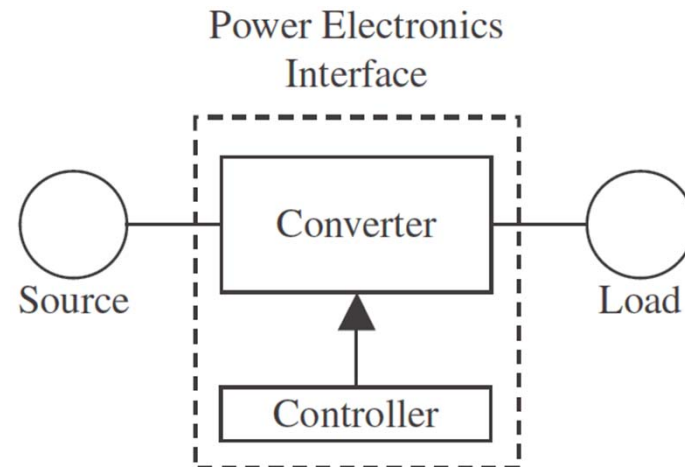
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# Power Electronics Technology

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- **Power electronics is an enabling technology, providing the needed interface between an electrical source and an electrical load**

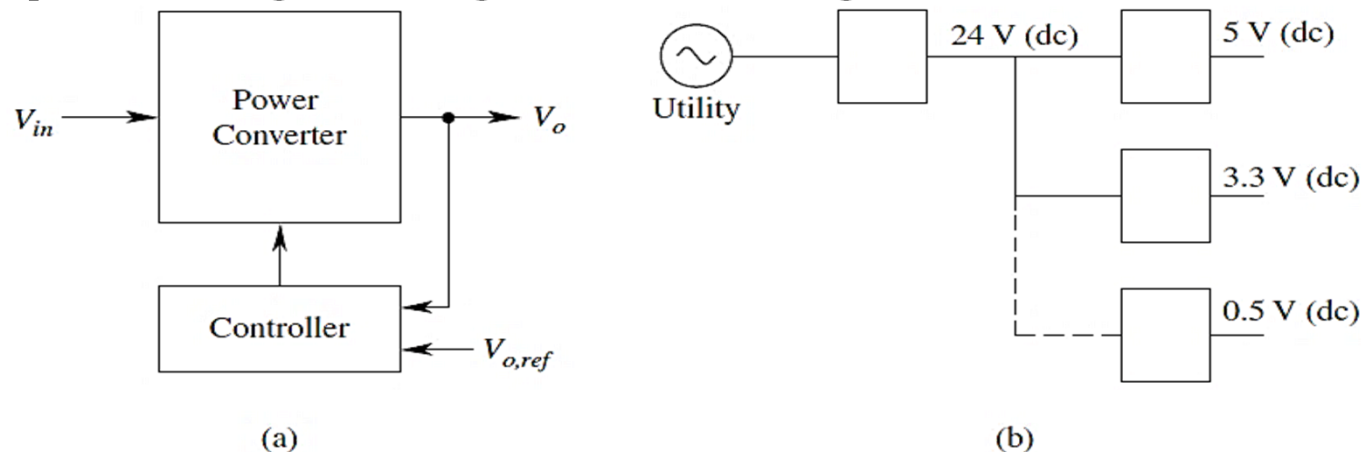


- **The electrical source and the electrical load can differ in frequency, voltage amplitudes, and the number of phases**
- **The power electronics interface facilitates the transfer of power from the source to the load by converting voltages and currents from one form to another, in which it is possible for the source and load to reverse roles**
- **The controller allows management of the power transfer process in which the conversion of voltages and currents should be achieved with as high energy-efficiency and high power density as possible.**
- **Adjustable-speed electric drives, for example in wind turbines, represent an important application of power electronics**

# Applications and Role of Power Electronics

## 1. Powering the information technology

- Most of the consumer electronics equipment such as personal computers (PCs) and entertainment systems supplied from the utility mains need very low dc voltages internally
- They require power electronics in the form of switch-mode dc power supplies for converting the input line voltage into a regulated low dc voltage



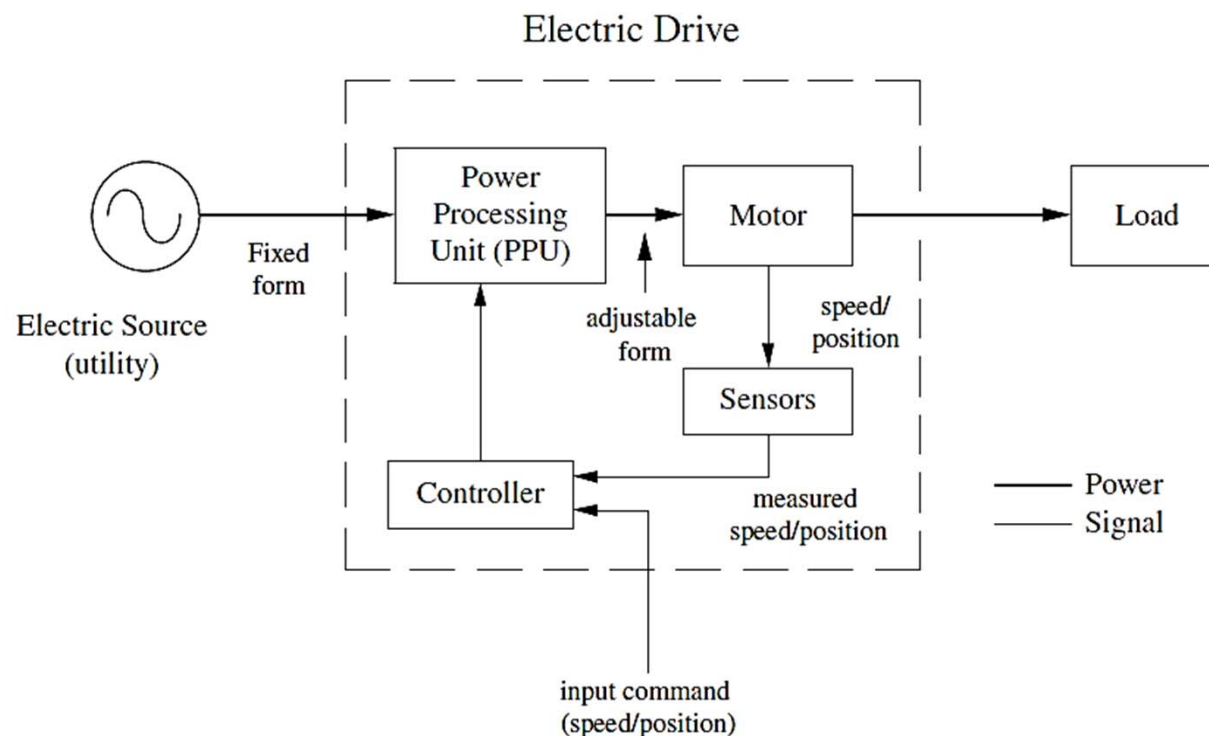
Regulated low-voltage dc power supplies

- Figures (a) and (b) shows the distributed architecture typically used in computers in which the incoming ac voltage from the utility is converted into dc voltage, for example, at 24 V.
- This semi-regulated voltage is distributed within the computer where on-board power supplies in logic-level printed circuit boards convert this 24V dc input voltage to a lower voltage, for example 5V dc, which is very tightly regulated.

# Applications and Role of Power Electronics Cont'd

## 2. Powering the information technology

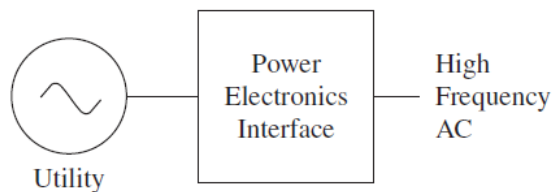
- Robotics and flexible production are now essential to industrial competitiveness in a global economy.
- These applications require adjustable-speed drives for precise speed and position control.
- The following block diagram shows adjustable-speed drives in which the ac input from a 1-phase or a 3-phase utility source is at the line frequency of 50 or 60 Hz.



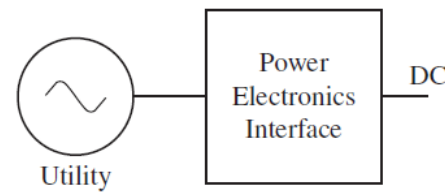
**Block diagram of adjustable-speed drives**

# Applications and Role of Power Electronics Cont'd

- The role of the power electronics interface, as a power-processing unit, is to provide the required voltage to the motor.
- In the case of a dc motor, dc voltage is supplied with adjustable magnitude that controls the motor speed.
- In the case of an ac motor, the power electronics interface provides sinusoidal ac voltages with adjustable amplitude and frequency to control the motor speed.
- In certain cases, the power electronics interface may be required to allow bi-directional power flow through it, between the utility and the motor-load.
- Induction heating and electric welding, the following figures show their block diagrams, are other important industrial applications of power electronics for flexible production.



Power electronics interface required for induction heating.

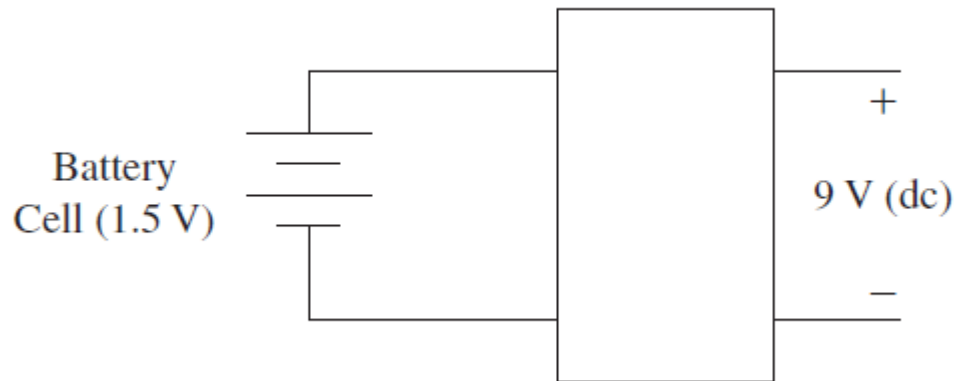


Power electronics interface required for electric welding.

# *Applications and Role of Power Electronics Cont'd*

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- **Very large-scale integration and higher logic circuitry speed require operating voltages much lower than 5 V, hence 3.3 V, 1 V, and eventually, 0.5V levels would be needed.**
- **Many devices such as cell phones operate from low battery voltages with one or two battery cells as inputs.**
- **However, the electronic circuitry within them requires higher voltages, thus necessitating a circuit to boost input dc to a higher dc voltage as shown in the following block diagram**

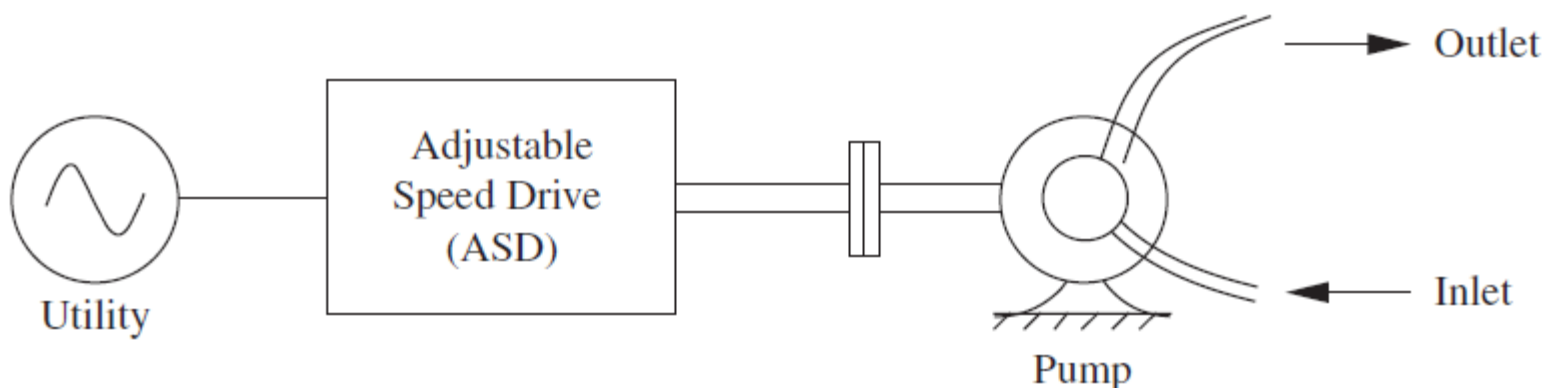


**Boost dc-dc converter needed in cell operated equipment**

# Applications and Role of Power Electronics Cont'd

## 3. Electric-Motor Driven Systems

- Traditionally, motor-driven systems run at a nearly constant speed and their output, for example, flow rate in a pump, is controlled by wasting a portion of the input energy across a throttling valve.
- This waste is eliminated by an adjustable-speed electric drive by efficiently controlling the motor speed, hence the pump speed, by means of power electronics.
- One out of three new homes in the United States now uses an electric heat pump, in which an adjustable-speed drive can reduce energy consumption by as much as 30% by eliminating on-off cycling of the compressor and running the heat pump at a speed that matches the thermal load of the building. The same is true for air conditioners.



**Role of adjustable-speed drives in pump-driven systems**

# *Applications and Role of Power Electronics Cont'd*

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## **4. Lighting**

- **Traditionally, approximately one-fifth of electricity produced is used for lighting.**
- **Fluorescent lights are more efficient than incandescent lights by a factor of three to four.**
- **The efficiency of fluorescent lights can be further improved by using high-frequency power electronic ballasts that supply 30 kHz to 40 kHz to the light bulb, further increasing the efficiency by approximately 15%.**
- **Compared to incandescent light bulbs, high-frequency compact fluorescent lamps (CFLs) improve efficiency by a factor of nearly four, last much longer (several thousand hours more), and their cost, although high in the past has become highly affordable.**
- **At present, there is a great deal of excitement about LED (Light-Emitting Diode) lighting.**
- **However, LED lights must have higher efficiencies and longer lifetime to offset their higher initial cost.**



# *Applications and Role of Power Electronics Cont'd*

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## **5. Transportation**

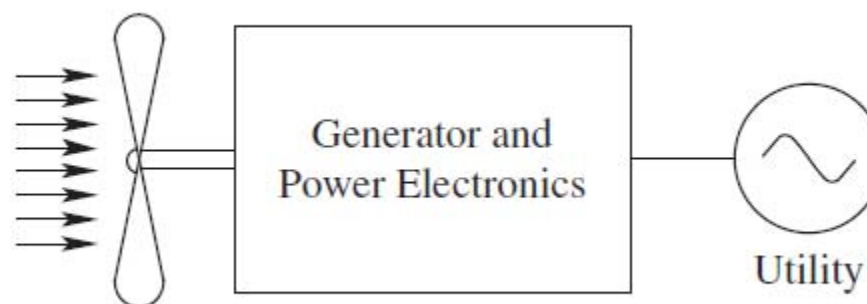
- **Electric drives offer huge potential for energy conservation in transportation.**
- **While efforts to introduce commercially-viable Electric Vehicles (EVs) continue with progress in battery and fuel cell technologies being reported, hybrid electric vehicles (HEVs) are sure to make a huge impact.**
- **According to the U.S. Environmental Protection Agency, the estimated gas mileage of the hybrid-electrical vehicle in combined city and highway driving is 48 miles per gallon.**
- **This is in comparison to the gas mileage of 22.1 miles per gallon for an average passenger car.**
- **Since automobiles are estimated to account for about 20% of emission of all CO<sub>2</sub> that is a greenhouse gas, doubling the gas mileage of automobiles would have an enormous positive impact.**
- **Conventional automobiles need power electronics for various applications EVs and HEVs, of course, need power electronics in the form of adjustable-speed electric drives.**
- **Add to automobiles other transportation systems, such as light rail, fly-by-wire planes, all-electric ships, and drive-by-wire automobiles, and transportation represents a major application area of power electronics.**

# Applications and Role of Power Electronics Cont'd

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## 6. Renewable Energy

- Clean and renewable energy that is environmentally friendly can be derived from the sun and the wind.
- In photovoltaic systems, solar cells produce dc, with an i-v characteristic that requires a power electronics interface to transfer power to the utility system.
- Wind is the fastest-growing energy resource with enormous potential the need of power electronics in wind-electric systems to interface variable-frequency ac to the line-frequency ac voltages of the utility grid.



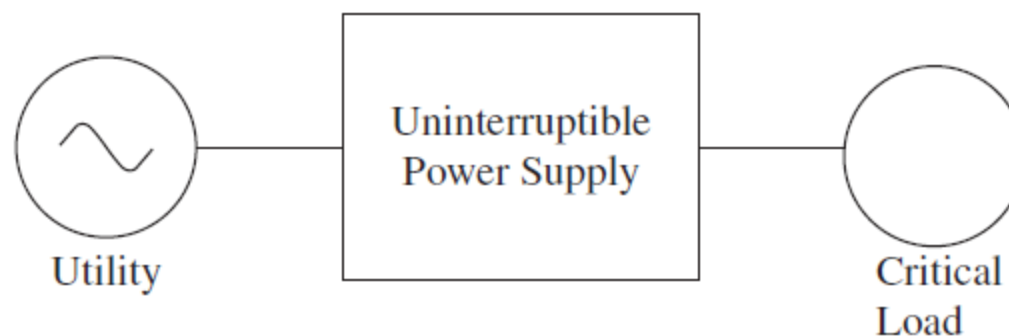
**Wind-electric systems**

# *Applications and Role of Power Electronics Cont'd*

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## **7. Uninterruptible Power Supplies (UPS)**

- **Uninterruptible power supplies (UPS) are used for critical loads that must not be interrupted during power outages.**
- **The power electronics interface for UPS has line-frequency voltages at both ends, although the number of phases may be different, and a means for energy storage is provided usually by batteries, which supply power to the load during the utility outage.**



**Uninterruptible power supply (UPS) system**

# *Applications and Role of Power Electronics Cont'd*

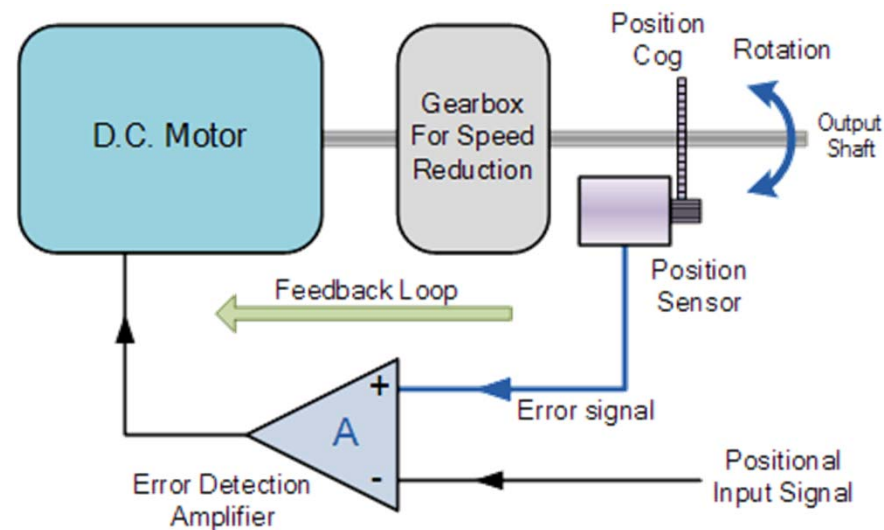
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## **8. Space and Defense Applications**

- **Power electronics is essential for space exploration and for interplanetary travel.**
- **Defense has always been an important application.**
- **Power electronics will play a huge role in tanks, ships, and planes in which replacement of hydraulic drives by electric drives can offer significant cost, weight and reliability advantages.**

# The DC Servo Moto

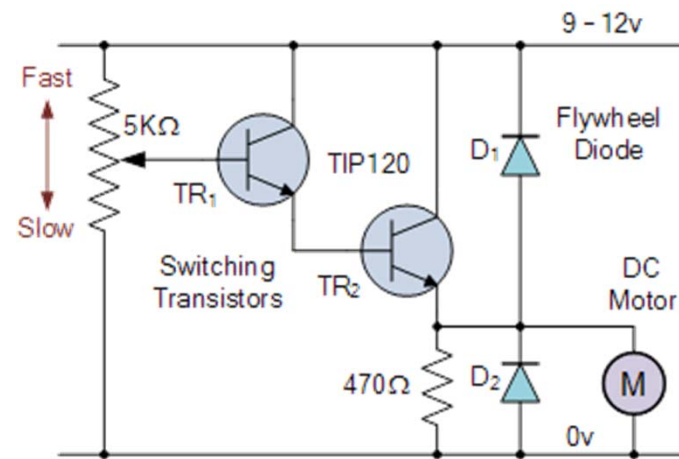
- DC Servo motors are used in closed loop type applications where the position of the output motor shaft is fed back to the motor control circuit. Typical positional “Feedback” devices include Resolvers, Encoders and Potentiometers as used in radio control models such as aeroplanes and boats etc.
- A servo motor generally includes a built-in gearbox for speed reduction and is capable of delivering high torques directly. The output shaft of a servo motor does not rotate freely as do the shafts of DC motors because of the gearbox and feedback devices attached.



**DC Servo Motor Block Diagram**

# DC Motor Switching and Control

- Small DC motors can be switched “On” or “Off” by means of switches, relays, transistors or MOSFET circuits with the simplest form of motor control being “Linear” control.
- This type of circuit uses a bipolar Transistor as a Switch (A Darlington transistor may also be used were a higher current rating is required) to control the motor from a single power supply.

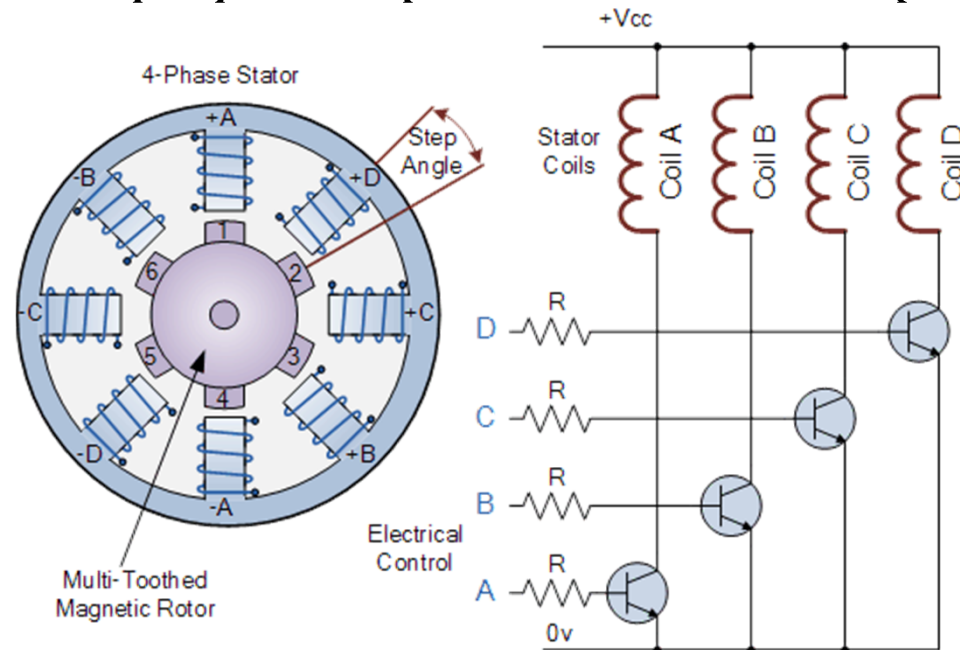


**Motor Speed Control**

- The simple switching circuit above shows the circuit for a Uni-directional (one direction only) motor speed control circuit. As the rotational speed of a DC motor is proportional to the voltage across its terminals, we can regulate this terminal voltage using a transistor.

# The DC Stepper Motor

- Like the DC motor above, Stepper Motors are also electromechanical actuators that convert a pulsed digital input signal into a discrete (incremental) mechanical movement are used widely in industrial control applications.
- A stepper motor is a type of synchronous brushless motor in that it does not have an armature with a commutator and carbon brushes but has a rotor made up of many, some types have hundreds of permanent magnetic teeth and a stator with individual windings.
- As its name implies, the stepper motor does not rotate in a continuous fashion like a conventional DC motor but moves in discrete “Steps” or “Increments”, with the angle of each rotational movement or step dependent upon the number of stator poles and rotor teeth the stepper motor has.



**Stepper Motor Construction and Control**

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*End of Chapter One!*