# AC DRIVES

# AC Drive Fundamentals

- The speed of an AC motor is largely dependent upon two factors:
  - Frequency of the incoming AC power
  - Number of poles

$$N = \frac{60f}{P}$$

N = speed (RPM)

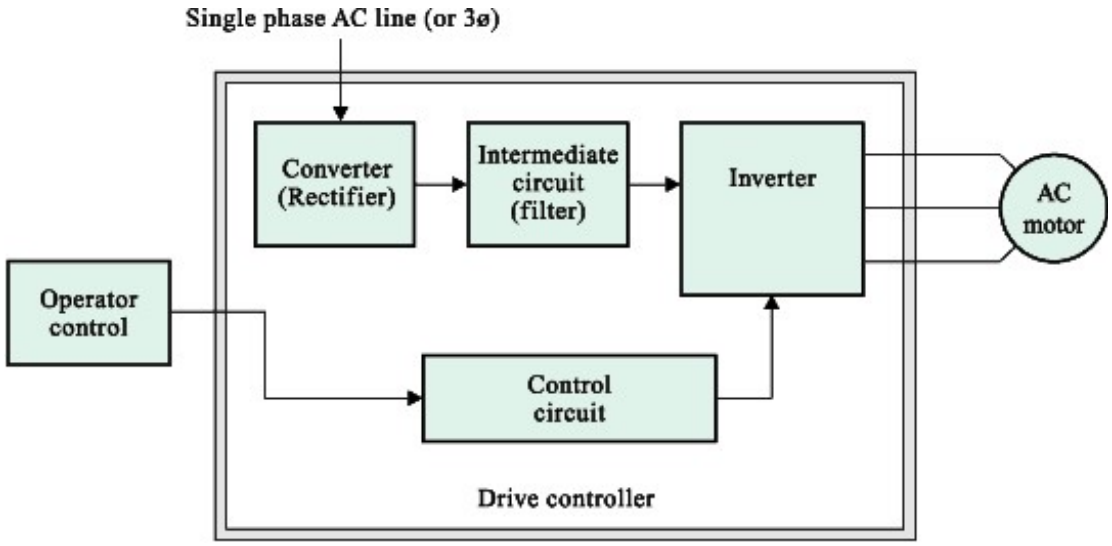
f = frequency

P = number of pole pairs

60 = constant

# AC Drive System

- Operator control -
- Drive controller - converts fixed voltage/frequency into adjustable voltage/frequency
- AC motor - typically three-phase squirrel cage motors

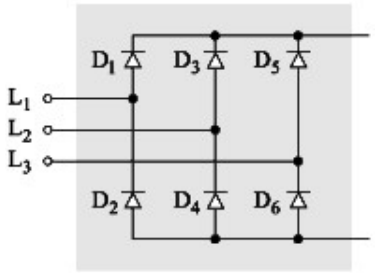


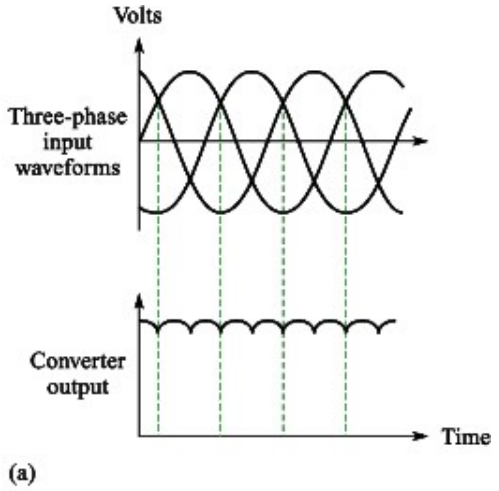
# Variable Voltage Inverter

- Also known as six-step voltage source inverter
- The VVI has four main sections:
  - **Converter** - switches AC to pulsating DC
    - For higher power applications, a three-phase rectifier is used. There are two types:
      - Controlled rectifier
      - Uncontrolled rectifier
  - **Intermediate Circuit**
  - **Inverter**
  - **Control Circuit**

# Rectifiers

- Uncontrolled Rectifier

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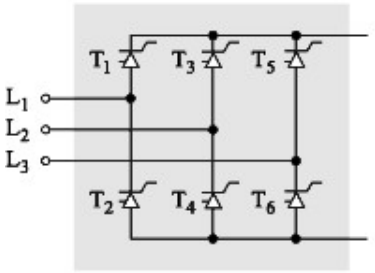
- Controlled Rectifier

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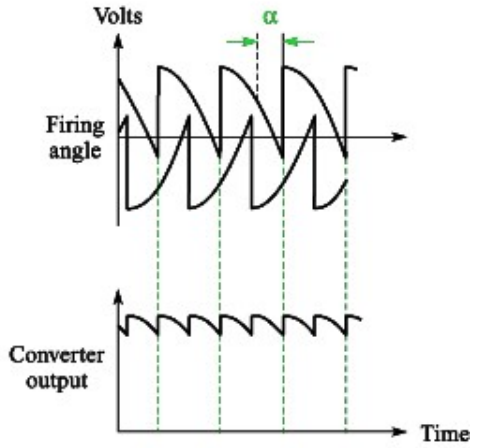


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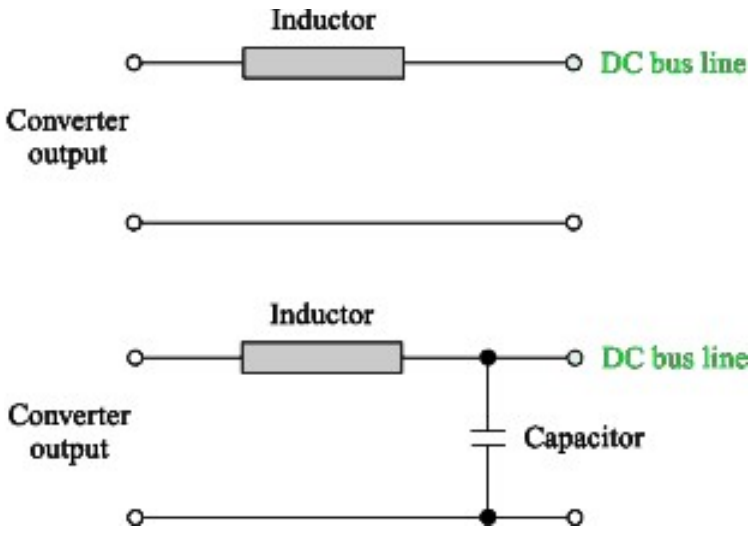
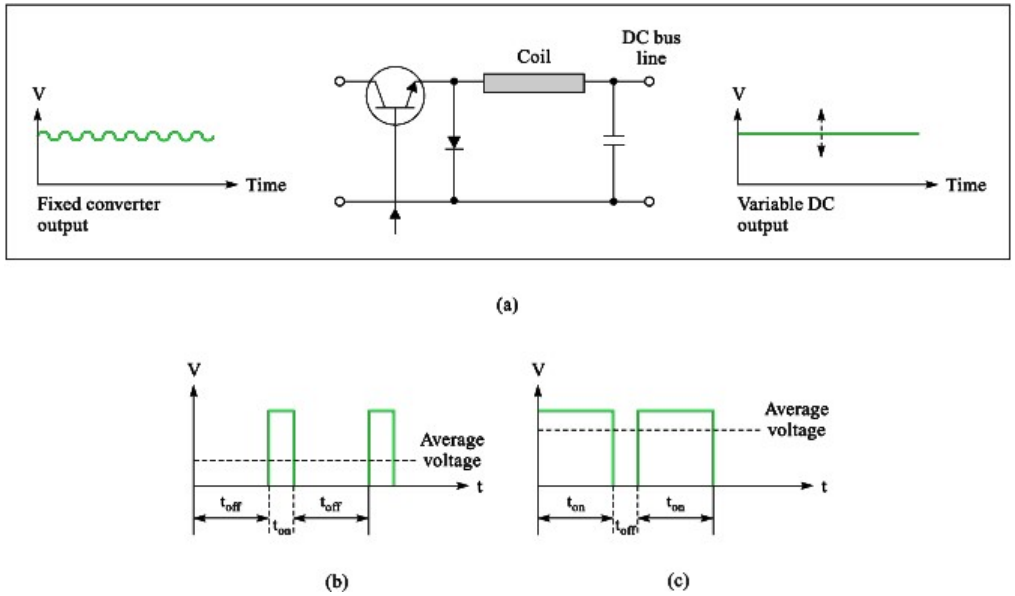
# The Intermediate Circuit

- Transforms the pulsating DC to a smooth DC waveform
- Output is called the *DC Bus Line*
- Three types of circuits typically used:
  - Inductive Filter
  - LC Filter
  - Chopper

# Intermediate Circuit Examples



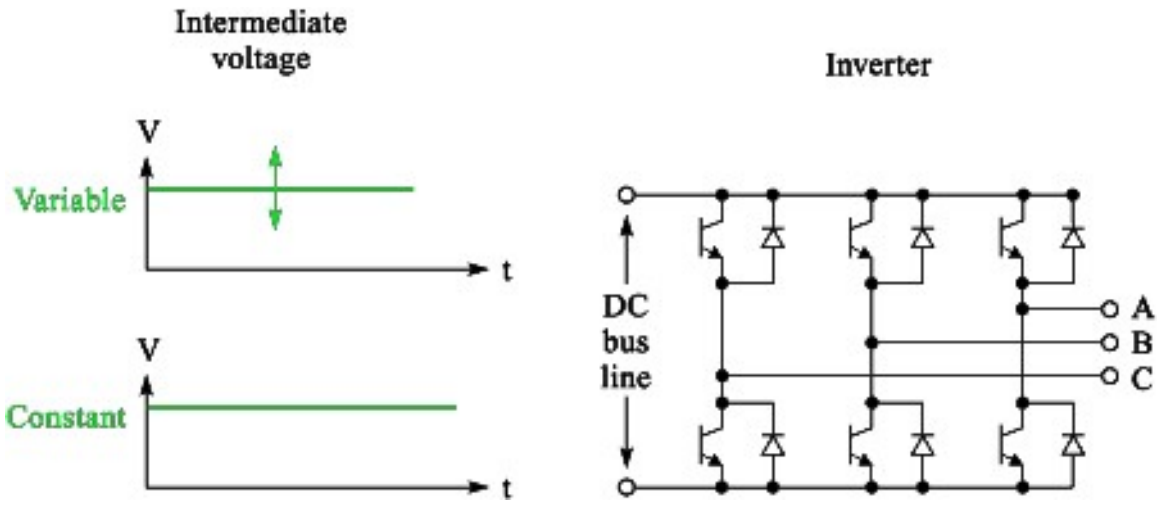

Inductive and LC filters




Chopper Circuit

# The Inverter

- The function of the inverter is to *invert* the DC bus line voltage back to a simulated AC voltage
- An inverter consists of six electronic switching devices used to approximate a three-phase AC source for the motor

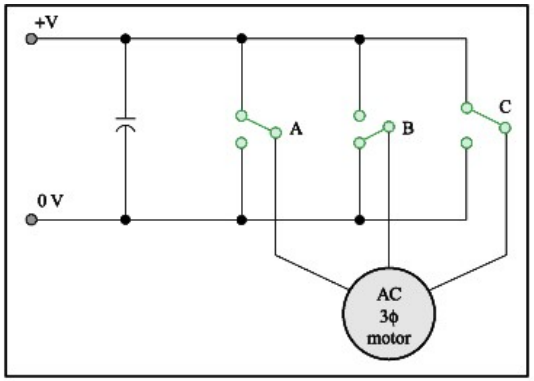


# Inverter Operation

- The VVI Drive inverter controls nothing but frequency.
- The diagrams on the following slides demonstrate the operation of a typical inverter

# Inverter Operation

(a)

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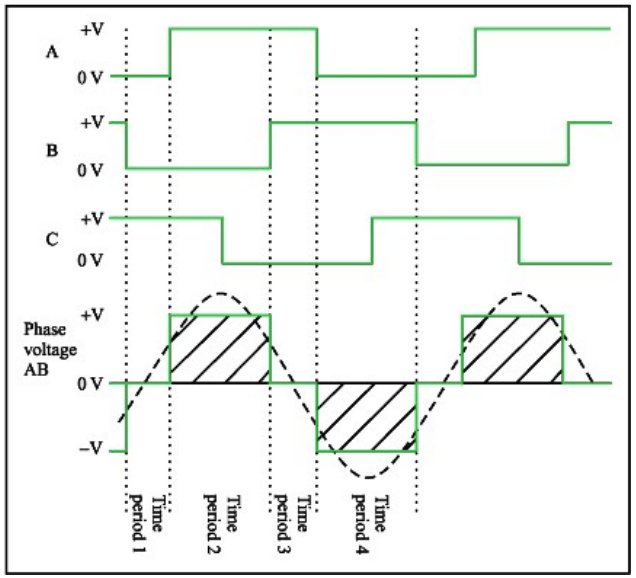
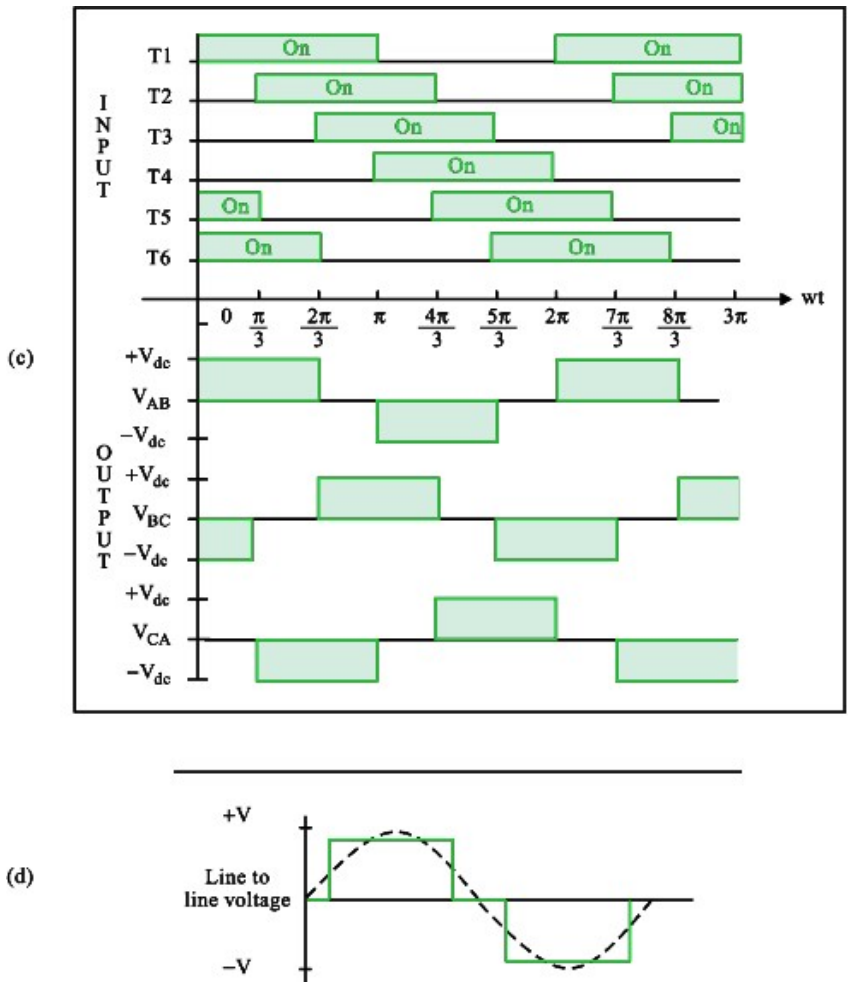


# Inverter Operation



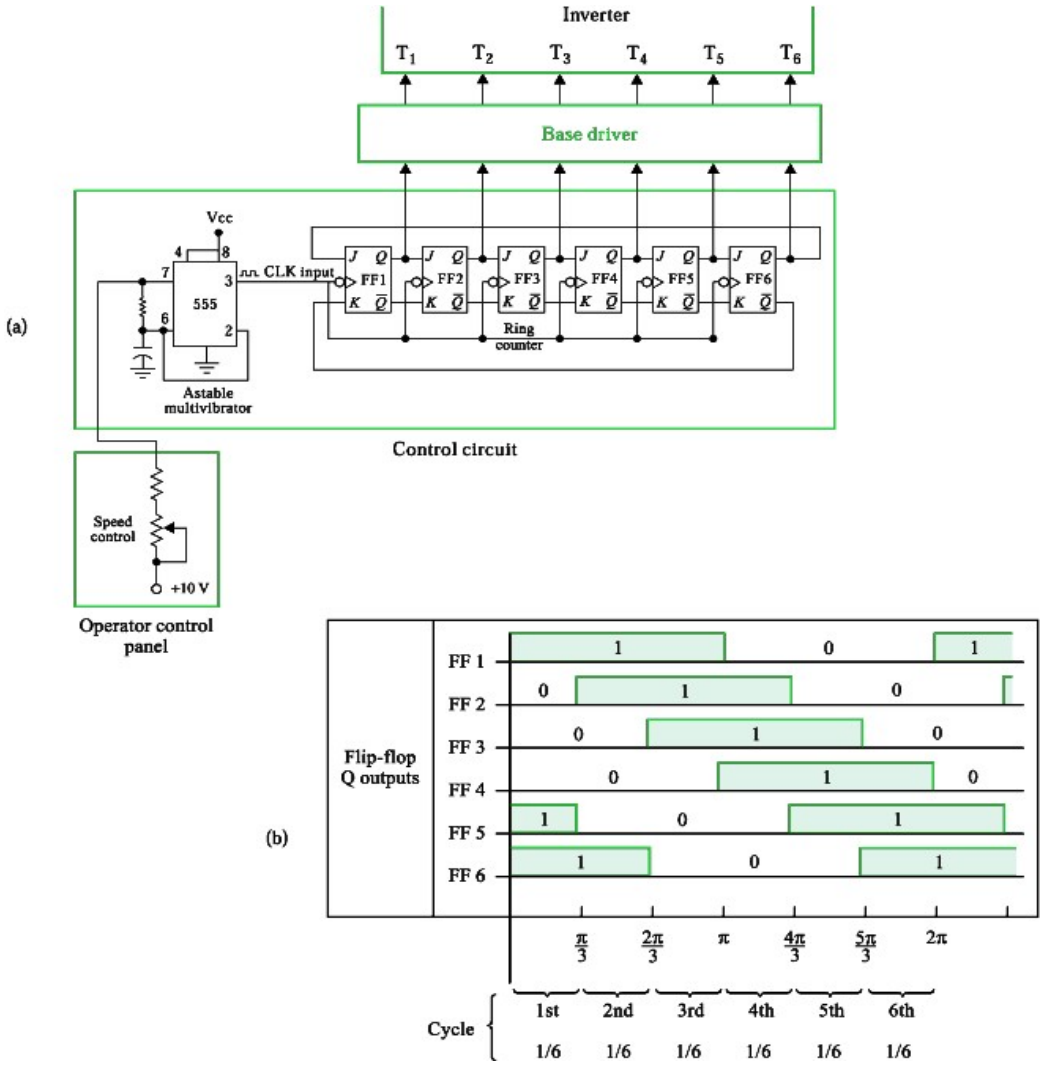
# Control Circuit

- The control circuit performs the following functions:
  - Receives the operating commands from the control panel and sets the system variables
  - Generates the command pulses which turn the semiconductors off and on
  - Produces outputs for the control panel to display various operating conditions
  - Performs an orderly shutdown procedure in the event of an abnormal condition

# Control Circuit Operation

- The speed control (rheostat) feeds an input signal into the control circuit input terminal
- This control signal is delivered, after conditioning, to a shift register
- Control circuit operation is illustrated in the next slide

# Drive Controller Section



# Voltage/Hz Ratio

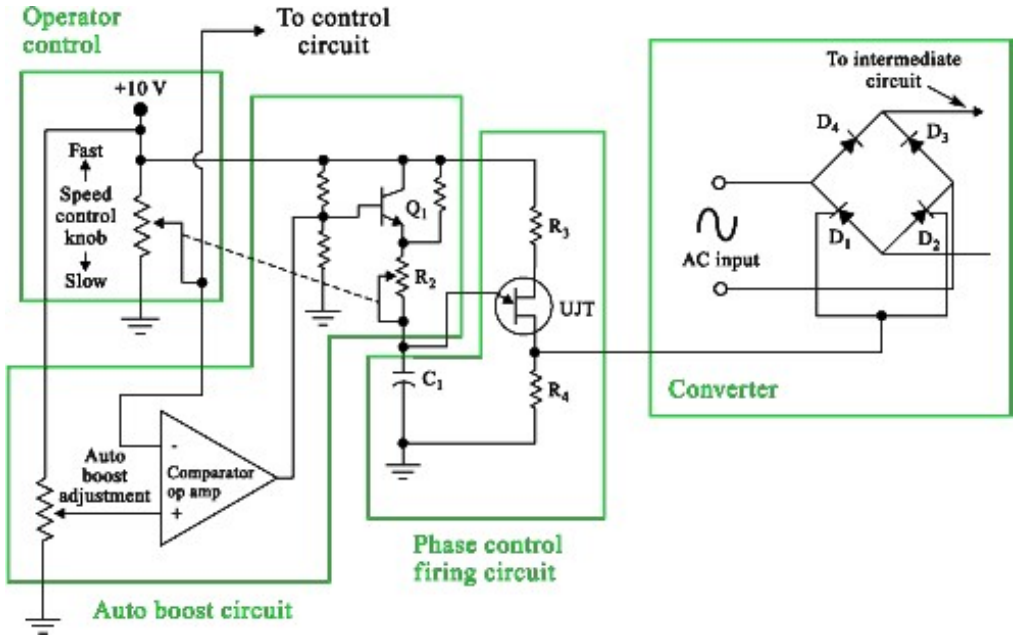
- If the frequency of the drive voltage is changed without changing the motor voltage, the current, and therefore the torque, of the motor will change
- If the frequency is lowered and the voltage remains constant, torque will rise
- However, the motor may overheat from excessive current
- To maintain constant current and torque under varying frequency conditions, the bus voltage must be varied to the inverter output frequency
- This variation is called **voltage-to-frequency** ratio

# Overcurrent Protection

- To protect motors from overcurrent in malfunction situations, circuitry must be included to prevent overcurrent
- Overcurrent conditions may arise because:
  - Physical load is excessive
  - Starting inertia of the motor is excessive
  - A short circuit exists in the motor windings
  - A device in the drive inverter has short-circuited

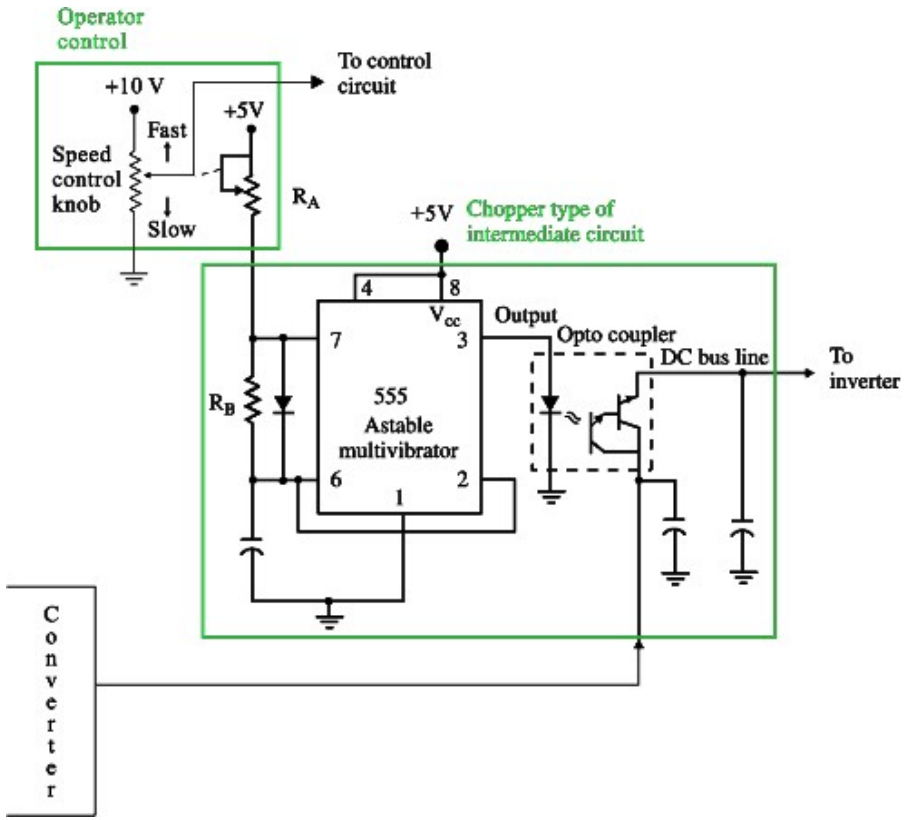
# Auto Boost Circuit

- Used when starting a motor or when a motor is running at a slow RPM
- The auto boost circuit provides additional current to overcome inertia
- Typically located in the control section of the drive



# V/Hz Ratio Control

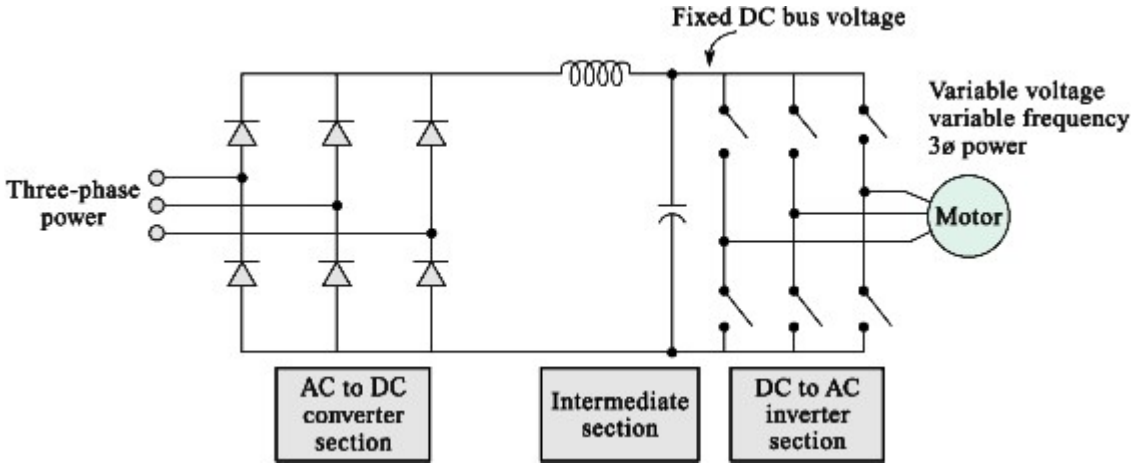
- V/Hz ratio is controlled by one of two methods in a VVI drive
  - Phase control
  - Diode rectifier and chopper configuration



# Pulse Width Modulation Drives

- VVI Drives are being replaced with PWM Drives
- Single-phase bridges used in VVI drives may not generate enough current for high-horsepower motors
- A three-phase rectifier provides more power than a single-phase rectifier because its pulsations are closer together and require less filtering

# PWM Drive Circuit



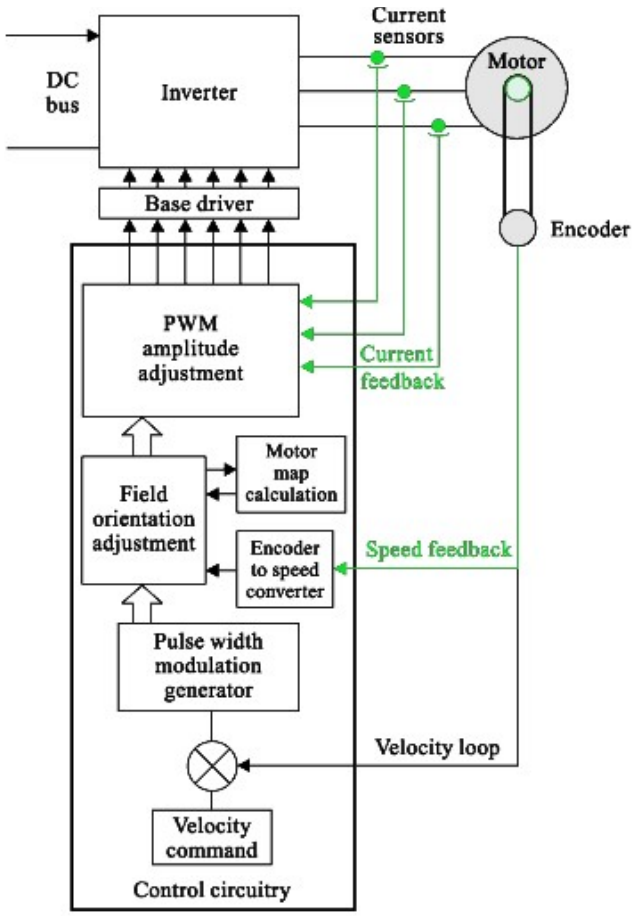
# Flux Vector Drives

- VVI and PWM drives are adequate for steady-state conditions or where slow response times in speed changes when load variations are encountered
- Conditions that have abrupt load, speed, and position changes require a different drive system
- The Flux Vector Drive is better suited to handle these condition requirements

# Flux Vector Characteristics

- Able to drive squirrel cage motors so that its performance is equal to DC motors and drive systems
- Maximum torque is available at all times
- Dynamic response is quick
- Constant velocity is maintained under varying load conditions

# Vector Control Block Diagram

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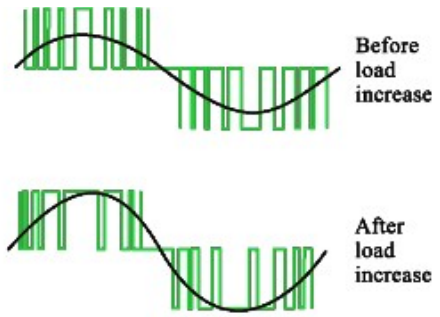


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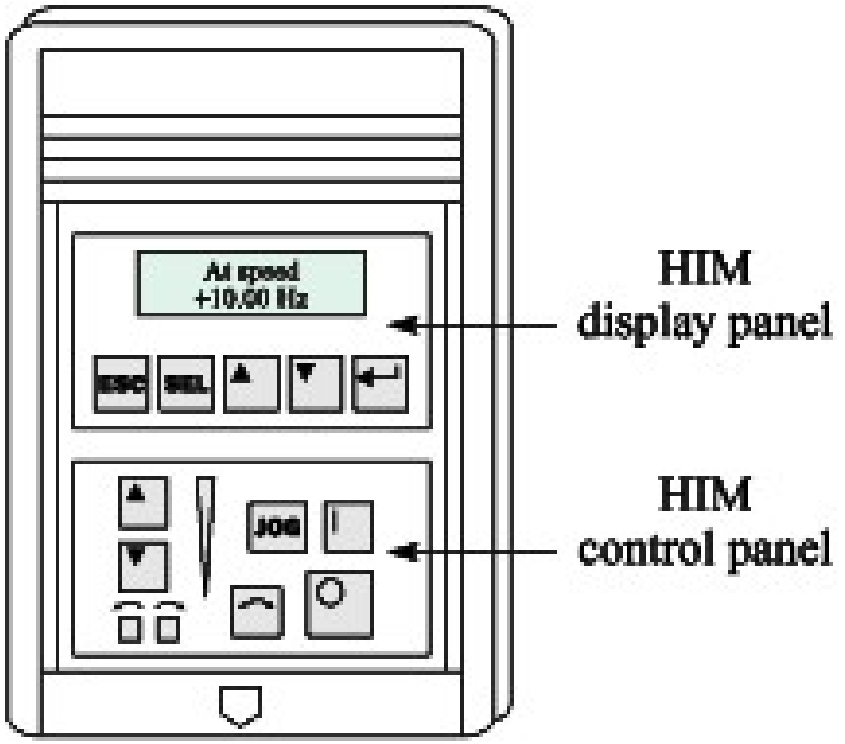
# Motors Driven by AC Drives

- Standard AC motors are designed to operate with fixed frequency/fixed voltage supplies
- AC drives generate high frequency pulses that result in voltage spikes being produced by the stator coil; these may 'punch through' or stress the insulation
- Specially designed motors are required for operation with AC drives that have heavier insulation on the windings
- These motors are labeled as *inverter duty*, or *inverter rated* motors

# Control Panel Inputs and Drive Functions

- Provide the interface between the operator and the drive system for establishing the operational parameters and providing information about the system



# Drive Functions

- **Acceleration** - provides *soft start* or *ramping*
- **Deceleration** - rapid stopping of the motor
- **S-Curve** - alters the start/stop curve of the motor
- **Slip Compensation** - reduces slip in critical applications
- **Critical Frequency Rejection** - prevents resonant frequencies from developing
- **Power Loss Ride-Through** - provides continuous operation of the motor during power loss for brief periods of time
- **Automatic Restart** - in cases of power loss, auto restart may be a requirement of the process

# Inverter Self-Protection Function

- Must protect itself against various faults
  - Overcurrent protection
  - Overload protection
  - Overvoltage protection
  - Undervoltage protection
  - Overheating protection

# Motor Braking

- Too large a load can cause *overhauling* in a motor
- Typically, dynamic braking is used in AC drive systems
- Other methods include *antiparallel* and *regenerative* braking