Electronics
Inductive Output Transducers

Terry Sturtevant

Wilfrid Laurier University

October 18, 2016

Output transducers

Output transducers

- also called “actuators”

Output transducers

- also called "actuators"
- basically of two types

Output transducers

- also called “actuators”
- 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

Solenoid

- consists of a coil and plunger
- can be of either "push" or "pull" type

Solenoid

- consists of a coil and plunger
- can be of either “push” or “pull” type

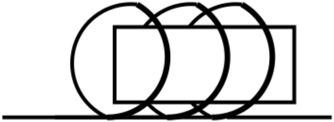
  “pull” type are much more common

Solenoid

- consists of a coil and plunger
- can be of either “push” or “pull” type

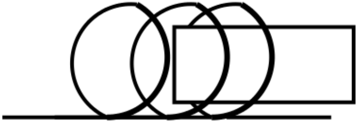
  “pull” type are much more common

Solenoid

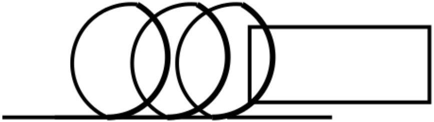


- plunger in

Solenoid



Solenoid



- plunger out

Induced EMF

Induced EMF

- Quickly changing voltage across inductor produces *induced EMF*

Induced EMF

- Quickly changing voltage across inductor produces *induced EMF*

  induced voltage tries to counteract change in current

Induced EMF

- Quickly changing voltage across inductor produces *induced EMF*

  induced voltage tries to counteract change in current

  can produce big voltage spikes

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 $\approx 0.7V$.

Induced EMF

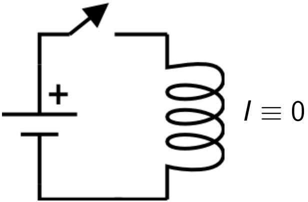
- Quickly changing voltage across inductor produces *induced EMF*

  induced voltage tries to counteract change in current

  can produce big voltage spikes
- A diode across a coil will limit voltages to $\approx 0.7V$.

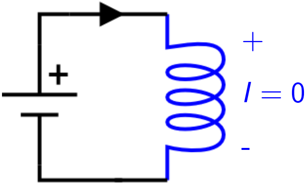
  A zener diode can limit voltages the other way to about the zener voltage.

No diode to reduce induced EMF



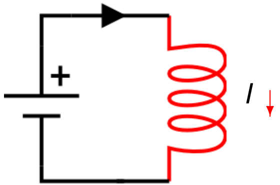
Initially $I = 0$.

No diode to reduce induced EMF



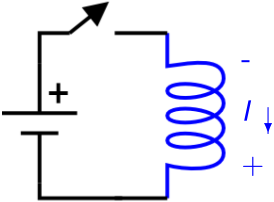
Induced voltage tries to maintain $I = 0$.

No diode to reduce induced EMF



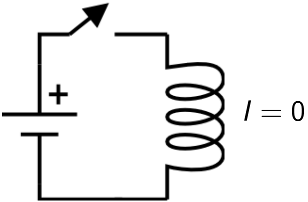
Eventually current is established determined by resistance in circuit.

No diode to reduce induced EMF



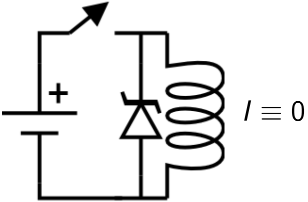
Induced voltage tries to maintain I at the previous value.

No diode to reduce induced EMF



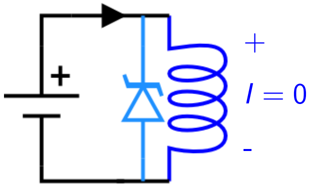
Eventually current is reduced to $I = 0$.

Diode to reduce induced EMF



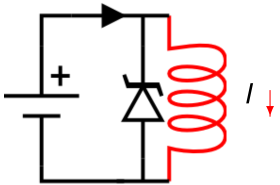
Initially $I = 0$.

Diode to reduce induced EMF



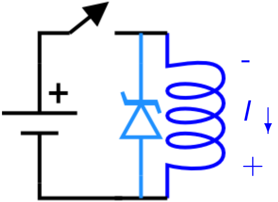
Induced voltage tries to maintain $I = 0$, *but cannot exceed* V_Z.

Diode to reduce induced EMF



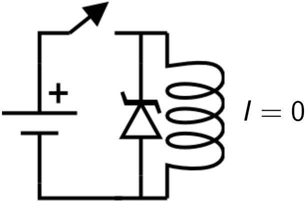
Eventually current is established determined by resistance in circuit.

Diode to reduce induced EMF



Induced voltage tries to maintain I *but cannot exceed* $\approx 0.7V$.

Diode to reduce induced EMF



Eventually current is reduced to $I = 0$.

Current requirements

Current requirements

- A solenoid requires more current to move plunger than to hold it.

Current requirements

- A solenoid requires more current to move plunger than to hold it.

  Maintaining current larger than necessary wastes power and produces heat.

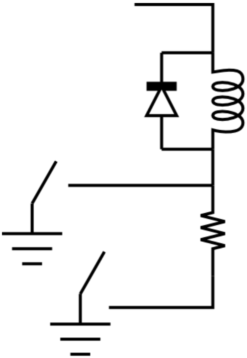
Current requirements

- A solenoid requires more current to move plunger than to hold it.

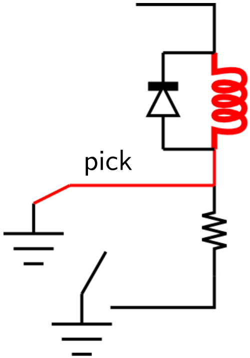
  Maintaining current larger than necessary wastes power and produces heat.
- Several options exist for adjusting current between moving the plunger and holding it.

Series resistor

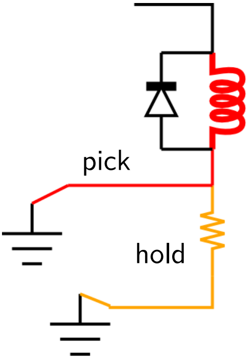
Series resistor



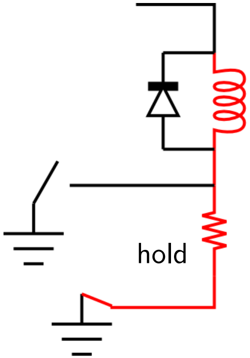
Series resistor



Series resistor

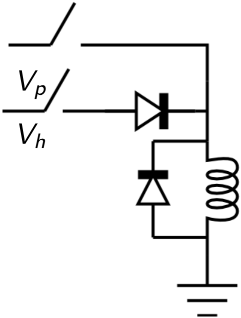


Series resistor

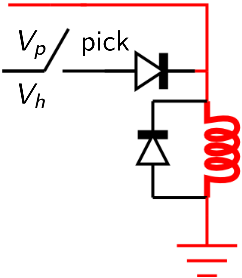


Multiple supplies

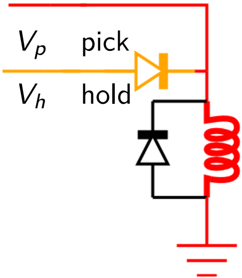
Multiple supplies



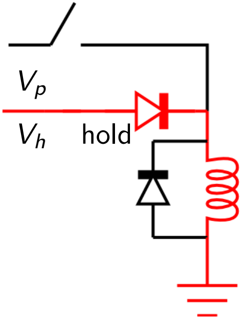
Multiple supplies



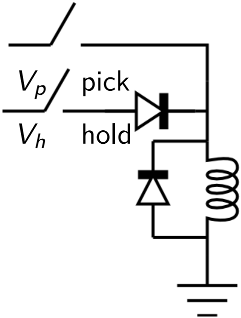
Multiple supplies



Multiple supplies

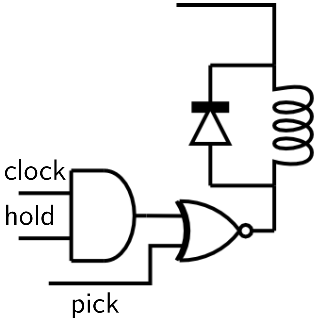


Multiple supplies

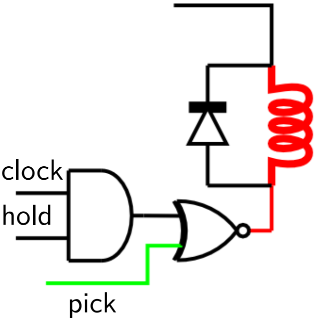


$V_p > V_h$

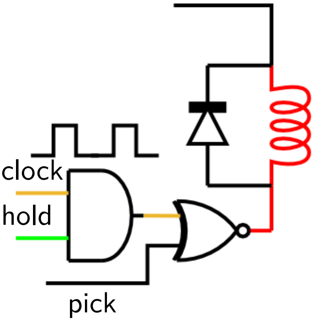
Pulse width modulation to limit current



Pulse width modulation to limit current



Pulse width modulation to limit current



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.

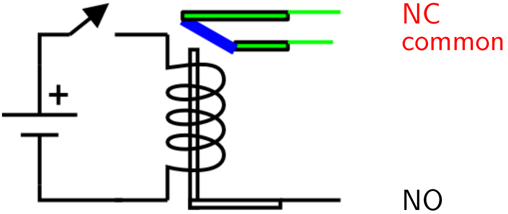
Solenoids in action: Relays

A relay is a device for switching, which is based on a solenoid.

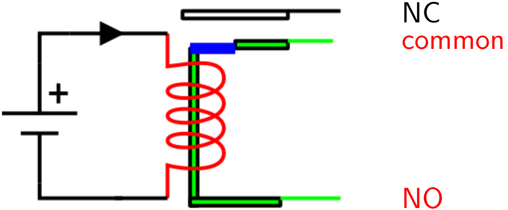
The solenoid is used to open and close a switch.

An internal spring returns the solenoid to its original position.

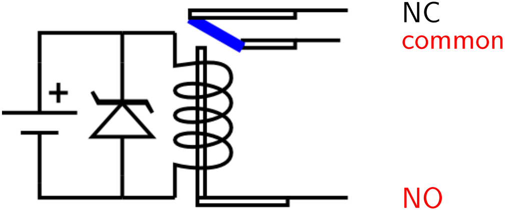
Relay **OFF**



Relay ON



Zener diode to reduce EMF



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

DC motor

- PMDC (Permanent Magnet DC)

DC motor

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

DC motor

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

  armature on shaft has electromagnet

DC motor

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

  armature on shaft has electromagnet

  commutator on shaft reverses current direction every half rotation

DC motor

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

  armature on shaft has electromagnet

  commutator on shaft reverses current direction every half rotation
- speed controlled by current

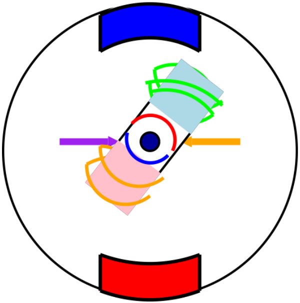
DC motor

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

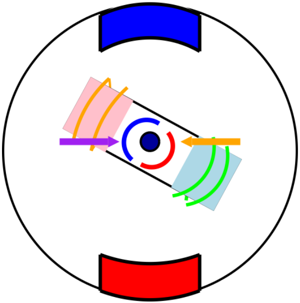
  armature on shaft has electromagnet

  commutator on shaft reverses current direction every half rotation
- speed controlled by current
- continuous motion

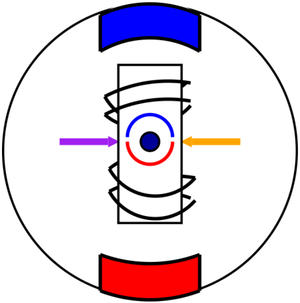
Permanent magnet DC motor



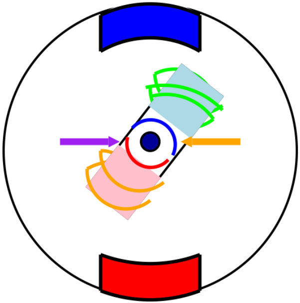
Permanent magnet DC motor



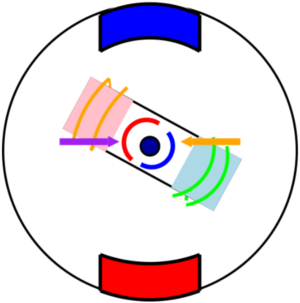
Permanent magnet DC motor



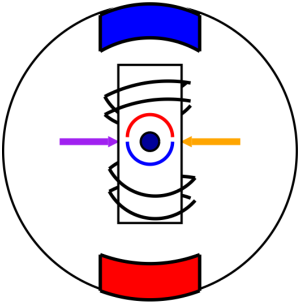
Permanent magnet DC motor



Permanent magnet DC motor



Permanent magnet DC motor



Brushless DC motor

Brushless DC motor

- uses fixed electromagnets

Brushless DC motor

- uses fixed electromagnets

  armature on shaft has permanent magnets

Brushless DC motor

- uses fixed electromagnets

  armature on shaft has permanent magnets
- continuous motion

Brushless DC motor

- uses fixed electromagnets

  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

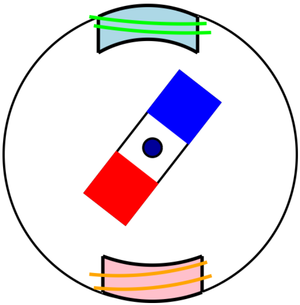
- uses fixed electromagnets

  armature on shaft has permanent magnets
- continuous motion

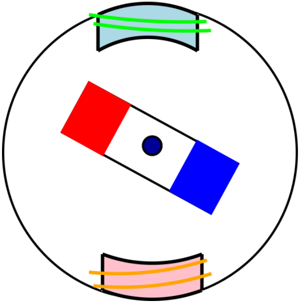
  capable of holding one position
- need to sense position

  can use a hall effect sensor or sense induced voltage in unused coils

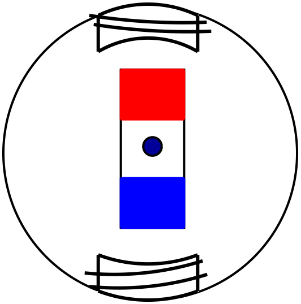
Brushless DC motor



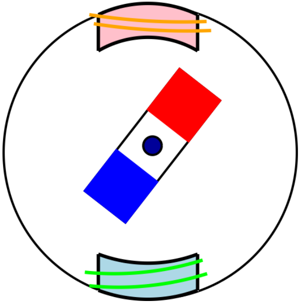
Brushless DC motor



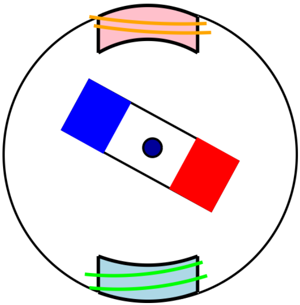
Brushless DC motor



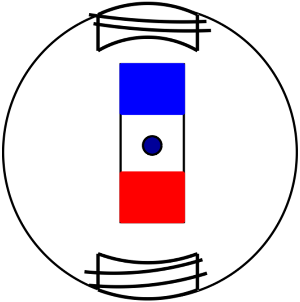
Brushless DC motor



Brushless DC motor



Brushless DC motor



Stepper motor

Stepper motor

- uses fixed electromagnets

Stepper motor

- uses fixed electromagnets

  armature on shaft has soft iron core

Stepper motor

- uses fixed electromagnets

  armature on shaft has soft iron core

  i.e. no permanent magnets

Stepper motor

- uses fixed electromagnets

  armature on shaft has soft iron core

  i.e. no permanent magnets
- similar operation to brushless motors

Stepper motor

- uses fixed electromagnets

  armature on shaft has soft iron core

  i.e. no permanent magnets
- similar operation to brushless motors
- discrete steps

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

Stepper motor

- uses fixed electromagnets

  armature on shaft has soft iron core

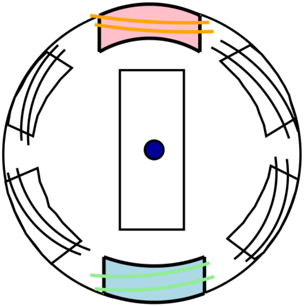
  i.e. no permanent magnets
- similar operation to brushless motors
- discrete steps
- drive electronics controls speed and direction
- half-stepping is possible

Stepper motor

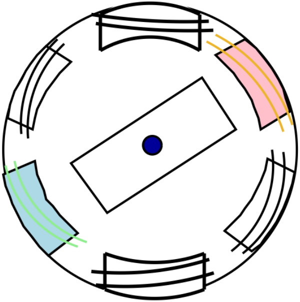
- uses fixed electromagnets

  armature on shaft has soft iron core

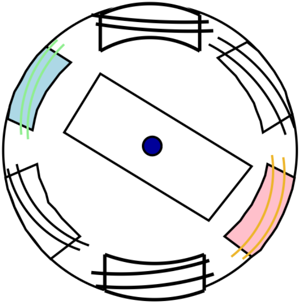
  i.e. no permanent magnets
- similar operation to brushless motors
- discrete steps
- drive electronics controls speed and direction
- half-stepping is possible
- can hold in position



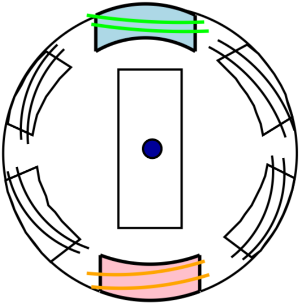
Single stepping



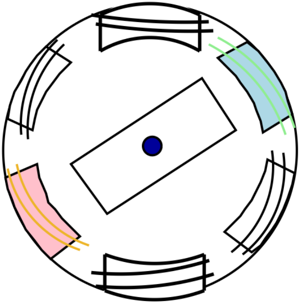
Single stepping



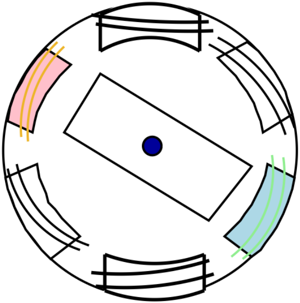
Single stepping



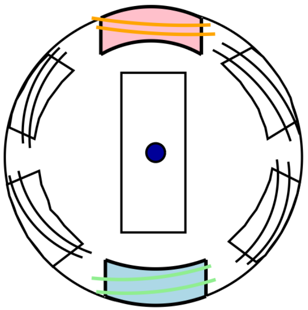
Single stepping



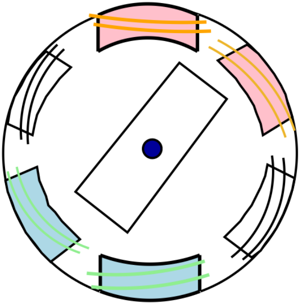
Single stepping



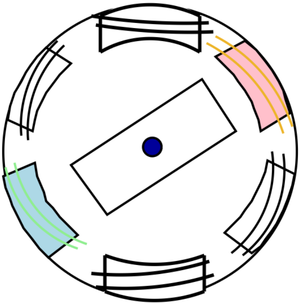
Single stepping



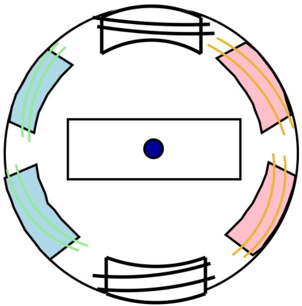
Half stepping



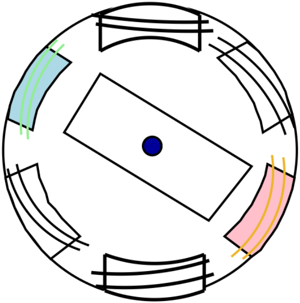
Half stepping



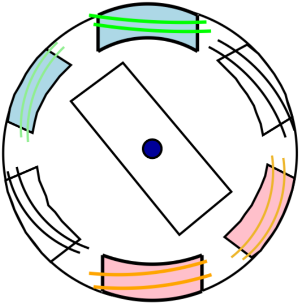
Half stepping



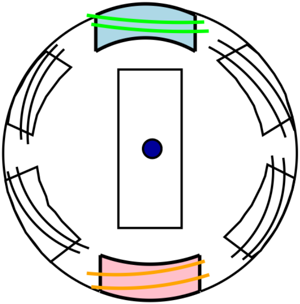
Half stepping



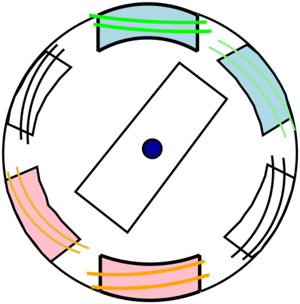
Half stepping



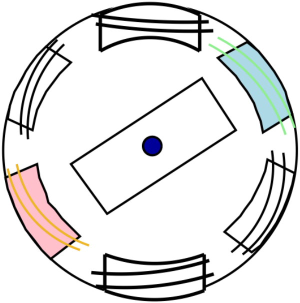
Half stepping



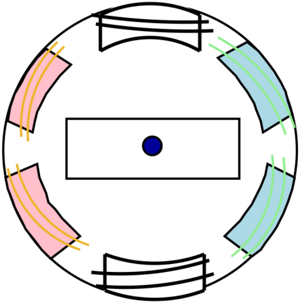
Half stepping



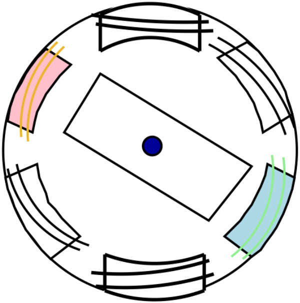
Half stepping



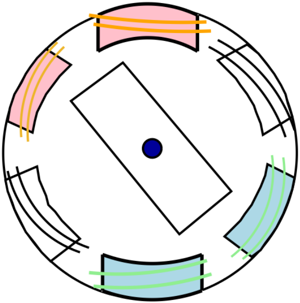
Half stepping



Half stepping



Half stepping



Half stepping

Servo motor

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

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

  default width keeps motor stationary (e.g. 1.5 ms)

Servo motor

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

  default width keeps motor stationary (e.g. 1.5 ms)

  longer pulse makes motor rotate in one direction

Servo motor

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

  default width keeps motor stationary (e.g. 1.5 ms)

  longer pulse makes motor rotate in one direction

  shorter pulse makes motor rotate in the other direction

Servo motor

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

  default width keeps motor stationary (e.g. 1.5 ms)

  longer pulse makes motor rotate in one direction

  shorter pulse makes motor rotate in the other direction

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

Servo motor

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

  default width keeps motor stationary (e.g. 1.5 ms)

  longer pulse makes motor rotate in one direction

  shorter pulse makes motor rotate in the other direction

  pulse must be repeated periodically (e.g. every 20 ms)
- often limited to less than 360 degree travel

Servo motor

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

  default width keeps motor stationary (e.g. 1.5 ms)

  longer pulse makes motor rotate in one direction

  shorter pulse makes motor 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

Servo motor

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

  default width keeps motor stationary (e.g. 1.5 ms)

  longer pulse makes motor rotate in one direction

  shorter pulse makes motor 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

  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

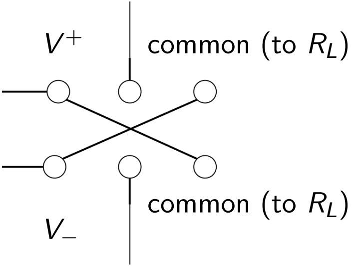
Methods to reverse current to PM DC motor

- dpdt switch
- bipolar supply

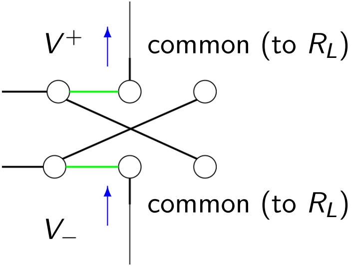
Methods to reverse current to PM DC motor

- dpdt switch
- bipolar supply
- H bridge

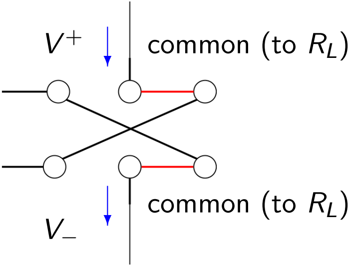
DPDT switch



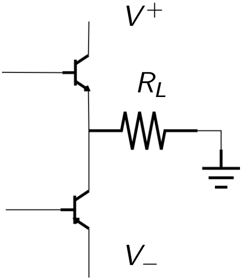
DPDT switch



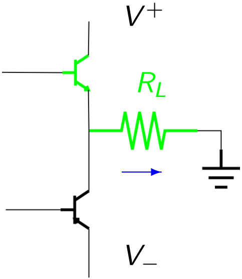
DPDT switch



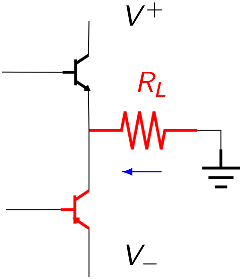
Bipolar supply



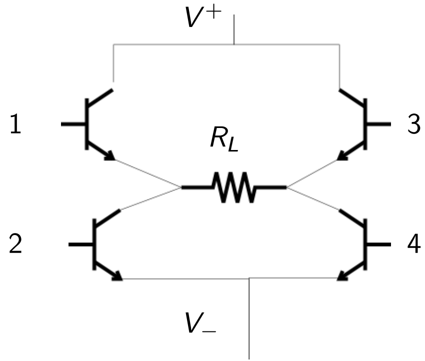
Bipolar supply



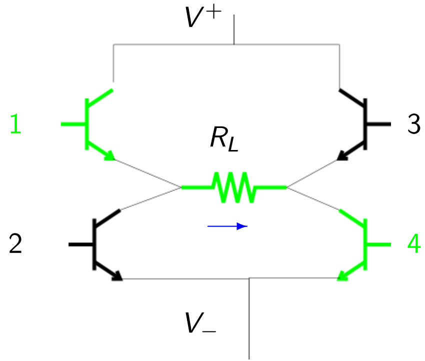
Bipolar supply



H bridge



H bridge



H bridge