

Part 1: What is the right motor for my application?

- Brushed, stepper and brushless-DC motors
- Common uses for each motor type
- Compare motors based on performance and use cases

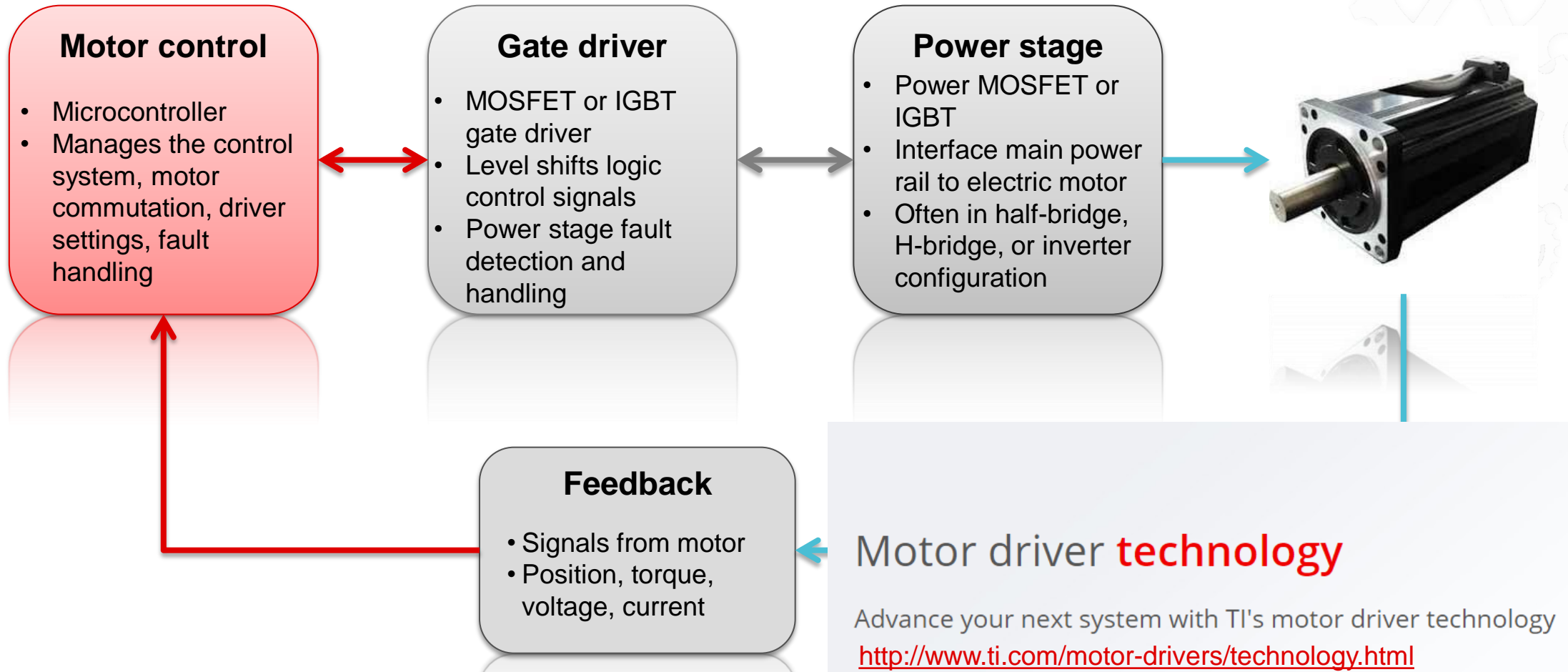
THE ART OF Driving Motors

A **WEBINAR SERIES** BY TEXAS INSTRUMENTS

Innocent Irakoze
Dalton Ortega

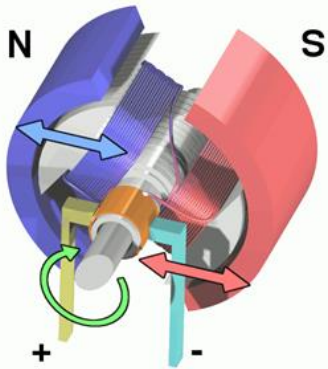
Date: Oct 29th, 2018

Electric motor control **system overview**



Motor types

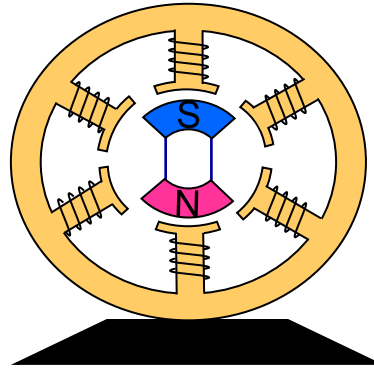
Brushed-DC motor



- + Low cost
- + Easy to design
- Brushes wear out
- Inefficient

Application Reference Designs
[Smart Meters](#), [Video Surveillance](#),
[Small and Large Appliances](#),
[Electronic Locks](#),

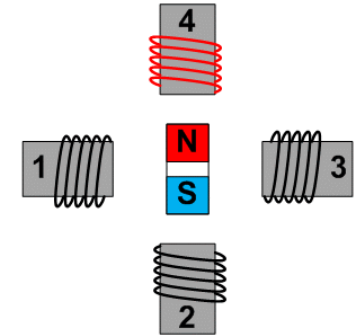
Brushless-DC motor



- + Very efficient
- + Long life / reliable
- Expensive
- Complex design

Application Reference Designs
[Garden and Power Tools](#), [Appliance Pumps and Fans](#), [E-Mobility](#), [Factory Automation & Logistics](#)

Stepper motor



- + Open loop position / speed control
- + Simple control
- Resonance
- Noise

Application Reference Designs
[Printers](#), [Refrigerator & Freezer](#),
[Mobile EPOS Printers](#), [Stage Lighting](#)

[Brushed & Stepper] Image source: www.robot-and-machines-design.com

Drive performance with Brushed DC (BDC) motor drivers

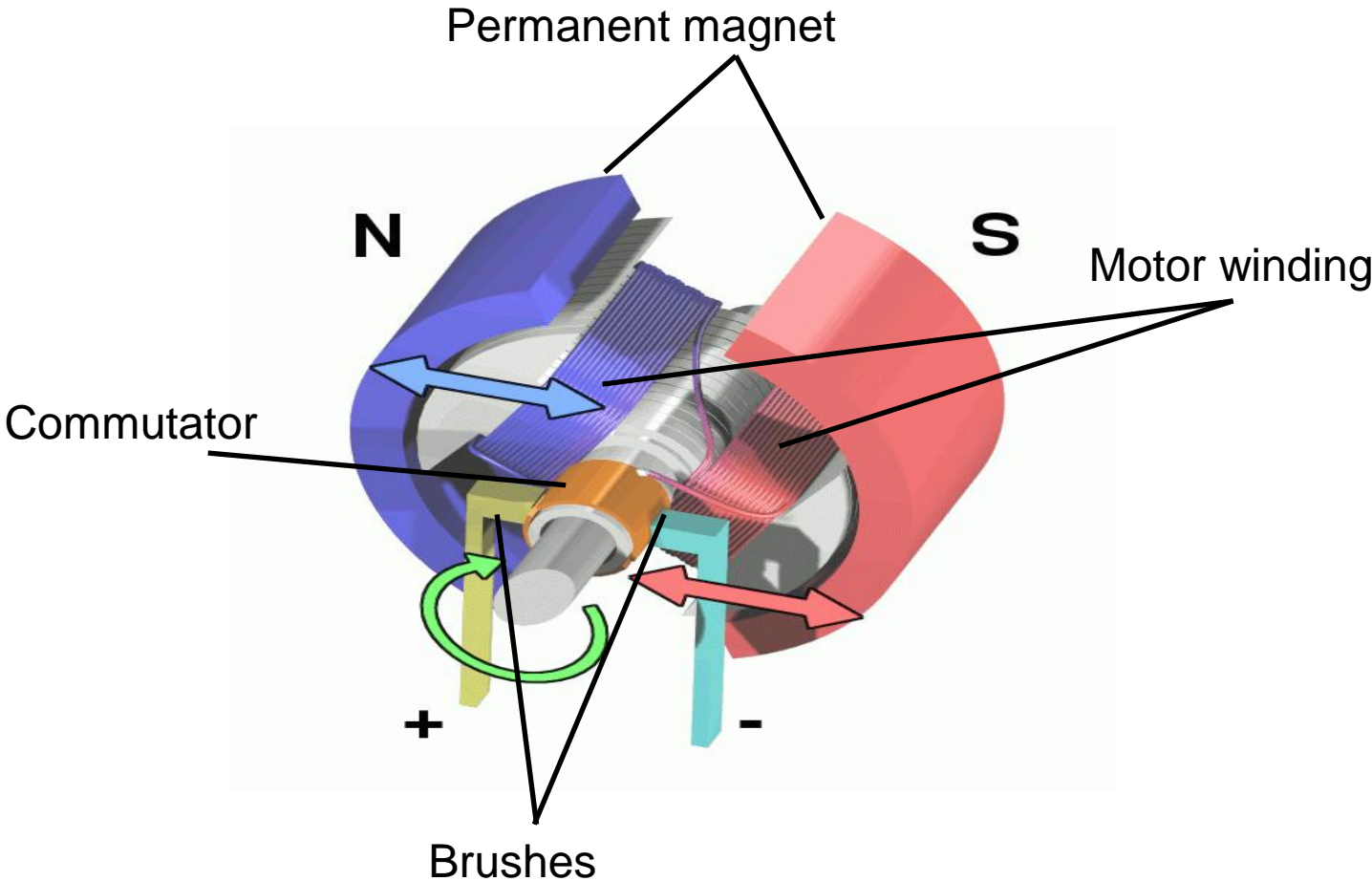
Integrated FET and Smart Gate Drive solutions for Brushed DC motor control

Brushed-DC Motors

Texas Instruments – Motor Drives

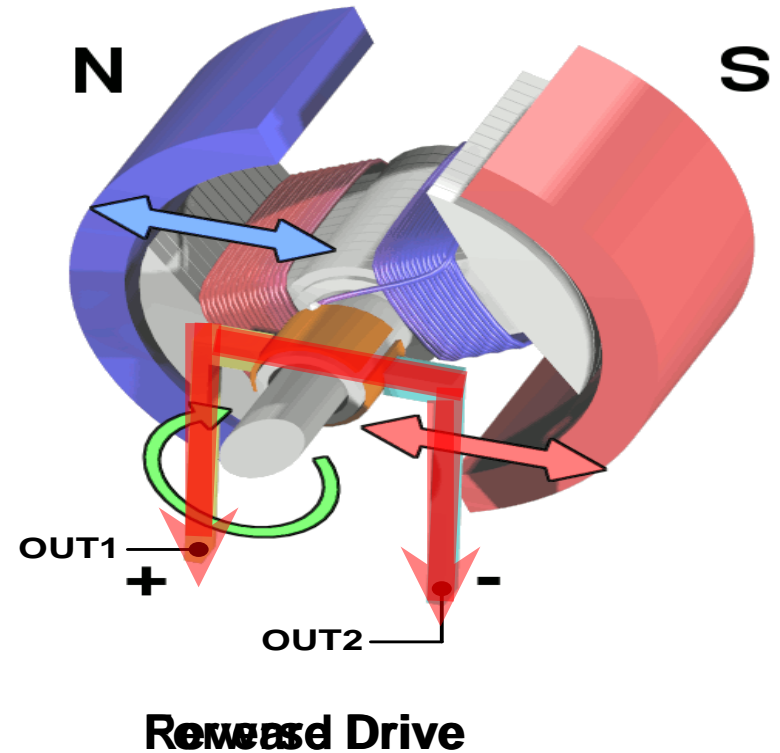
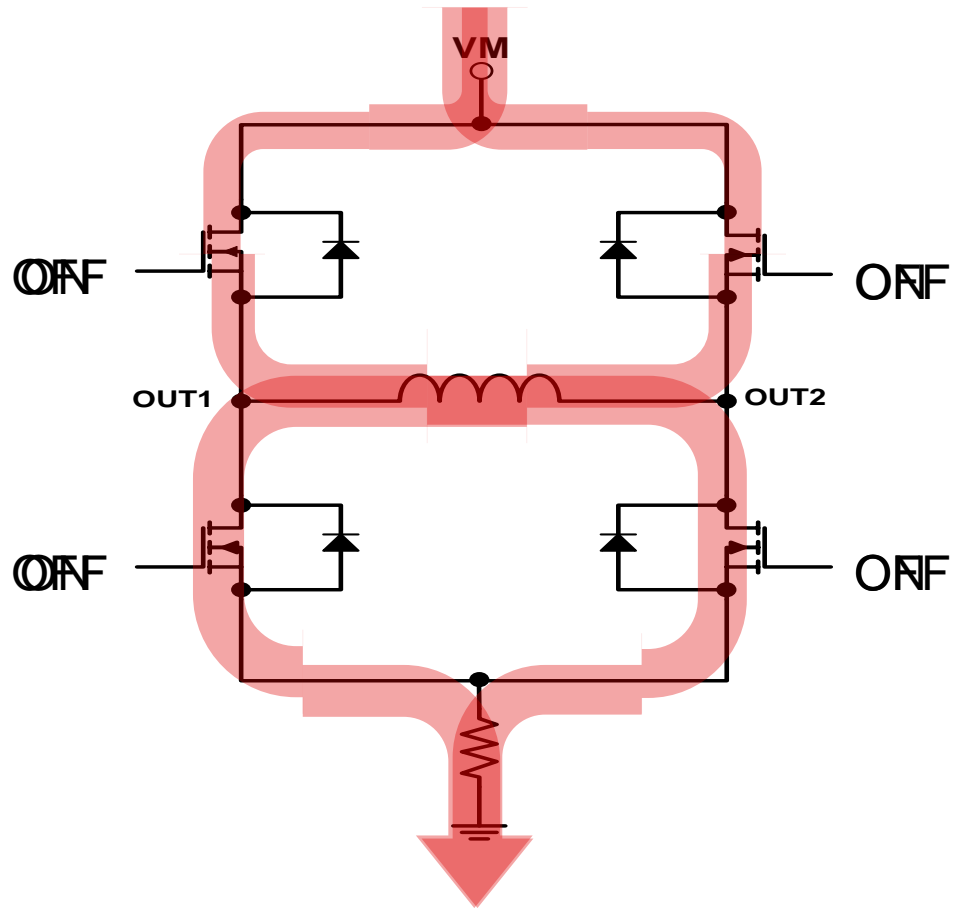


Brushed – DC motor construction



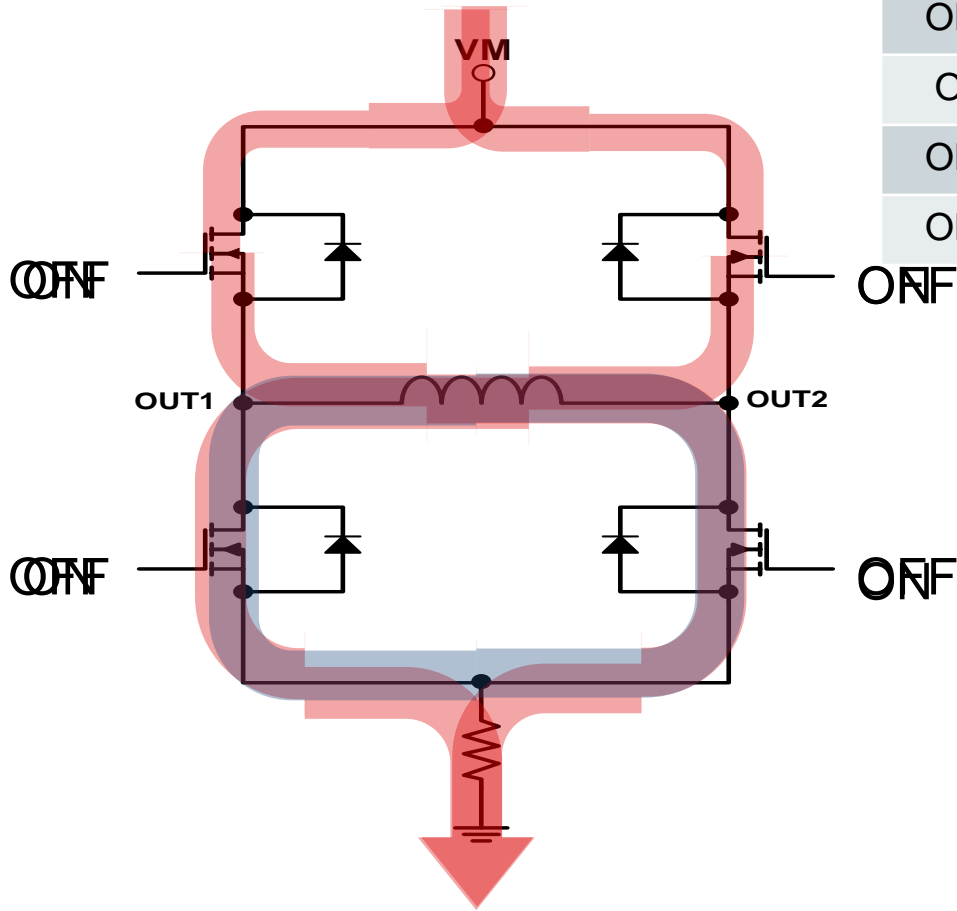
Brushed – DC motor commutation

Bidirectional brushed motor driver



Brushed – DC motor: H-Bridge states

H-Bridge States



HS1	LS1	HS2	LS2	OUT1	OUT2	Mode
OFF	OFF	OFF	OFF	Z	Z	Coast
ON	OFF	OFF	ON	H	L	Forward
OFF	ON	ON	OFF	L	H	Reverse
OFF	ON	OFF	ON	L	L	Brake

- **Coast** – current will flow through the body diodes into VM
- **Forward** – current flows from OUT1 to OUT2
- **Reverse** – current flows from OUT2 to OUT1
- **Brake** – current recirculates through the low side FETs

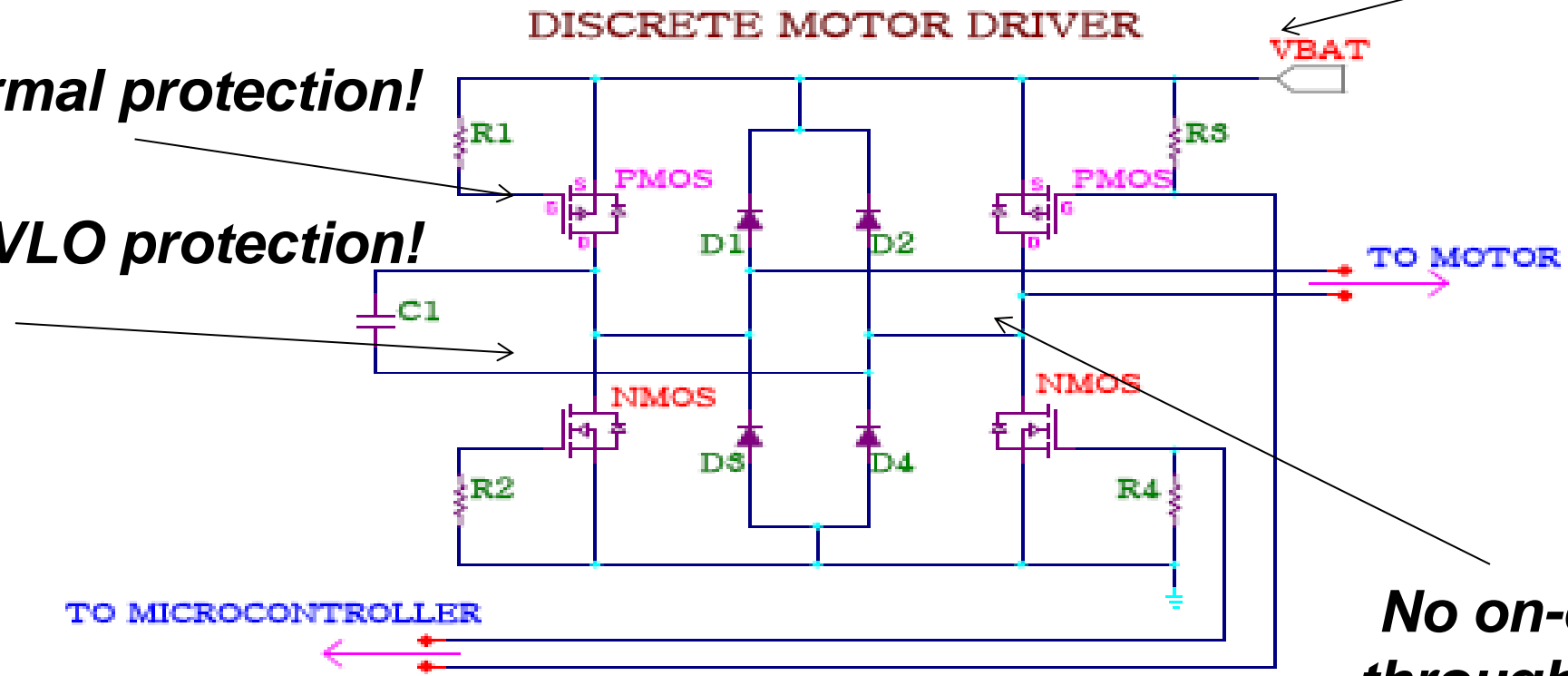
Brushed – DC motor: Protection

Integrated Brushed-DC drivers, like [DRV8837](#), offer increased protection over discrete

No fuse, no protection!

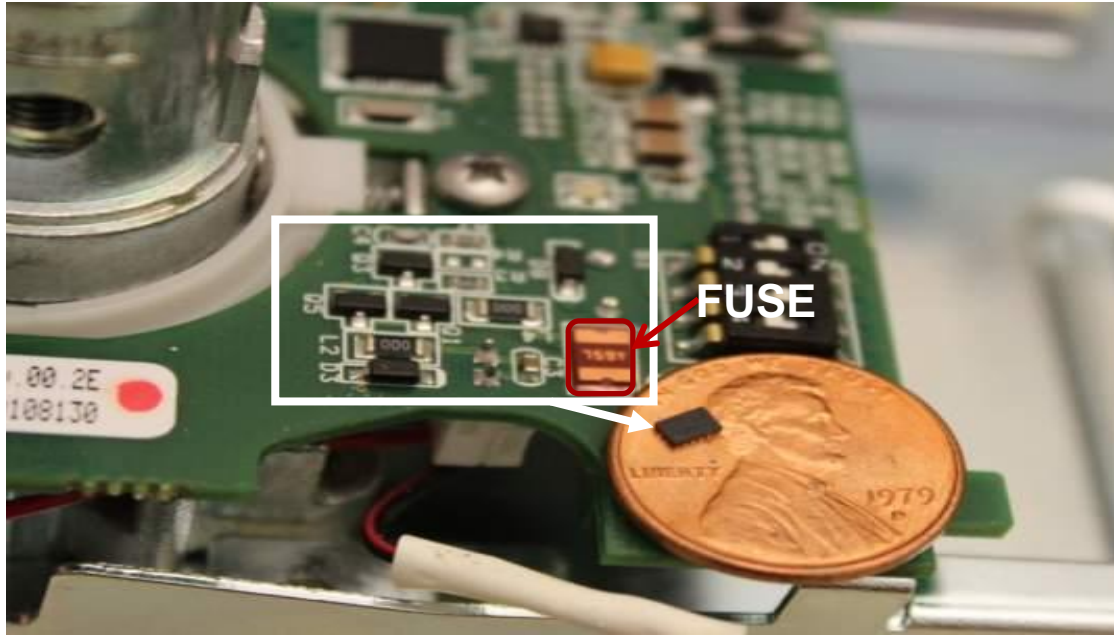
No thermal protection!

No UVLO protection!



No on-chip shoot through protection

DRV8x Bushed DC Drivers



- ✓ Smaller board space
Enables small and simple design
- ✓ Embedded intelligence
Reduces software design; allows lower-end MCU
- ✓ Complete protection
Improves robustness and reliability
- ✓ Ease of use
Accelerates design / ramping; simplifies assembly

Example: In an e-lock system, TI's DRV8837 replaced various discrete components, including the **fuse**, due to its small form factor and ease of design

Common applications with size constraints:

- IP Network Cameras
- Power Tools
- Vacuum Robots

DRV8837



DRV8701



Bushed-DC Motor Applications



Power Tools
DRV8701



E-Locks
DRV8837



Toys
DRV8837C



Currency Counter
DRV8842, DRV8871



Smart Meters
DRV8837, DRV8837C



Coffee Machine
DRV8847, DRV8870



Vacuum Robots
DRV8701, DRV8870



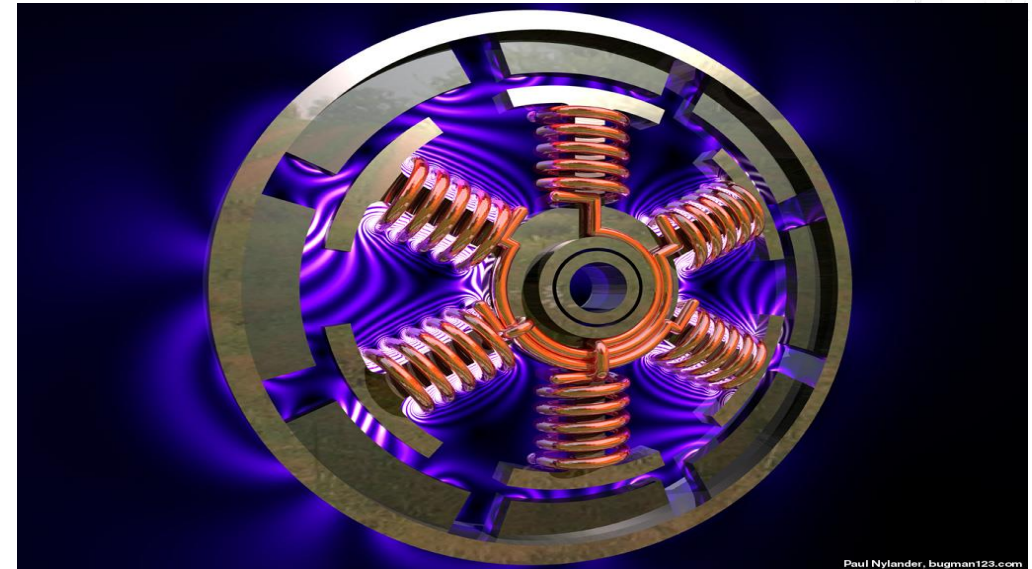
IP Network Cameras
DRV8837, DRV8835

Brushless DC (BLDC) Motor Drivers

Smart gate drivers and integrated motor drivers for BLDC motor control

Brushless-DC Motors

Texas Instruments – Motor Drives



Brushed-DC versus brushless-DC

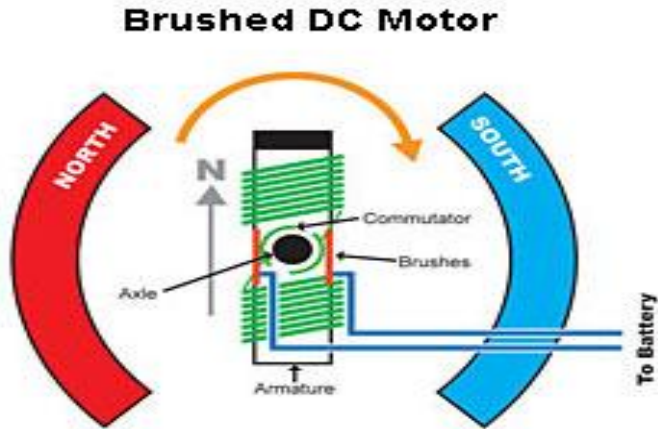
Brushed-DC

- Less torque per weight
- Less torque per watt
- More audible noise
- Shorter lifetime
- Lower reliability
- Commutator sparking
- More EMI radiation
- May need airflow to cool rotor
- Lower RPM
- ...
- Easy to drive

Brushless-DC

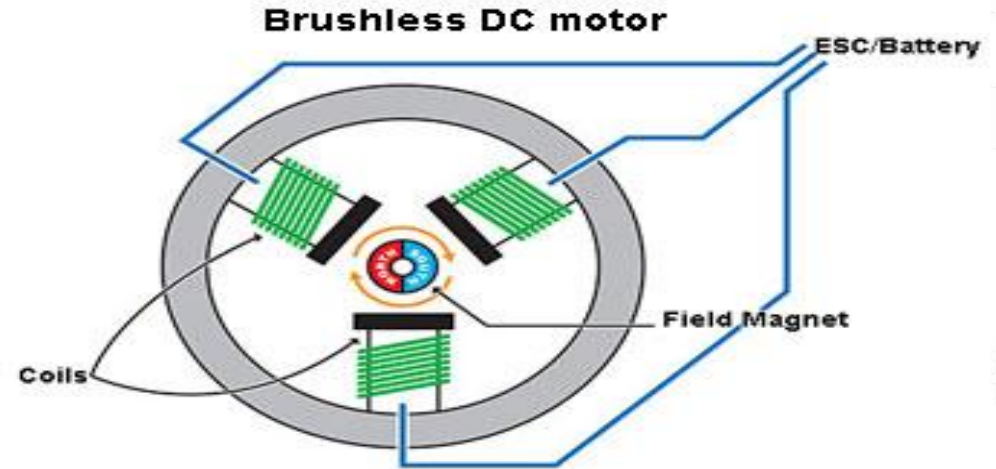
- More torque per weight
- More torque per watt
- Less audible noise
- Longer lifetime
- Higher reliability
- No sparking
- Less EMI radiation
- Can be completely enclosed
- Higher RPM
- ...
- Hard to drive (\$\$\$)

Brushless-DC motor construction



Permanent magnets on stator
Coils on rotor

Bad dissipation because the heat is
confined to the small rotor

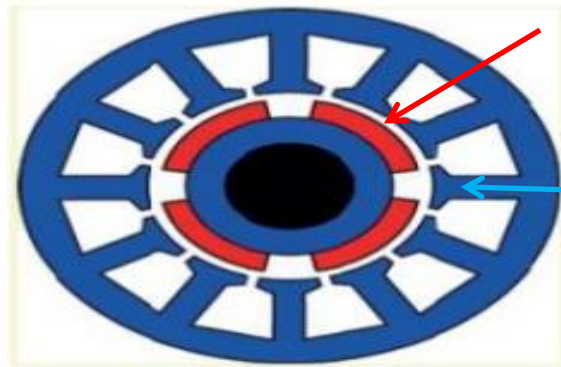


Permanent magnets on rotor
Coils on stator

Good dissipation because the heat is
generated on the stator

Brushless-DC motor construction

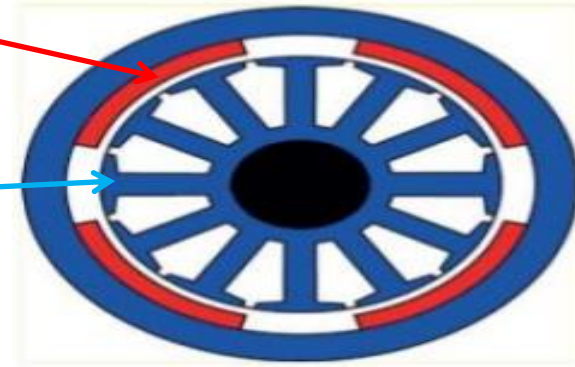
Inner Rotor (Conventional)



Permanent magnet

Coil windings

Outer Rotor (Outrunner)



Smaller construction (compact)
Better heat dissipation
Lower rotor inertia
Quick speed change applications
High torque and speed
High cogging torque
Harder to wind the coils
High performance magnets

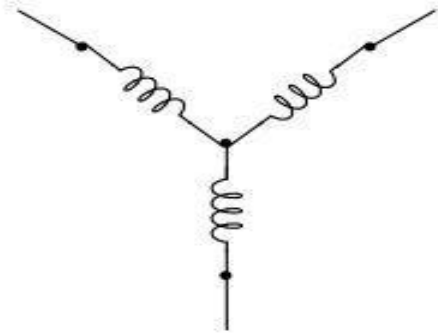
Servos, actuators, pumps

Larger construction
Worse heat dissipation
Higher rotor inertia
Constant speed applications
Higher torque at low rpm
Low cogging torque
Easier to wind the coils
Lower performance magnets

Fans, hard disk, printers

Brushless-DC motor winding connections

**Wye (Y) Winding
Star connection**

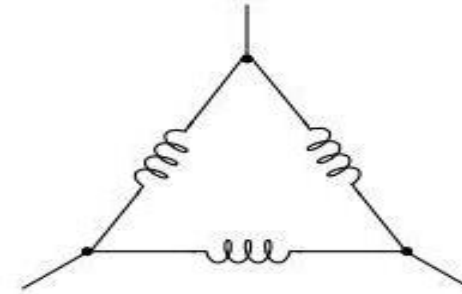


Normally more efficient
Less resistive losses
Immune to parasitic currents

Higher torque at low speed
Lower top speed

Most common

Delta (Δ) Winding



Normally less efficient
More resistive losses
Parasitic currents can circulate

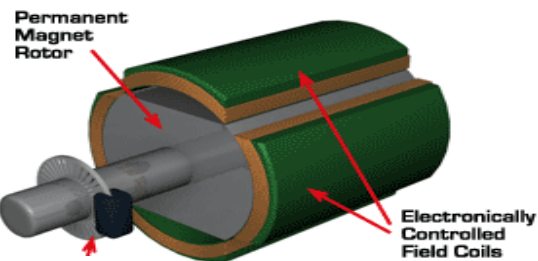
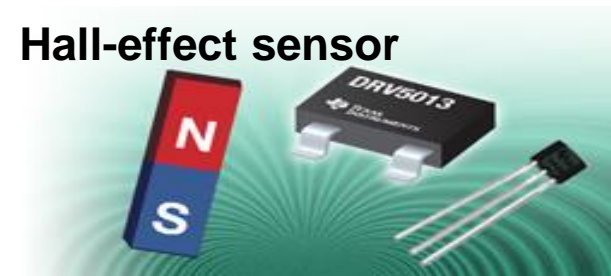
Lower torque at low speed
Higher top speed

Both are driven the same way

Detecting rotor position

Sensored

Hall-effect sensor



Encoder

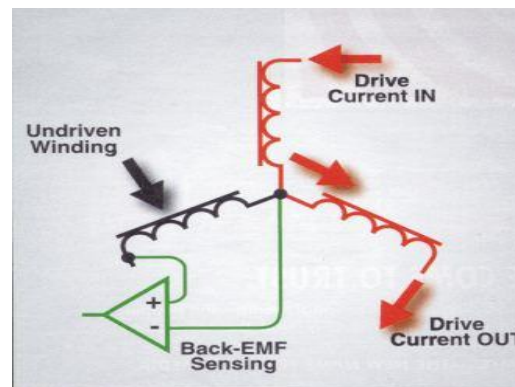


FG trace

- Definite rotor position
- Easier to start
- Simple processing
- More components
- Better jitter performance

Sensorless

Motor flux



Back-EMF measurement

- Have to estimate rotor position
- More difficult to start
- More complicated calculations
- Fewer components
- Worse jitter performance

Brushless-DC motor applications



PC & Notebooks

Hero Device: [DRV10964](#)



Drones

Hero Device: [DRV832x](#)



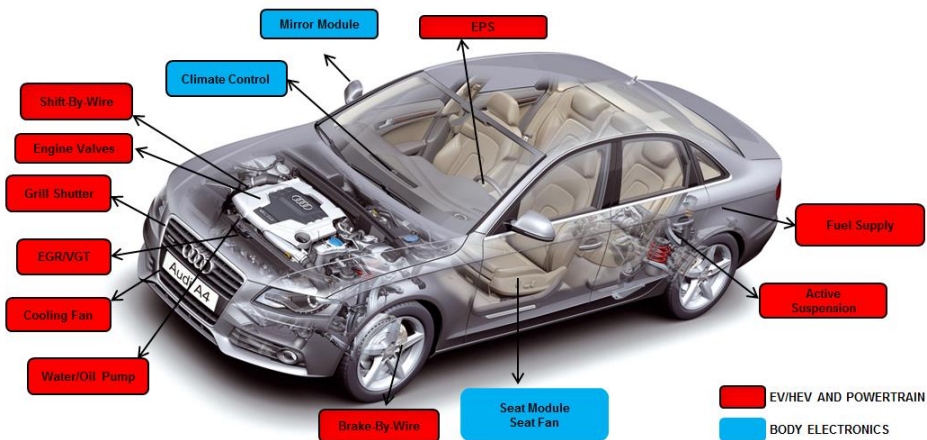
Residential and Living fans

Hero Device: [DRV10983/DRV832x](#)



Power Tools

Hero Device: [DRV832x](#)



Automotive Overview

Hero Devices: [DRV10983-Q1](#) / [DRV8320-Q1](#) / [DRV3205-Q1](#)



Vacuum Robots

Hero Device: [DRV10983/DRV8320](#)



Refrigerators & washers

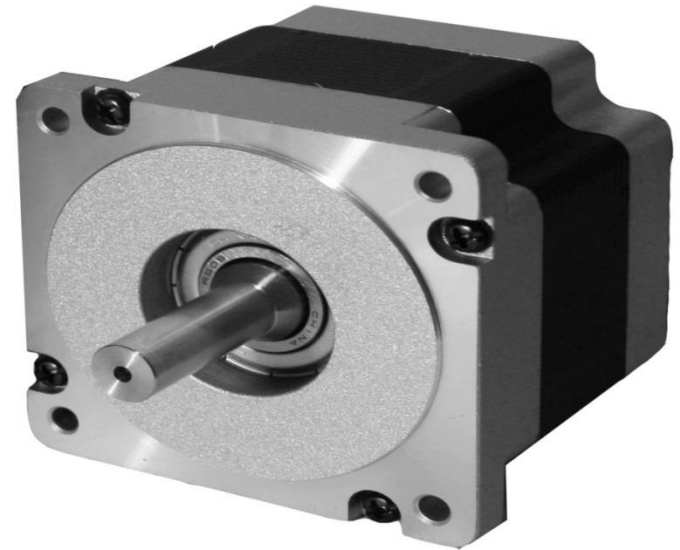
Hero Device: [DRV10987/DRV832x](#)

Step into simple speed and position control

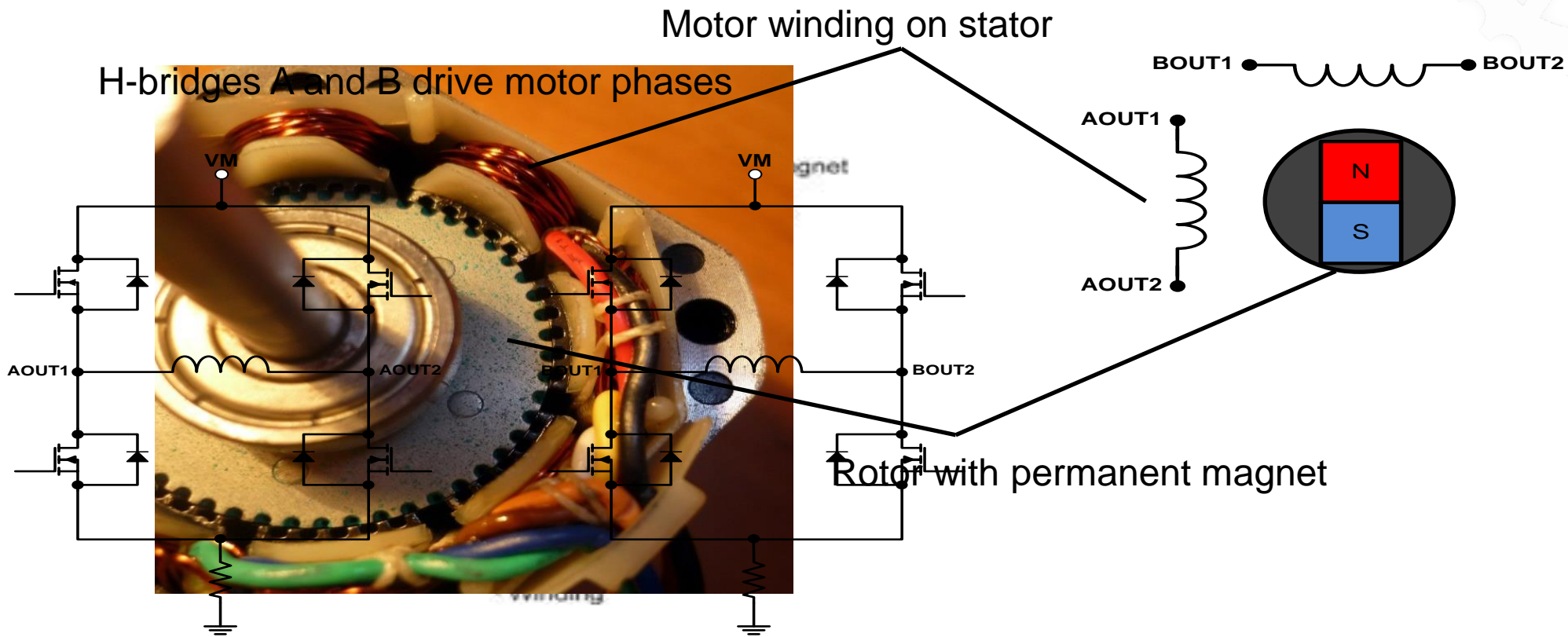
Highly accurate & smooth motion that is easy to design

Stepper Motors

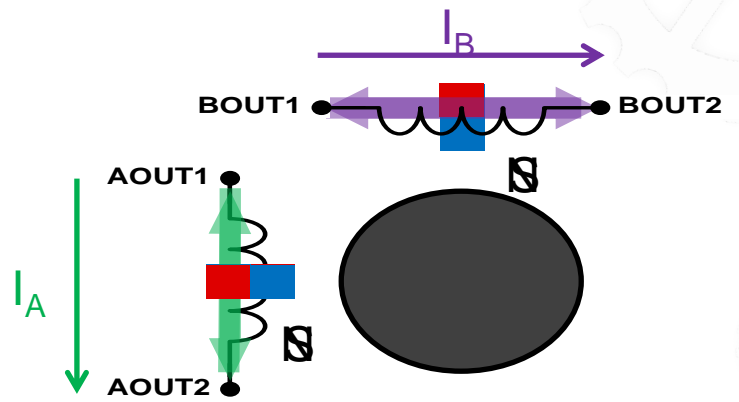
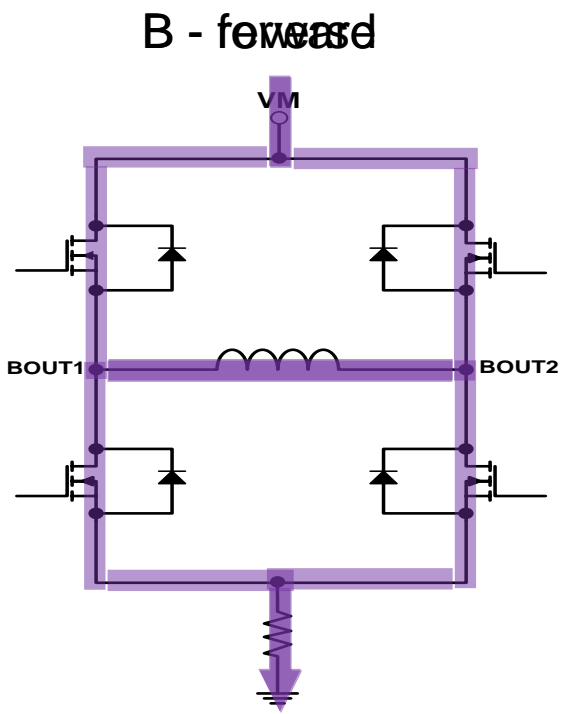
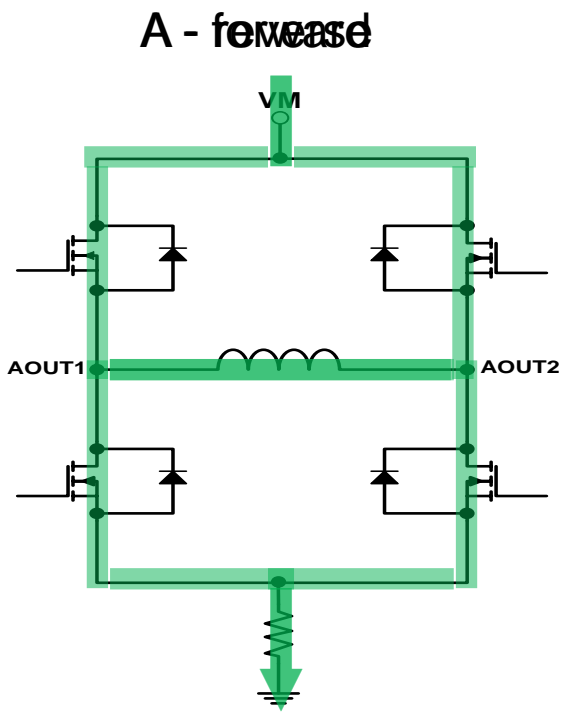
Texas Instruments – Motor Drives



Stepper motor construction

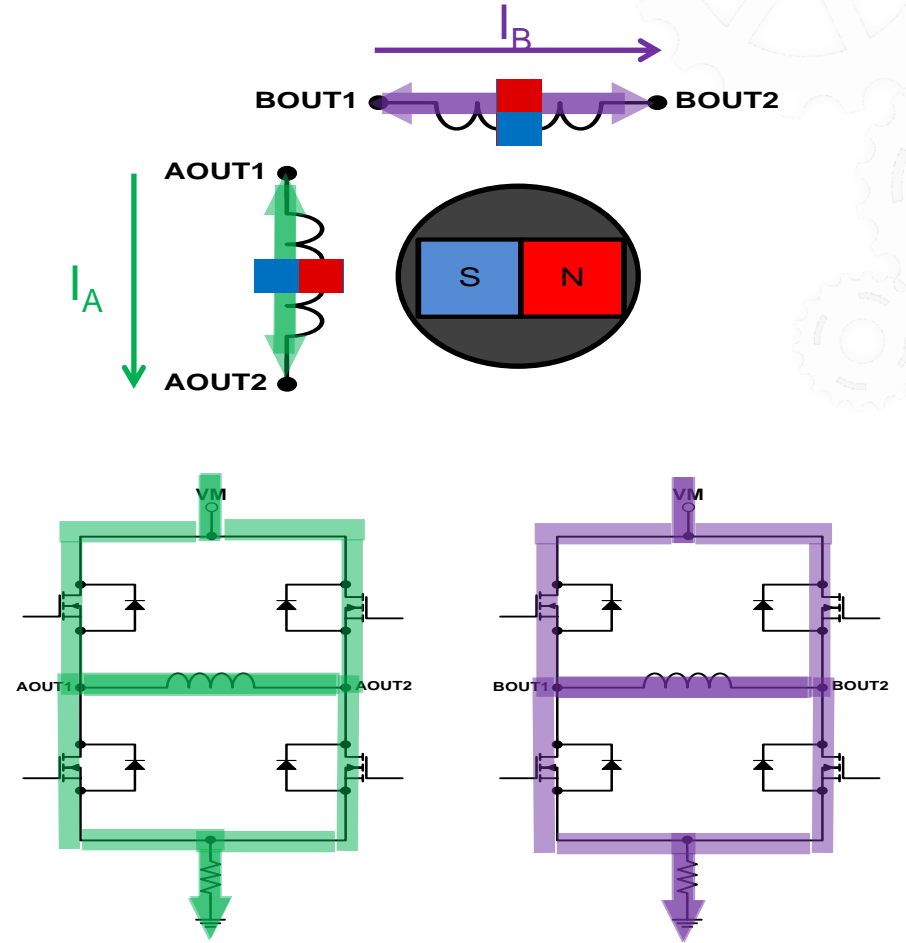
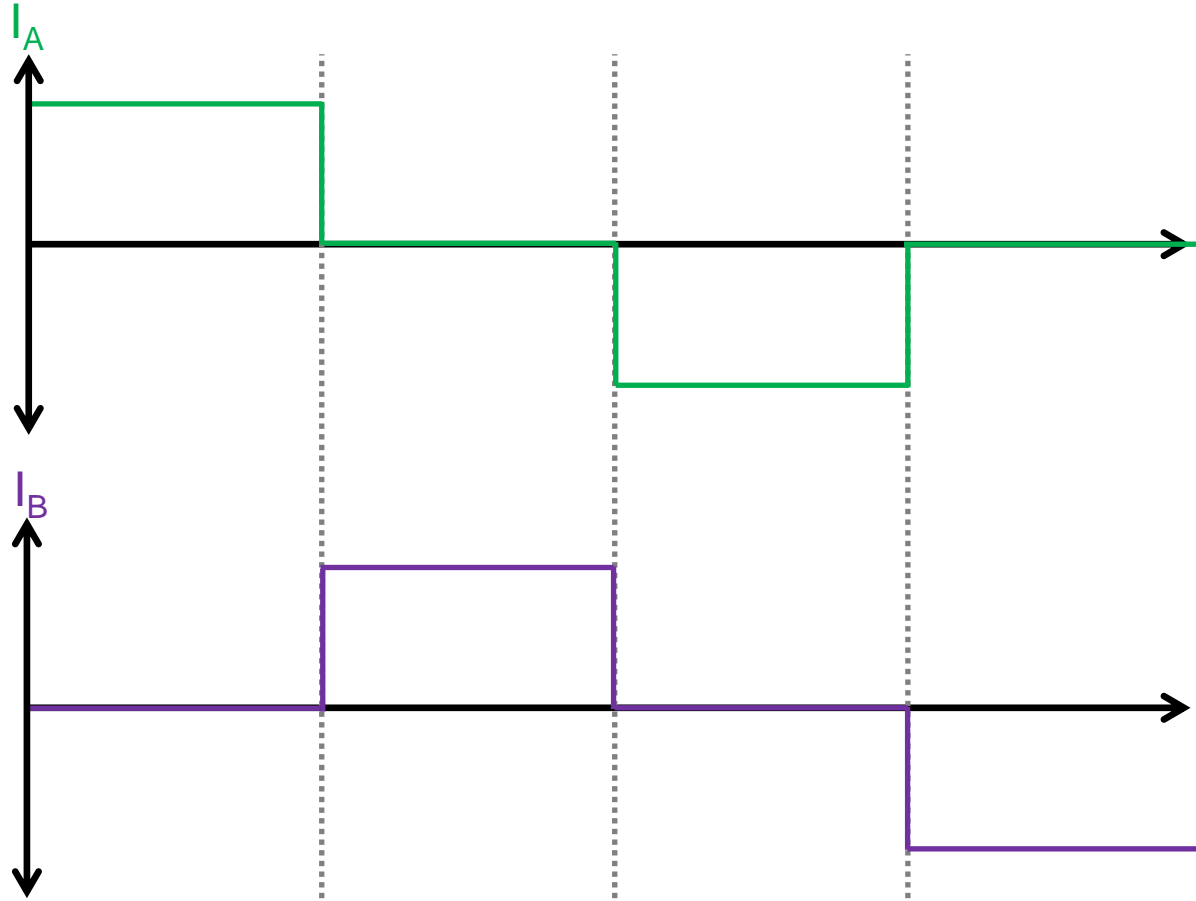


Bipolar stepper motor construction



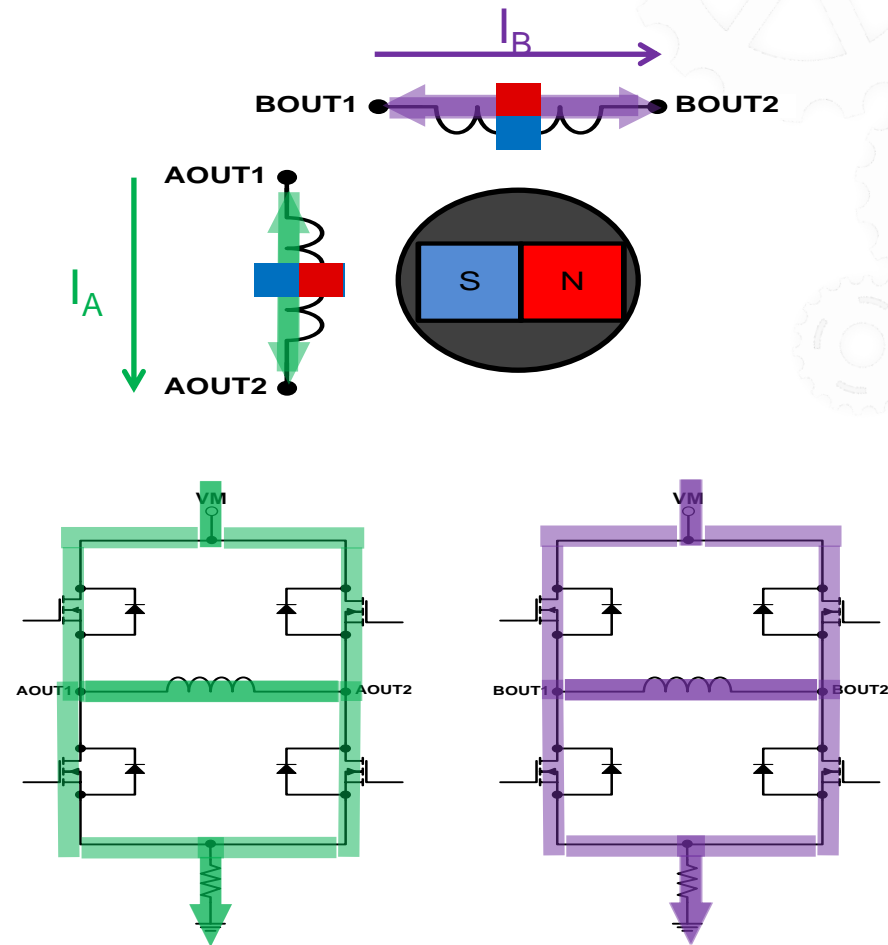
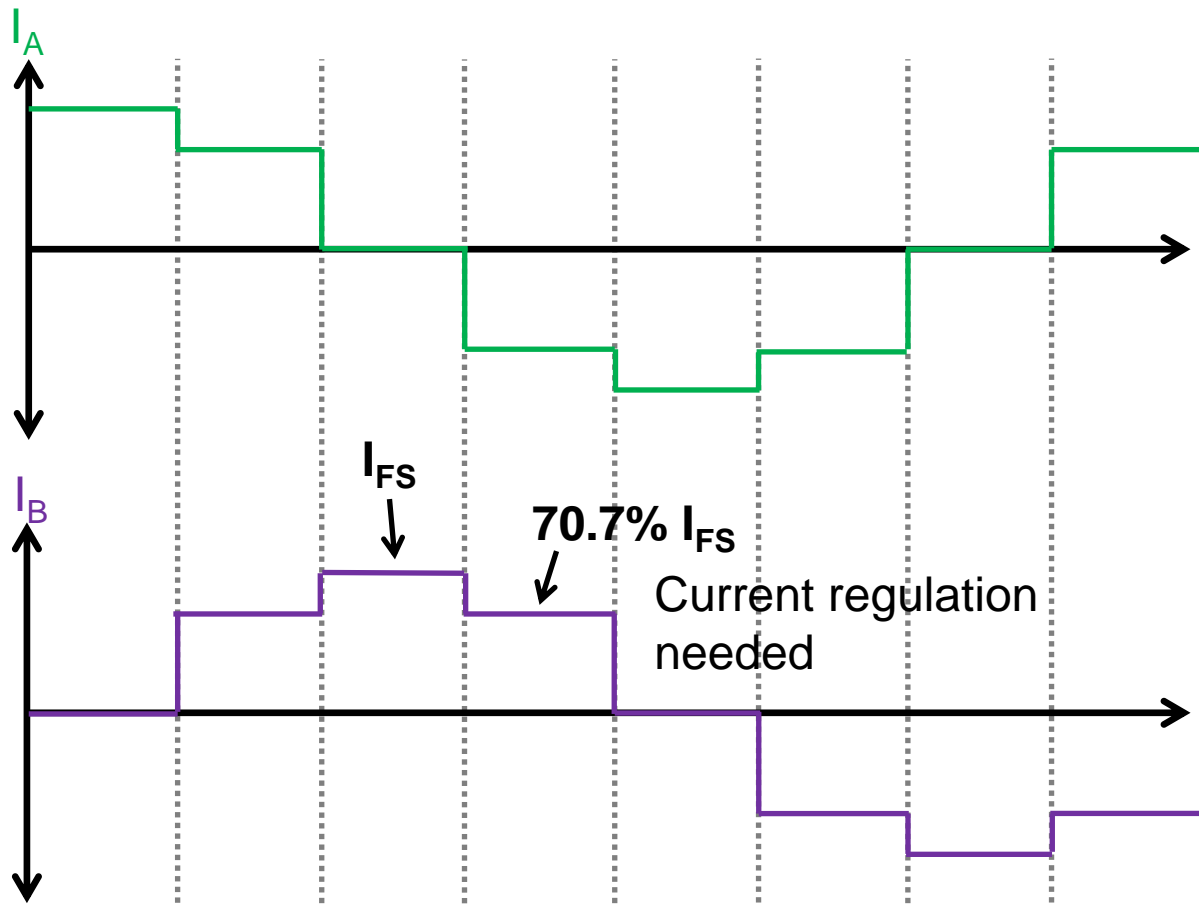
Bipolar stepper motor control

Full Stepping – option #1 “wave drive”



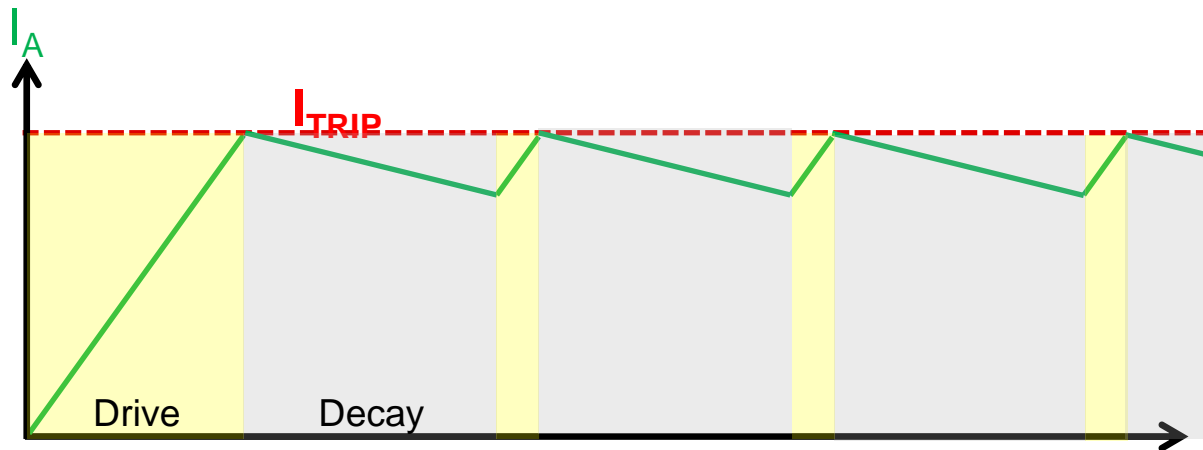
Bipolar stepper motor control

Standard half stepping



Regulating current in stepper motors

PWM current chopping used to regulate current



At each current step, current is driven until it hits I_{TRIP} , then the bridge enters a decay mode for a period of time

Decay Modes: Slow, fast, mixed decay

Timers: Fixed frequency and fixed time-off

TERMS:

I_{TRIP} – Current trip level

t_{DRIVE} – Drive time

t_{OFF} – Decay mode time

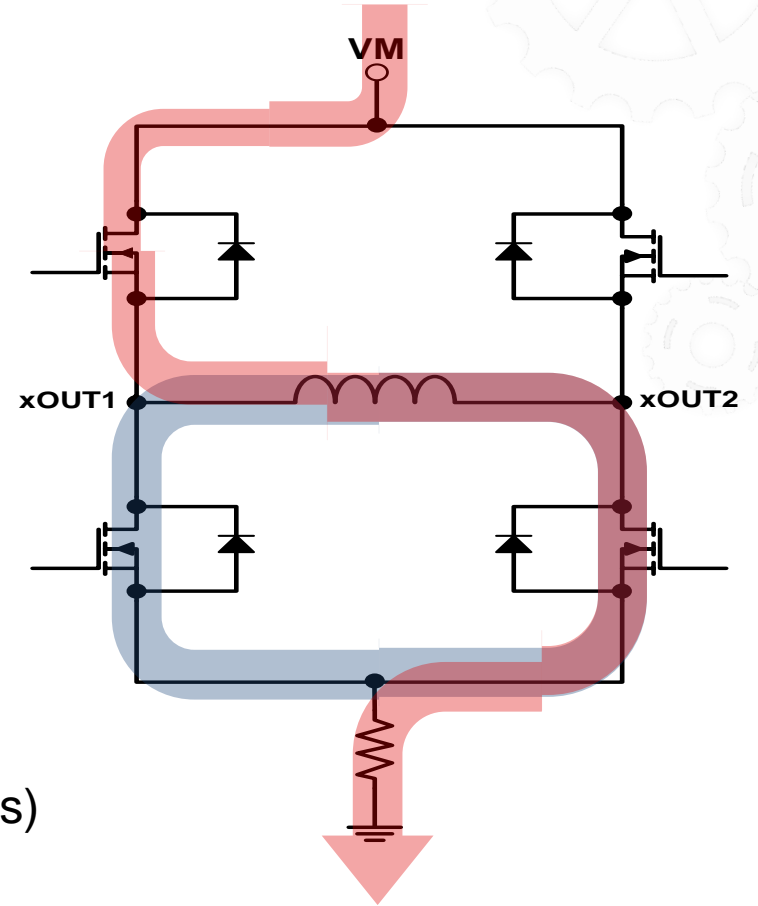
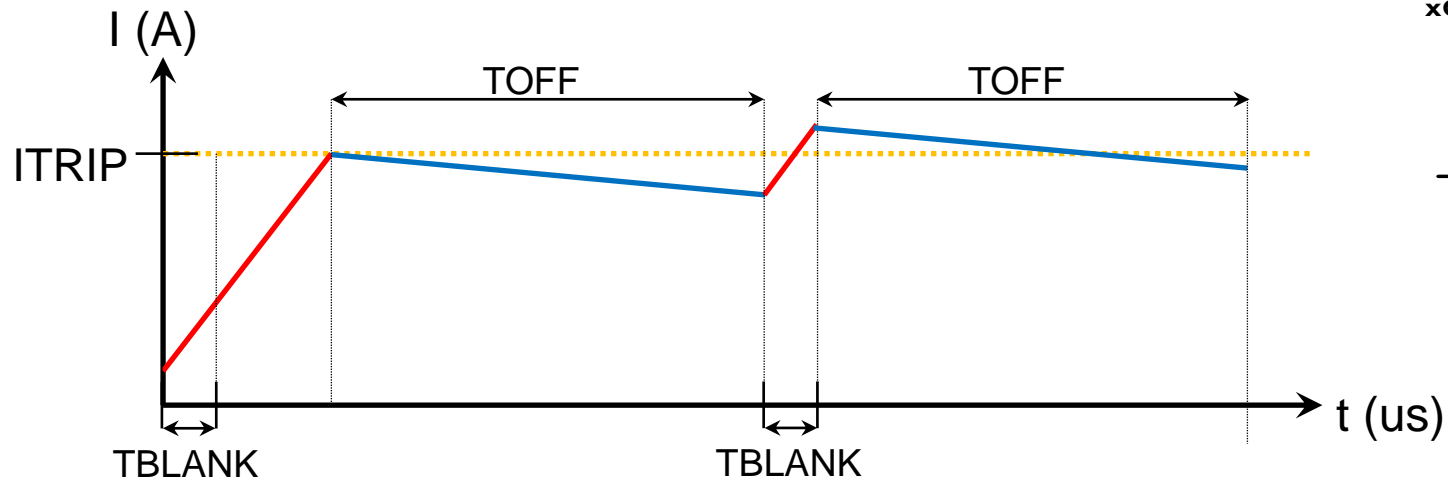
t_{DECAY} – Fast decay time during mixed decay

t_{BLANK} – Minimum drive time

Regulate current with decay modes

Slow decay

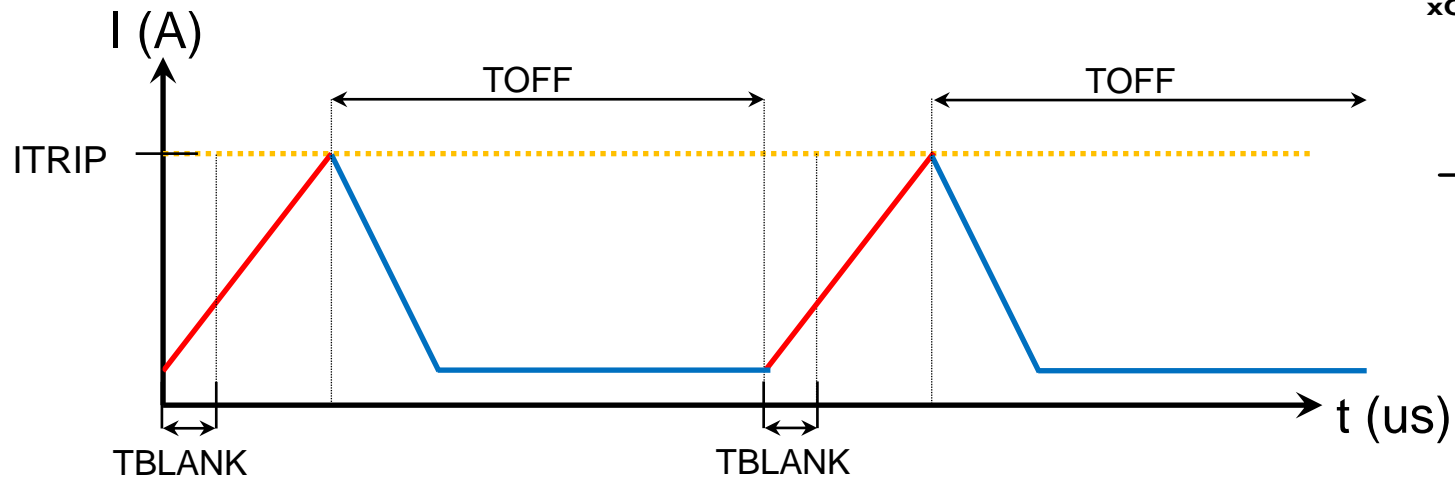
- Winding current is recirculated in both low-side FETs
- Smallest ripple



Regulate current with decay modes

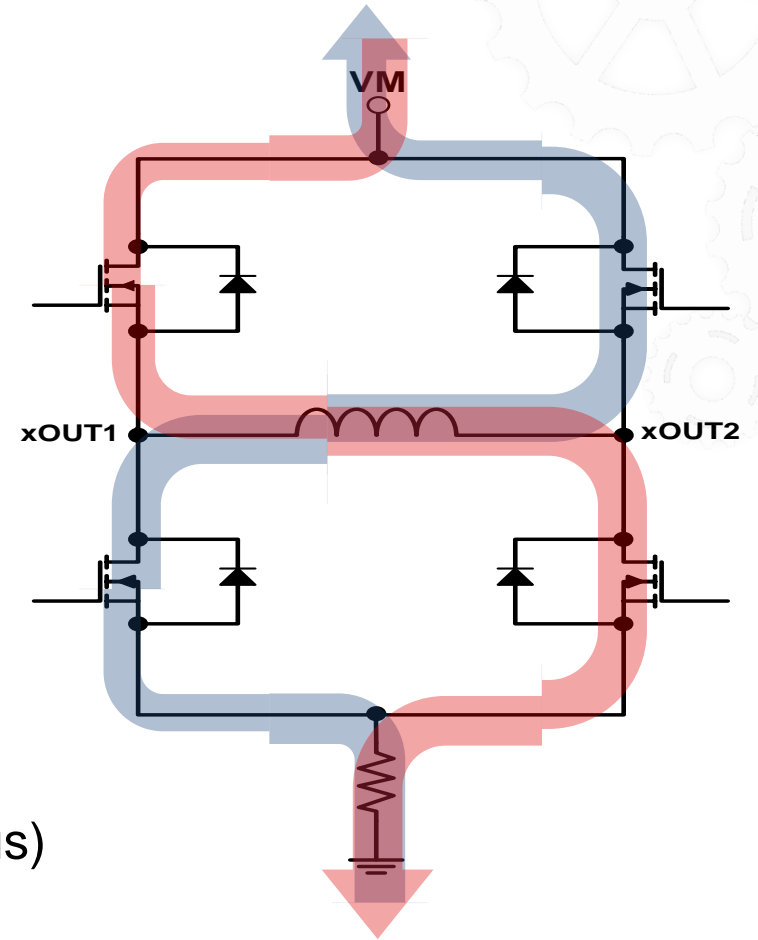
Fast decay

- H-bridge reverses state to allow current to flow in reverse
- H-bridge disabled when current decays to zero to prevent reverse current
- Largest ripple



This is only an example.

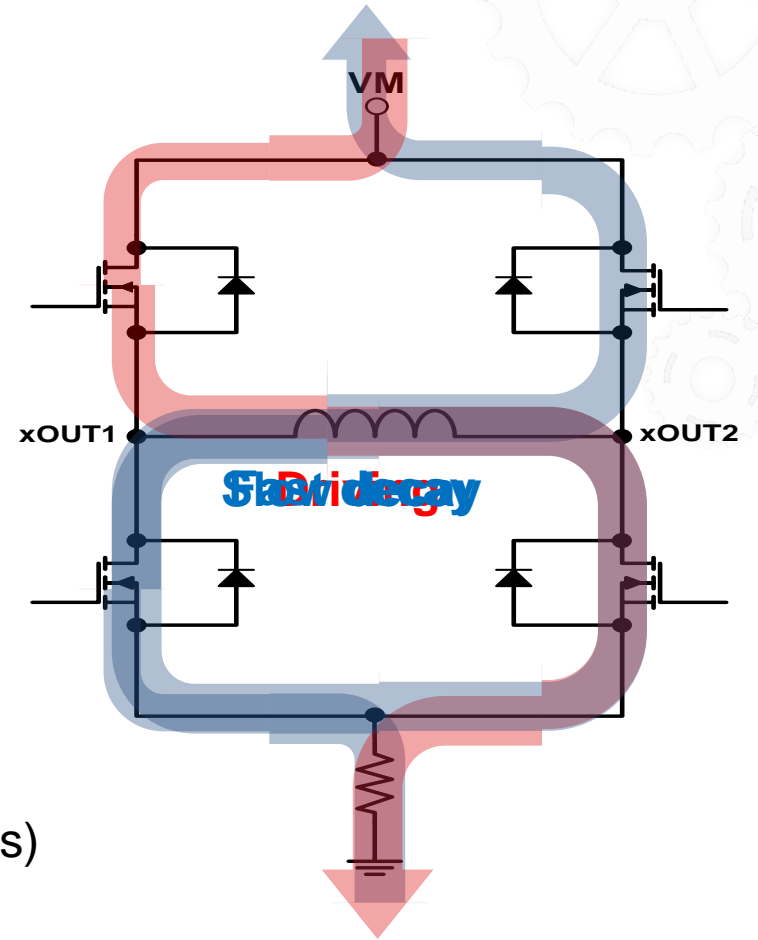
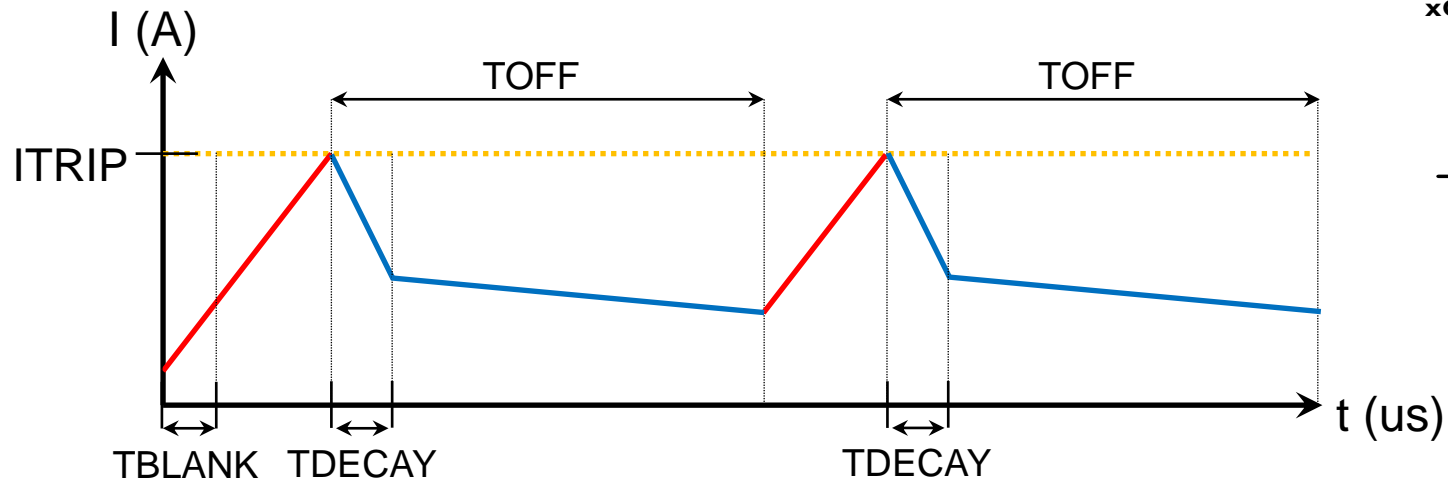
Motor current may not decay to zero!



Regulate current with decay modes

Mixed decay

- Begins as fast decay
- After TDECAY, switches to slow decay
- Attend Webinar 3 where we will discuss Smart Tune – automatically decay mode based on dynamic decay and ripple control technology



Stepper Motor Applications



Stage Lighting
DRV8881, DRV8841



Security Camera
DRV8835



Antenna Positioning
DRV8824



ATMs
DRV8886AT, DRV8880



Retail & POS Printers
DRV8833C, DRV8847



Refrigerator
DRV8847, DRV8812



Textile Equipment
DRV8818, DRV8886AT



Printers
DRV8886AT, DRV8885

Comparison between motor types

	Brushed-DC	Brushless-DC	Stepper
Low cost	\$	\$\$\$	\$\$
Current control required?	X	X	Needed*
Long motor life	Worst	Best	Better
Open loop position control	X	X	Yes
High efficiency	Worst	Best	Bad
Low noise	Worst	Best	Better**
High RPM	Limited by voltage	Best	Limited by step frequency
# of FETs for bidirectional control	4	6	8

* Current control needed for microstepping. Not needed if full stepping only

** Stepper motors can have low noise, but only if decay modes are tuned properly!!!

THE ART OF

Driving
Motors



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