Electronics
Inductive Output Transducers

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Output transducers
Output transducers

- also called “actuators”
Output transducers

- also called “actuators”
- basically of two types
Output transducers

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- basically of two types
  - resistive
Output transducers

- also called “actuators”
- basically of two types
  - resistive
  - inductive
Output transducers

- also called “actuators”
- basically of two types
  - resistive
  - inductive
- inductive loads require a few special considerations
Solenoid

Solenoid consists of a coil and plunger, which can be of either “push” or “pull” type. “Pull” type solenoids are much more common.
Solenoid

- consists of a coil and plunger
Solenoid

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  “pull” type are much more common
Solenoid

- plunger in
Solenoid
Solenoid

- plunger out
Induced EMF

Quickly changing voltage across an inductor produces induced EMF. Induced voltage tries to counteract the change in current, which can produce big voltage spikes. A diode across a coil will limit voltages to approximately 0.7 V. A zener diode can limit voltages the other way to about the zener voltage.
Induced EMF

- Quickly changing voltage across inductor produces *induced EMF*
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Induced EMF

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- A diode across a coil will limit voltages to $\approx 0.7\, \text{V}$. 
Induced EMF

- Quickly changing voltage across inductor produces *induced EMF*
- Induced voltage tries to counteract change in current
- Can produce big voltage spikes
- A diode across a coil will limit voltages to $\approx 0.7\,V$.
  - A zener diode can limit voltages the other way to about the zener voltage.
No diode to reduce induced EMF

Initially $I = 0$. 
No diode to reduce induced EMF

Induced voltage tries to maintain $I = 0$. 
No diode to reduce induced EMF

Eventually current is established determined by resistance in circuit.
No diode to reduce induced EMF

Induced voltage tries to maintain $I$ at the previous value.
No diode to reduce induced EMF

Eventually current is reduced to $I = 0$. 
Diode to reduce induced EMF

Initially $I = 0$. 

$I \equiv 0$
Diode to reduce induced EMF

Induced voltage tries to maintain \( I = 0 \), but cannot exceed \( V_Z \).
Diode to reduce induced EMF

Eventually current is established determined by resistance in circuit.
Diode to reduce induced EMF

Induced voltage tries to maintain $I$ but cannot exceed $\approx 0.7 \text{V}$.
Diode to reduce induced EMF

Eventually current is reduced to $I = 0$. 
Current requirements

A solenoid requires more current to move plunger than to hold it. Maintaining current larger than necessary wastes power and produces heat. Several options exist for adjusting current between moving the plunger and holding it.
Current requirements

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Current requirements

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Maintaining current larger than necessary wastes power and produces heat.

- Several options exist for adjusting current between moving the plunger and holding it.
Series resistor
Series resistor
Series resistor
Series resistor
Series resistor
Multiple supplies
Multiple supplies
Multiple supplies
Multiple supplies

\[ V_p \quad \text{pick} \]
\[ V_h \quad \text{hold} \]
Multiple supplies

![Diagram of Multiple Supplies]
Multiple supplies

\[ V_p > V_h \]
Pulse width modulation to limit current
Output Transducers
DC motors
Methods to reverse current to PM DC motor

Solenoid
Current requirements

Pulse width modulation to limit current

![Solenoid circuit diagram](image)
Pulse width modulation to limit current

![Diagram showing pulse width modulation circuitry](image)
Solenoids in action: Relays
Solenoids in action: Relays

A relay is a device for switching, which is based on a solenoid.
Solenoids in action: Relays

A relay is a device for switching, which is based on a solenoid. The solenoid is used to open and close a switch.
Solenoids in action: Relays

A relay is a device for switching, which is based on a solenoid. The solenoid is used to open and close a switch. An internal spring returns the solenoid to its original position.
Relay OFF

Solenoid
Current requirements

NC common

NO
Solenoid
Current requirements

Relay **ON**

![Diagram of relay and solenoid with labels NC common and NO]
Zener diode to reduce EMF

NC common

NO
DC motor types
DC motor types

- Four main types of DC motors
DC motor types

- Four main types of DC motors
  - Permanent Magnet
DC motor types

- Four main types of DC motors
  - Permanent Magnet
  - Brushless
DC motor types

- Four main types of DC motors
  - Permanent Magnet
  - Brushless
  - Stepper
DC motor types

- Four main types of DC motors
  - Permanent Magnet
  - Brushless
  - Stepper
  - Servo
DC motor

Permanent Magnet DC Motor (PMDC)
- Uses permanent fixed magnets
- Armature on shaft has electromagnet
- Commutator on shaft reverses current direction every half rotation
- Speed controlled by current
- Continuous motion

Methods to reverse current to PM DC motor

Brushless DC motors
Stepper motors
Servo motors
DC motor

- PMDC (Permanent Magnet DC Motor)
DC motor

- PMDC (Permanent Magnet DC)
- uses permanent fixed magnets
DC motor

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  armature on shaft has electromagnet
## DC motor

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Permanent magnet DC motor
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Permanent magnet DC motor
Permanent magnet DC motor
Brushless DC motor
Brushless DC motor

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Brushless DC motor

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  armature on shaft has permanent magnets
- continuous motion
  capable of holding one position
Brushless DC motor

- uses fixed electromagnets
  armature on shaft has permanent magnets
- continuous motion
  capable of holding one position
- need to sense position
Brushless DC motor

- uses fixed electromagnets
  armature on shaft has permanent magnets
- continuous motion
  capable of holding one position
- need to sense position
  can use a hall effect sensor or sense induced voltage in unused coils
Brushless DC motor
Brushless DC motor
Brushless DC motor
Brushless DC motor
Brushless DC motor
Brushless DC motor
Stepper motor

Stepper motor uses fixed electromagnets, armature on shaft has soft iron core, i.e. no permanent magnets. Similar operation to brushless motors, discrete steps. Drive electronics controls speed and direction. Half-stepping is possible, can hold in position.
Stepper motor

- uses fixed electromagnets
Stepper motor

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- armature on shaft has soft iron core
Stepper motor

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- armature on shaft has soft iron core
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Single stepping
Single stepping
Single stepping
Single stepping
Single stepping
Single stepping
Half stepping
Half stepping
Half stepping
Output Transducers
DC motors
Methods to reverse current to PM DC motor
Permanent Magnet DC Motor (PMDC)
Brushless DC motors
Stepper motors
Servo motors

Half stepping
Half stepping
Half stepping
Half stepping
Half stepping
Half stepping
Half stepping
Half stepping
Half stepping
### Servo Motor

A Servo motor is a type of rotary actuator that can control its position to within a few degrees. It is commonly used in applications where precise control over position is required, such as in robotics, automation, and hobbyist projects.

Servo motors work by using a digital pulse-width modulation (PWM) signal to control the motor's position. The PWM signal determines the duration of the pulse, which in turn determines the direction and speed of rotation. A longer pulse makes the motor rotate in one direction, while a shorter pulse makes it rotate in the other direction. The pulse must be repeated periodically to keep the motor moving.

**Permanent Magnet DC Motor (PMDC)**
- Uses a digital pulse to control output.
- The default width keeps the motor stationary (e.g., 1.5 ms).
- Longer pulse makes the motor rotate in one direction, and shorter pulse makes it rotate in the other direction.
- Pulse must be repeated periodically (e.g., every 20 ms).
- Often limited to less than 360-degree travel.
- Digital input does not have induced EMF problems, as the internal electronics handle that.
Servo motor

- PMDC motor with position sensing and feedback
Servo motor

- PMDC motor with position sensing and feedback
- Internal electronics
Servo motor

- PMDC motor with position sensing and feedback
- internal electronics
- uses a digital pulse to control
Servo motor

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  - Longer pulse makes motor rotate in one direction

Pulse must be repeated periodically (e.g., every 20 ms)

Often limited to less than 360 degree travel

Digital input does not have induced EMF problems

Internal electronics handles that
Servo motor

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- digital input does not have induced EMF problems
  internal electronics handles that
Induced EMFs and motors
Induced EMFs and motors

- Same problem as with solenoids
Induced EMFs and motors

- Same problem as with solenoids
  can produce big voltage spikes
Induced EMFs and motors

- Same problem as with solenoids
  can produce big voltage spikes
- Diodes across the coils can be used the same way
Methods to reverse current to PM DC motor
Methods to reverse current to PM DC motor

- dpdt switch
Methods to reverse current to PM DC motor

- dpdt switch
- bipolar supply
Methods to reverse current to PM DC motor

- dpdt switch
- bipolar supply
- H bridge
DPDT switch

\[ V^+ \quad \text{common (to } R_L \text{)} \]

\[ V^- \quad \text{common (to } R_L \text{)} \]
DPDT switch

\[ \begin{align*}
V^+ & \quad \text{common (to } R_L \text{)} \\
\text{common (to } R_L \text{)} & \\
V^- & \quad \text{common (to } R_L \text{)}
\end{align*} \]
Output Transducers

DC motors

Methods to reverse current to PM DC motor

DPDT switch

\[ V^+ \] common (to \( R_L \))

\[ V^- \] common (to \( R_L \))
Bipolar supply

\[ V^+ \]

\[ V_- \]

\[ R_L \]
Bipolar supply

\[ V^+ \]

\[ R_L \]

\[ V^- \]
Bipolar supply

\[ V^+ \]

\[ R_L \]

\[ V_- \]
H bridge
H bridge

\[ V^+ \]

\[ V^- \]

\[ R_L \]

1 2 3 4
H bridge

\[ V^+ \]

\[ R_L \]

\[ V^- \]