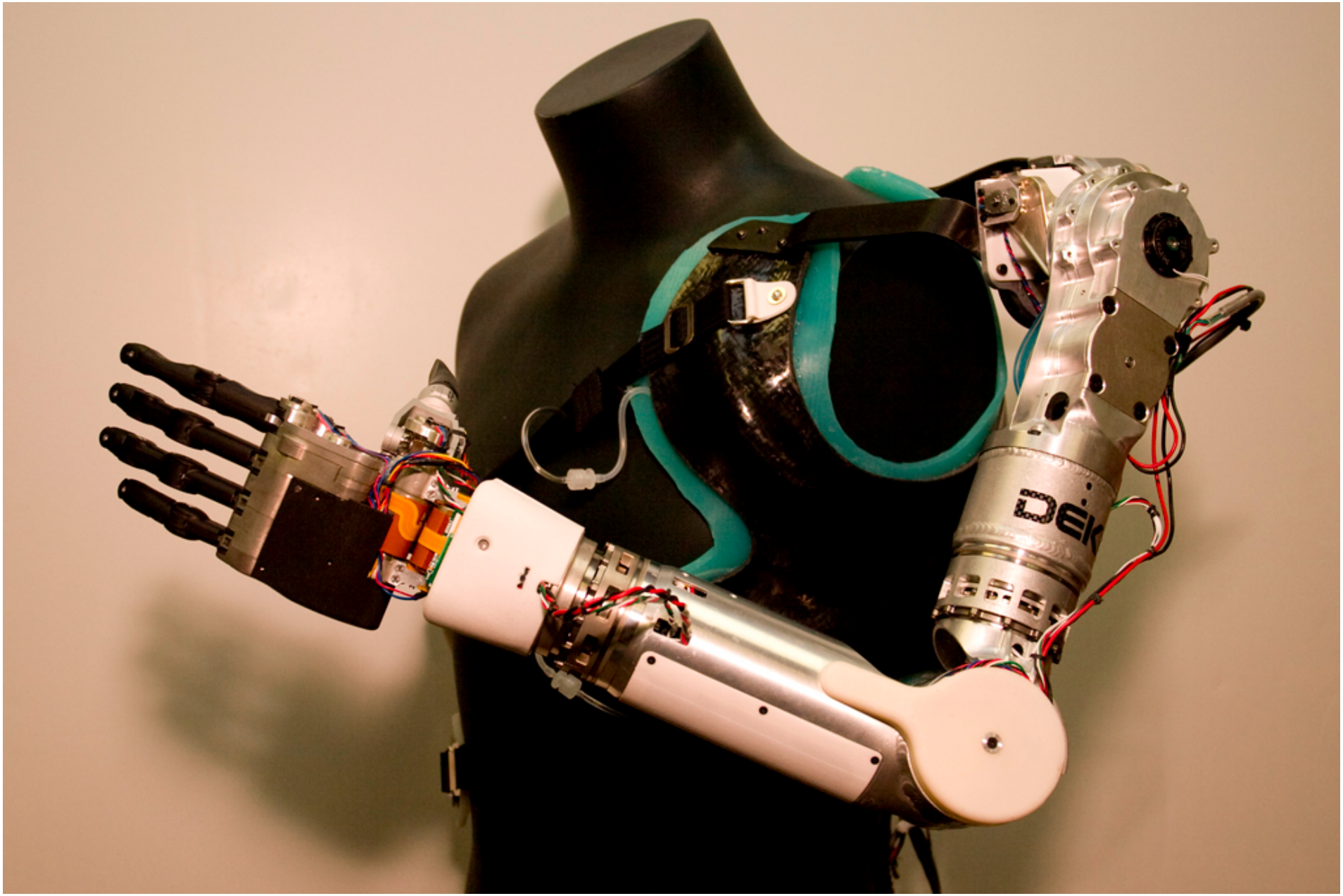
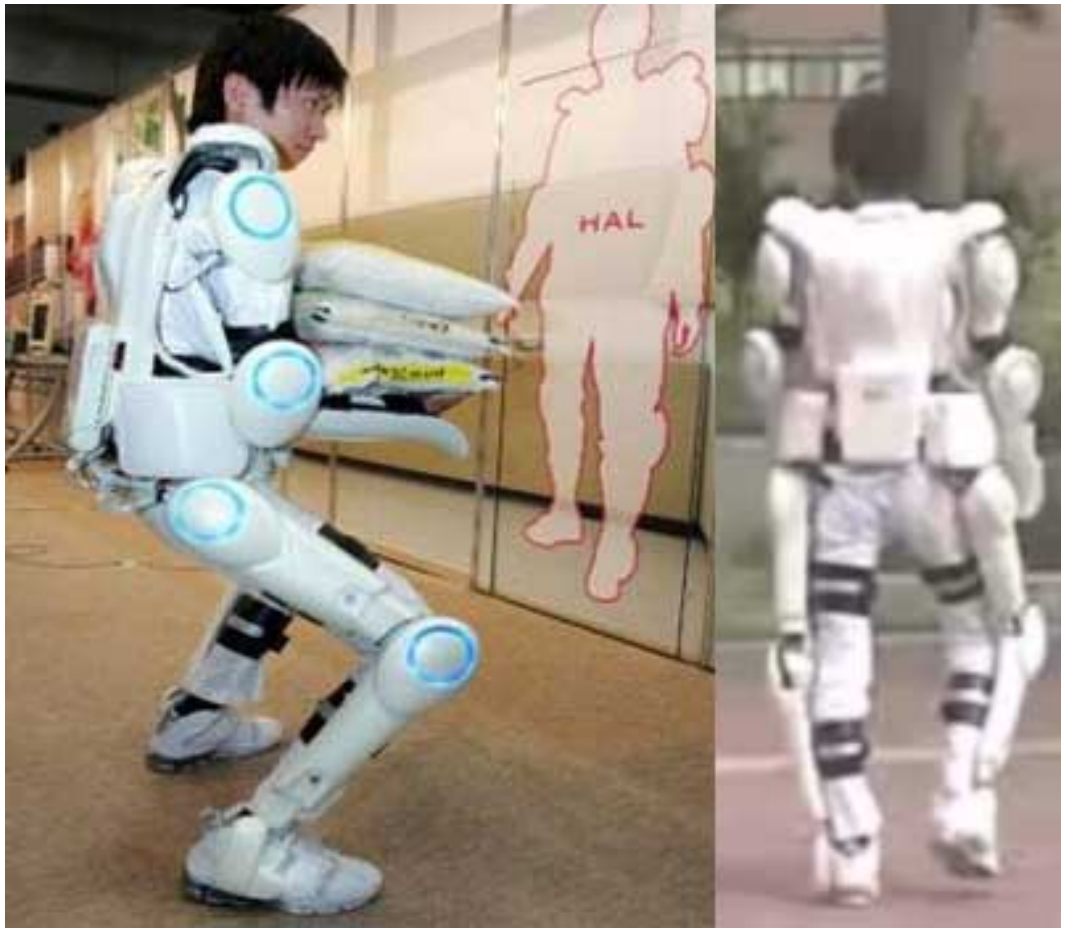
Actuator 1- Electric

ME490A
Dr. C. Alex Simpkins
SDSU
Dept. of Mechanical Engineering

Adapted from a presentation by Dr. Kee Moon




HAL

Types of Actuators

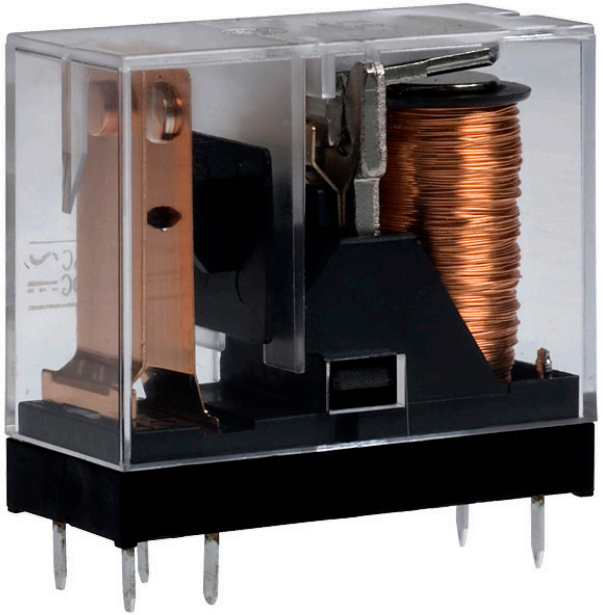
- Electrical
  - Ac and dc motors
  - Stepper motors
  - solenoids
- Hydraulic
  - Use hydraulic fluid to actuate motion
- Pneumatic
  - Use compressed air to actuate motion

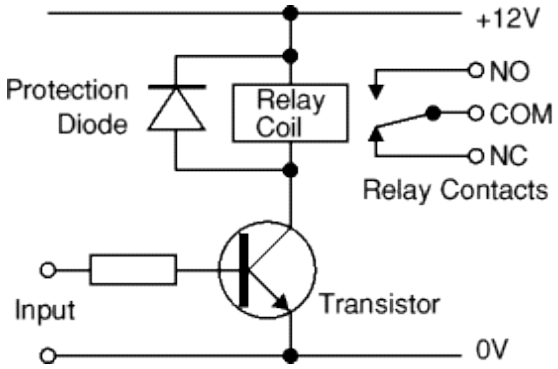
Electrical Actuation

- Switching devices
  - Mechanical switches
    - Keyboards, limit switches, switches
  - Relays
  - Solid-state switches
    - Diodes, thyristors, transistors
  - On-Off
- Solenoids
  - Push something
    - Starter solenoid, pneumatic or hydraulic valve
    - Usually binary
- Drive systems
  - For D.C., A.C., or stepper motors
  - Usually proportional speed control

Mechanical switches

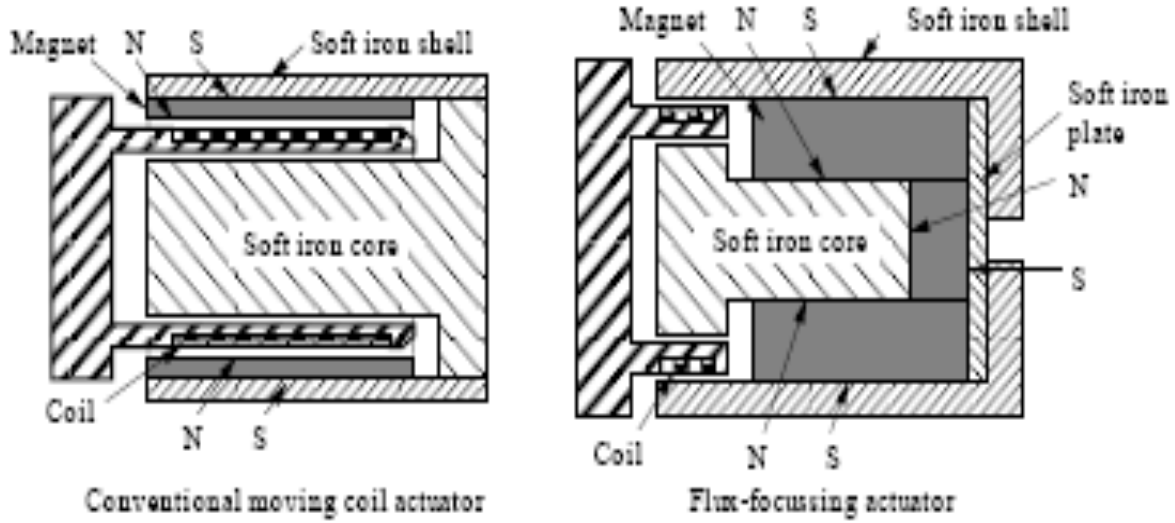
- Relay - A **relay** is
  an electrically operated switch.



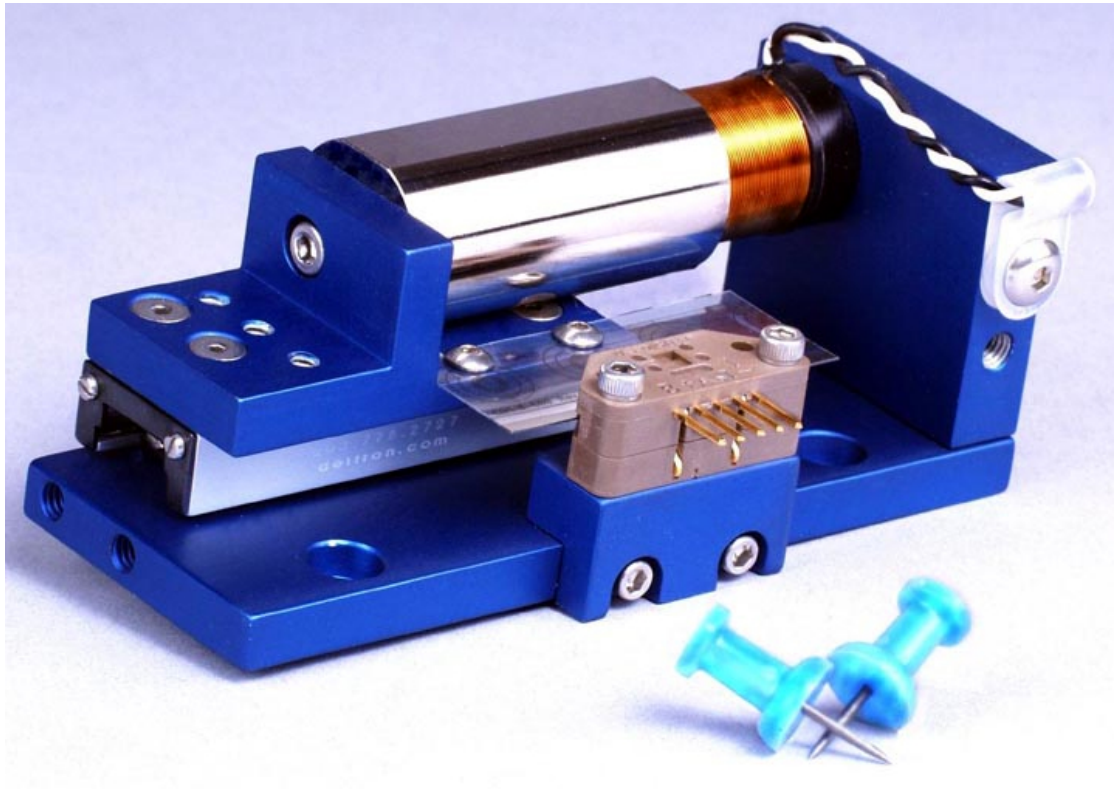


Voice Coil Motor (VCM)

- Ideal for short strokes.
- No phase switching circuitry required.
- Can be used to drive fast tool servos (e.g., for piston turning machines).



Voice Coil Positioning Stages have 0.1 micron resolution



With up to 2 in. of travel and no force or velocity ripple, voice coil stages suit precise motion control applications such as scanning, lens grinding, and laser and mirror positioning. Direct drive, zero backlash stages have no moving cables and are available with acceleration rates to 10 g, 0-50 lb continuous force, and 150 lb peak force. Closed loop products exhibit smooth motion and require linear servo amplifier.

Voice-Coil Scanning System

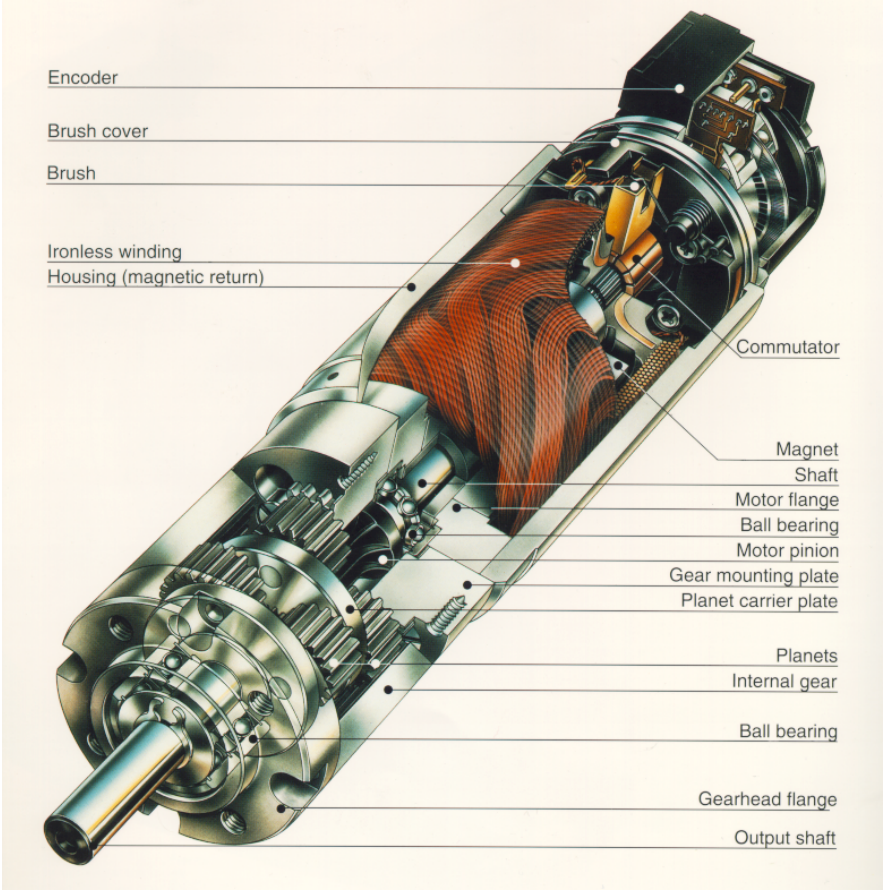
Fast Scanning & Positioning
X and XY Versions
Velocity up to 50 mm/sec
Travel Range: 5 mm
Resolution: 0.1 µm
PC-Card Servo-Controller
Windows™ Software

Electric Motors

- Develop maximum thrust at low speeds
  - Heavy, low power
  - Gearing magnifies motor torque
- Bending and thrust loads reduce motor bearing life dramatically
- AC motors
  - Fans
  - Pump motors
  - Control
- DC motors
  - Brushed, brushless
  - Max torque, continuous duty torque
  - Max speed, continuous duty speed

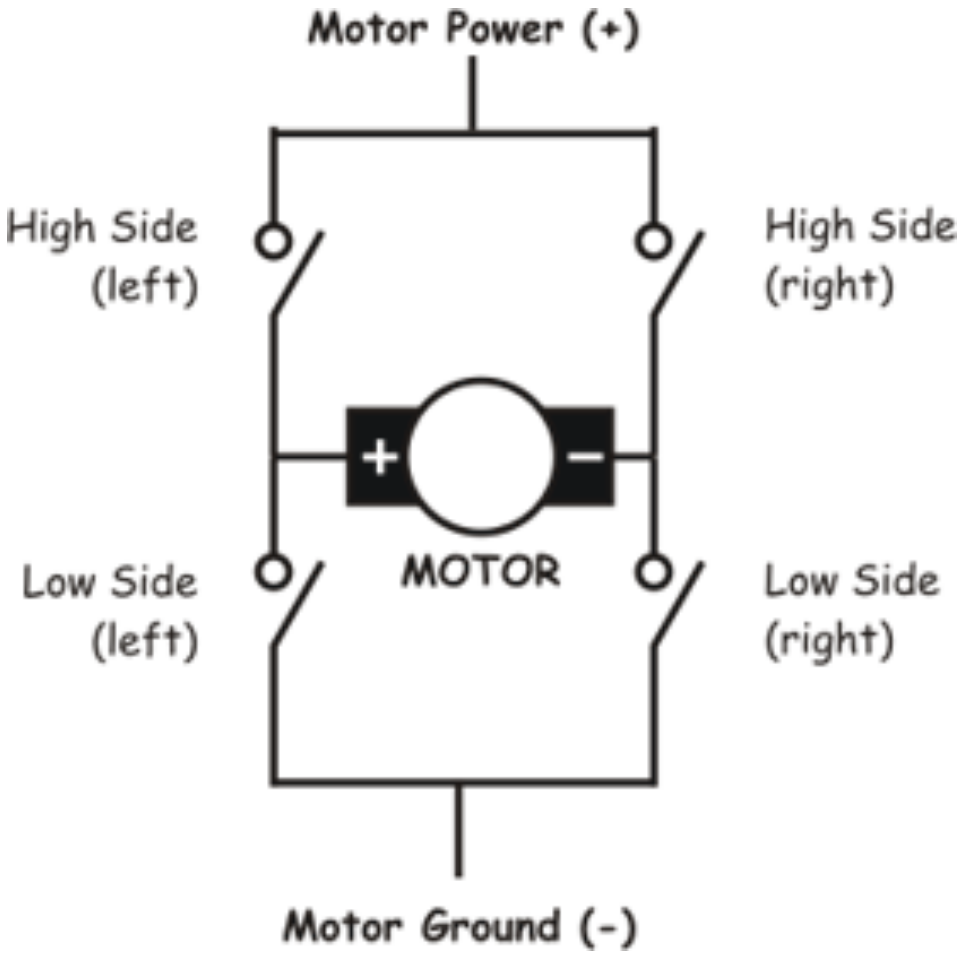
DC-Motors

- simple, cheap
- easy to control
- 1W - 1kW
- can be overloaded
- brushes wear
- limited overloading on high speeds

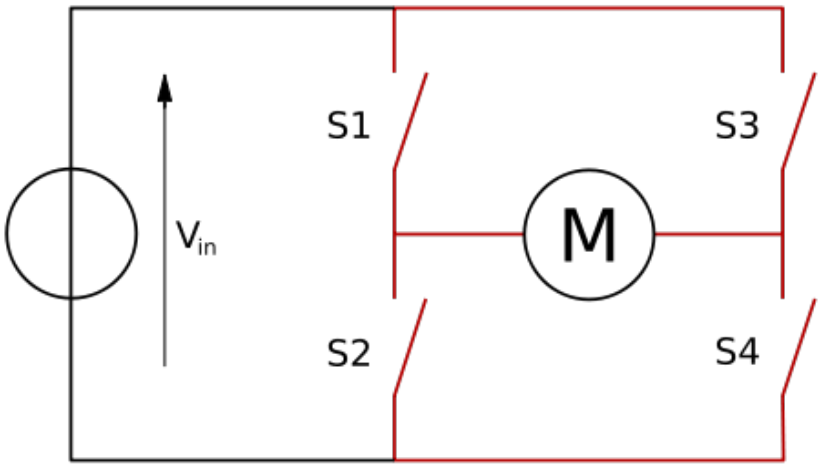


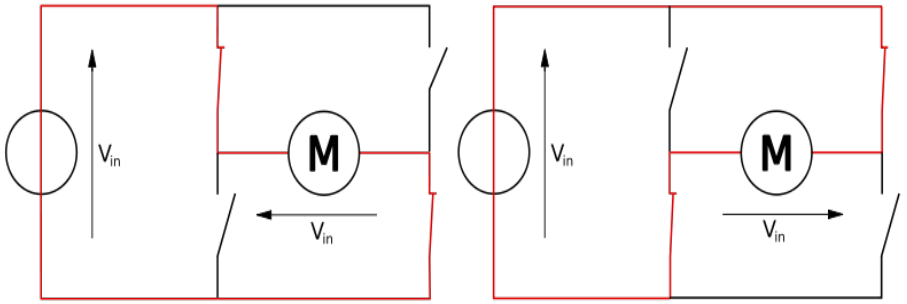
DC-motor control

- Controller + H-bridge
- PWM-control
- Speed control by controlling motor current=torque
- Efficient small components
- PID control



H bridge





S1	S2	S3	S4	Result
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
0	0	0	0	Motor free runs

Brushless DC-Motors

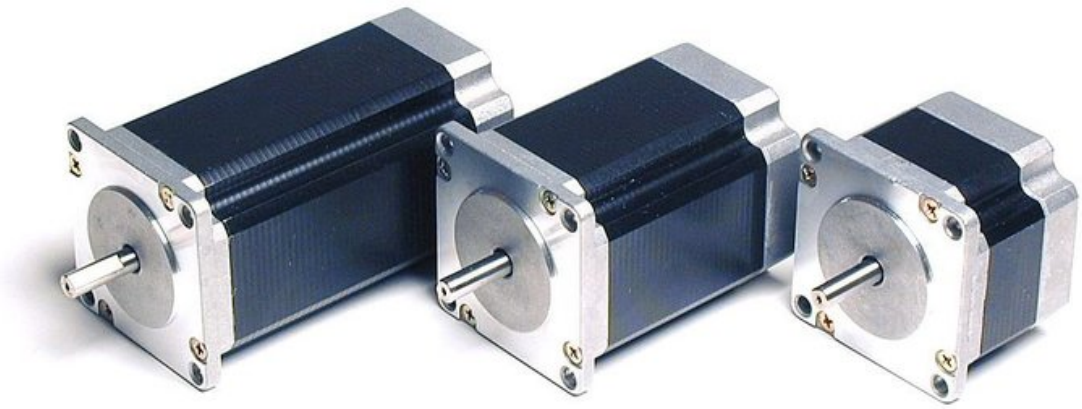
- no brushes → no wearing parts → high speeds
- coils on cover => better cooling
- excellent power/weight ratio
- simple
- needs both speed and angle feedback
- more complicated controller
- From small to medium power (10W – 50kW)

Stepper Motors

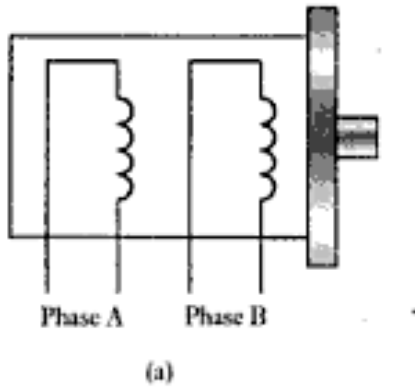
- angle control
- slow
- usually no feedback used
- accurate positioning
- without feedback not servos
- easy to control

Stepper motors

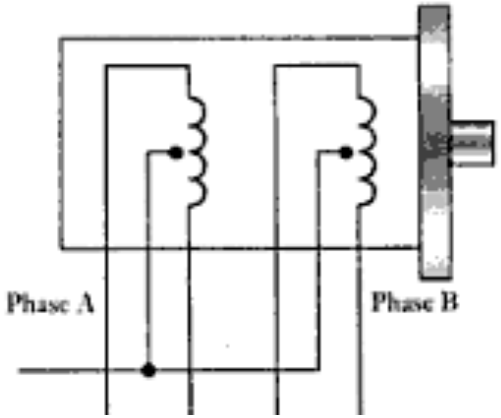
- *Stepper motor* is a device that produces rotation though equal angles called as steps, for each digital pulse supplied to its input.



- Bipolar stepper

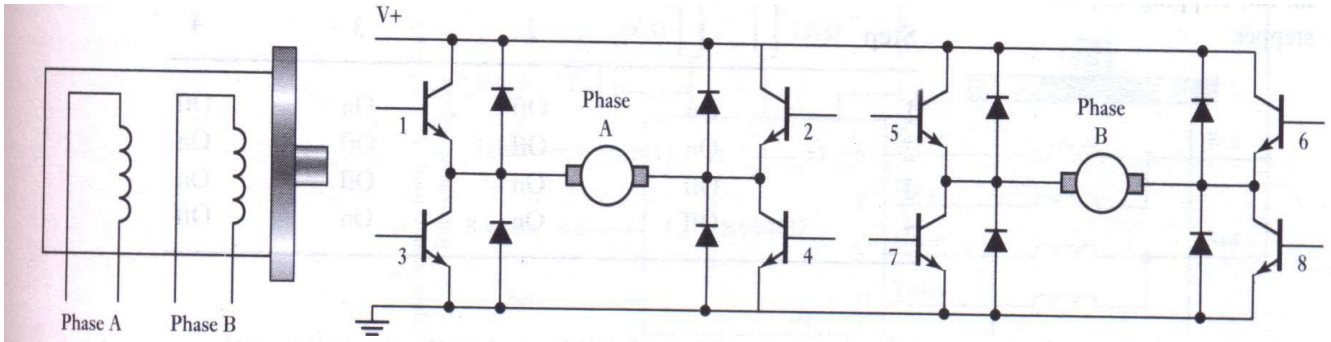


- Unipolar stepper



Stepper motor control

- Two phase motors are termed as bipolar motors when they have 4 connecting wires for signals.
- Solid state switches can be used to switch dc supply between the pair of stator windings.



Step	Transistors			
	1 and 4	2 and 3	5 and 8	6 and 7
1	On	Off	On	Off
2	On	Off	Off	On
3	Off	On	Off	On
4	Off	On	On	Off

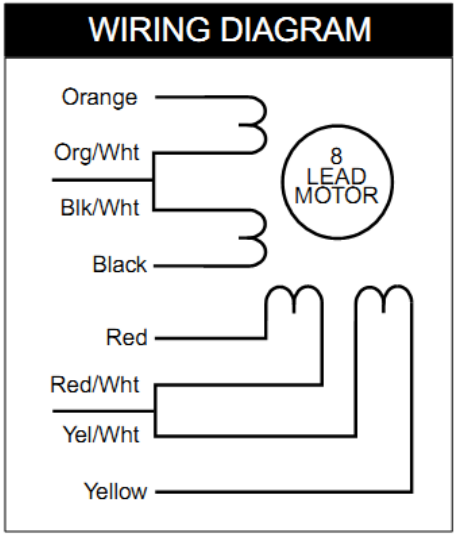
Bipolar stepper

8 Lead Wire Configuration

Unipolar Drive

STEP TABLE				
Step	Orange	Black	Red	Yellow
0	ON	OFF	ON	OFF
1	OFF	ON	ON	OFF
2	OFF	ON	OFF	ON
3	ON	OFF	OFF	ON
4	ON	OFF	ON	OFF

Connect orange/white,black/white, red/white, and yellow/white to plus (+) voltage.



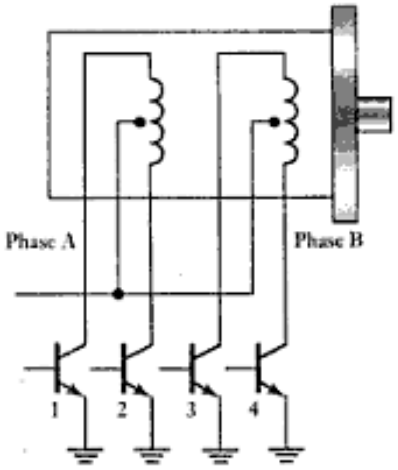


Figure 9.27 Unipolar motor.

Stepper Motors

- **Advantages**
  - No feedback hardware required
- **Disadvantages**
  - No feedback (!)

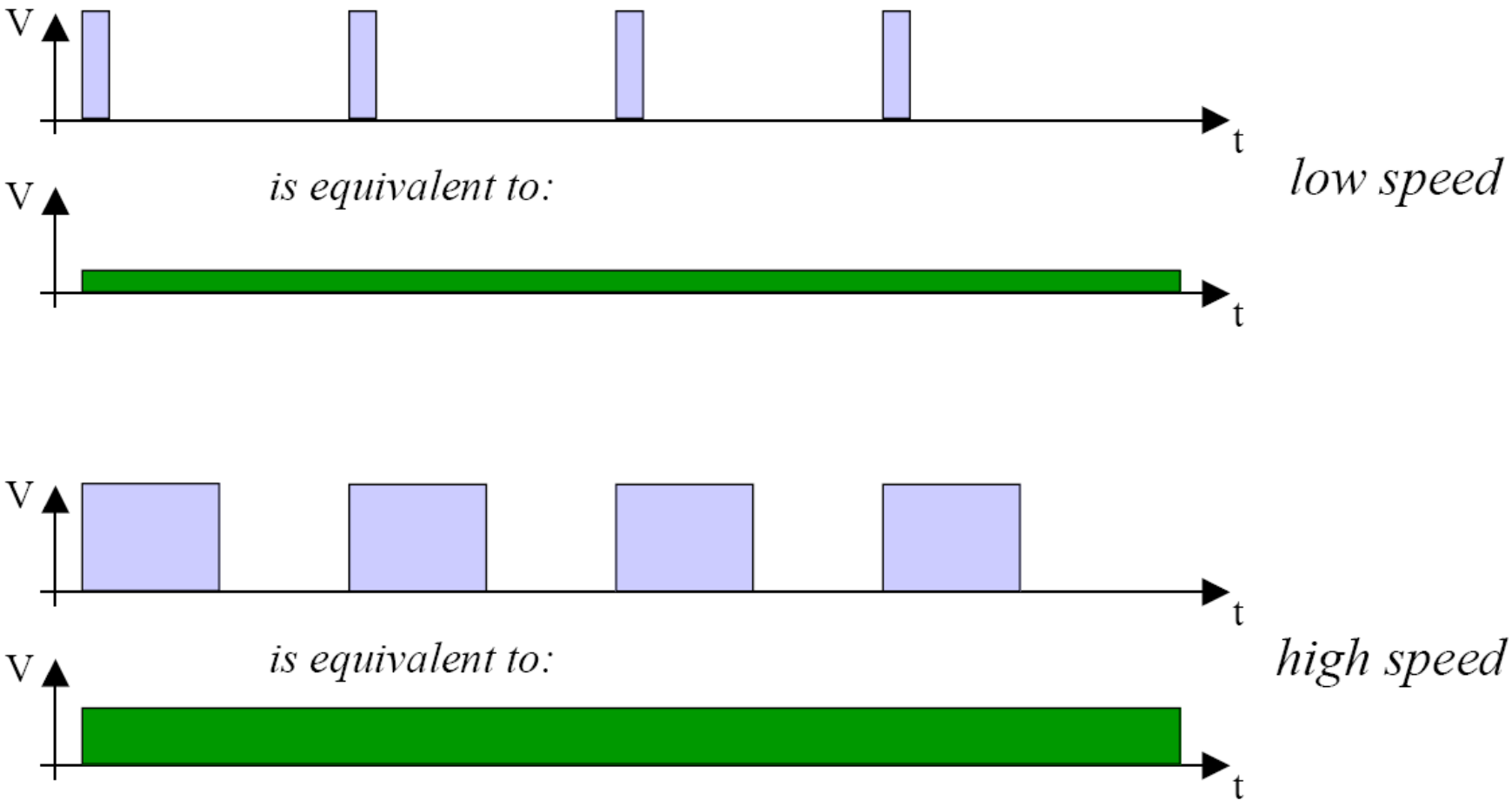
  Often feedback is still required,

  e.g. for precision reasons, since a stepper motor can “lose” a step signal.

Pulse-Width Modulation

- A/D converters are used for reading analog sensor signals
- Why **not** use D/A converter for motor control?
  - Too expensive (needs power circuitry)
  - Better do it by **software**, switching power on/off in intervals
  - This is called "**Pulse-Width Modulation**" or **PWM**

Pulse-Width Modulation

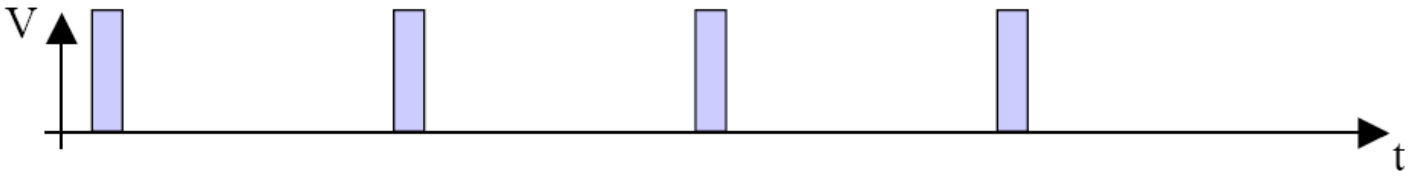


Pulse-Width Modulation

- **How does this work?**
  - We do not change the supplied voltage
  - Power is switched on/off at a certain pulse ratio matching the desired output power
- Signal has very high frequency (e.g. 20kHz)
- Motors are relatively slow to respond
  - The only thing that counts is the supplied power
  - ⇒ **Integral** (Summation)
- Pulse-Width Ratio = t_{on} / t_{period}

Servos

Servos

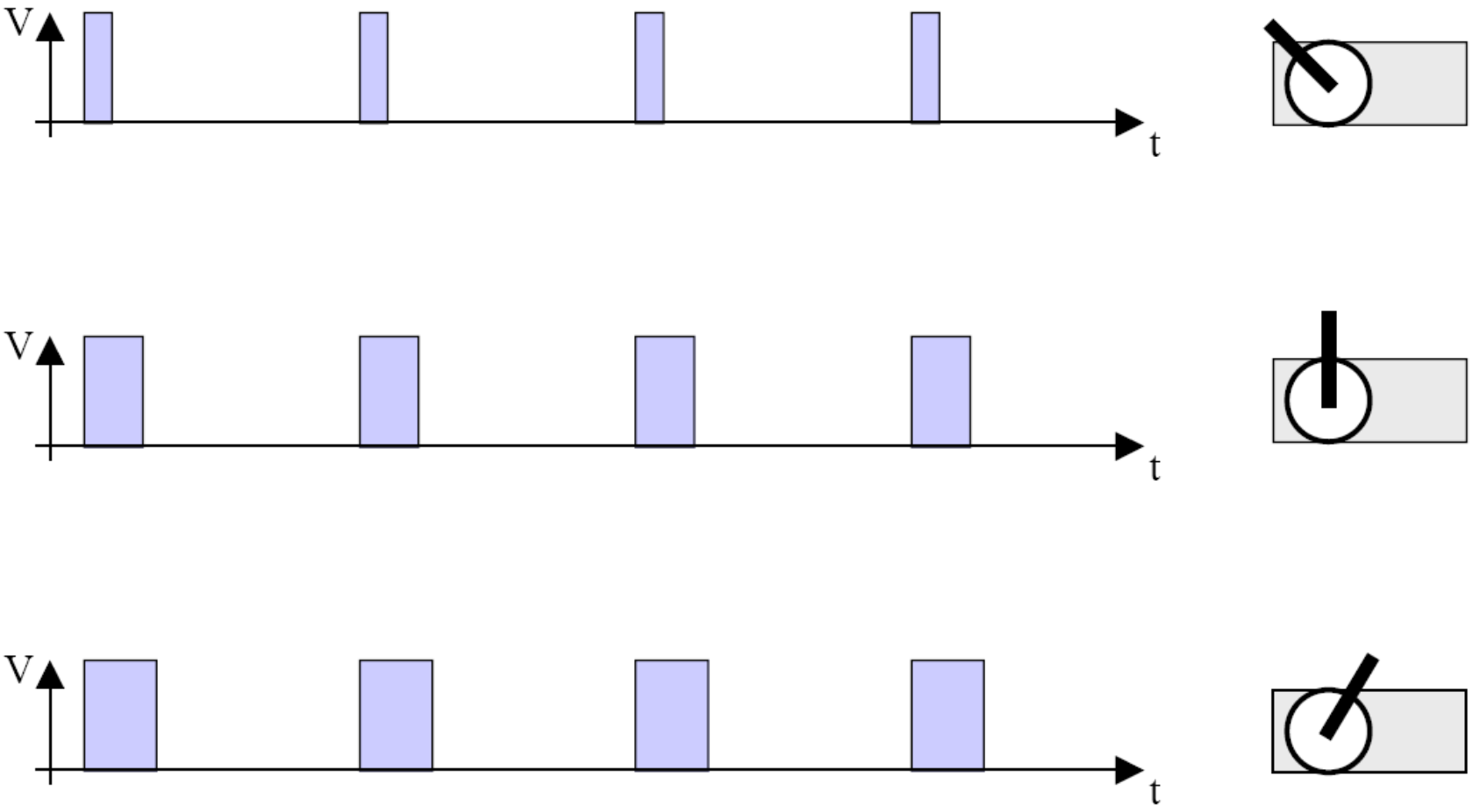


- Servos usually have three cables: power, ground and PWM-signal
- Servos require a PWM signal with 50Hz frequency (20ms)
- The pulse should be between 0.5 ms and 2.0 ms long
  this sets the servo to its extreme left or right position

Remember:

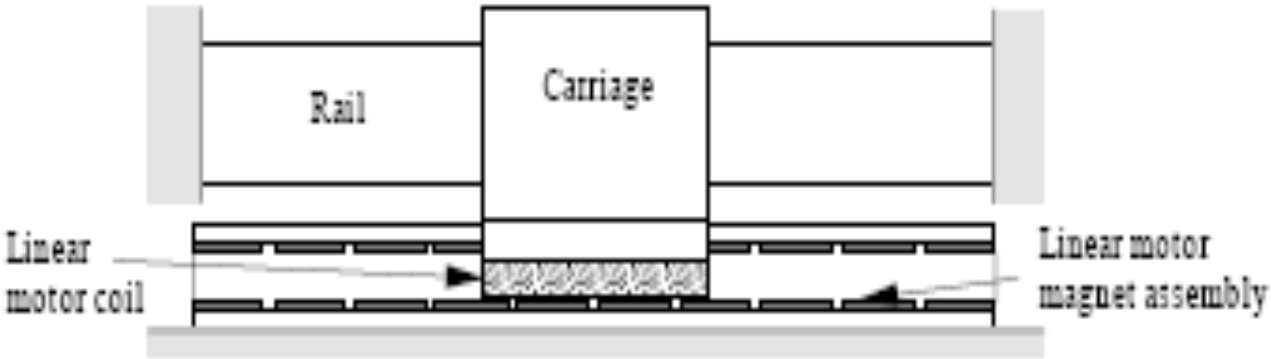
- Servo speed cannot be set
  servo tries to get to new position as fast as possible
- Servos do not provide feedback to the outside

Servos



Linear motor mounting

Linear motor moving coil mounted to underside of an air bearing carriage that rides on a simply supported rail:



Linear motors

- **Compact size for tight space constraints; 57.2 mm x 31.8 mm cross section**
- **Continuous force to 161 N (36 lb); peak force to 646 N (145 lb)**
- **Non-magnetic forcer coil provides high force with zero cogging for super-smooth velocity and position control**
- **Optional cooling provide even higher rms force**

- **Non-magnetic forcer coil provides high force with zero cogging for super smooth velocity and position control**
- **Continuous force to 160 N (36 lb); peak force to 638 N (143 lb)**
- **Unlimited travel length by stacking magnet tracks**
- **High-energy, rare-earth magnets used in magnet track for high acceleration capability**

Linear motor benefits:

High speeds, The maximum speed of a linear motor is limited only by the bus voltage and the speed of the control electronics. Typical speeds for linear motors are 3 meters per second with 1 micron resolution and over 5 meters per second, 200ips, with coarser resolution.

High Precision: The accuracy, resolution, and repeatability of a linear motor driven device is controlled by the feed back device. With the wide range of linear feedback devices available, resolution and accuracy are primarily limited to budget and control system bandwidth.

Fast Response: The response rate of a linear motor driven device can be over 100 times that of a mechanical transmission. This means faster accelerations and settling times, thus more throughput.

Stiffness: Because there is no mechanical linkage, increasing the stiffness is simply a matter of gain and current. The spring rate of a linear motor driven system can be many times that of a ball screw driven device. However it must be noted that this is limited by the motors peak force, the current available and the resolution of the feedback.

Zero Backlash: Without mechanical transmission components, there is no backlash. Resolution considerations do exist. That is the linear motor must be displaced by 1 feedback count before it will begin to correct its position.

Maintenance Free Operation: Because the linear motors of today have no contacting parts there is no wear.

Used for all Automation

- Actuators are used everywhere there is automation
  - robot, conveyor system, etc.

Linear Actuator

Rotary Electric Motor Actuator