TI-RSLK

Texas Instruments Robotics System Learning Kit

Module 12

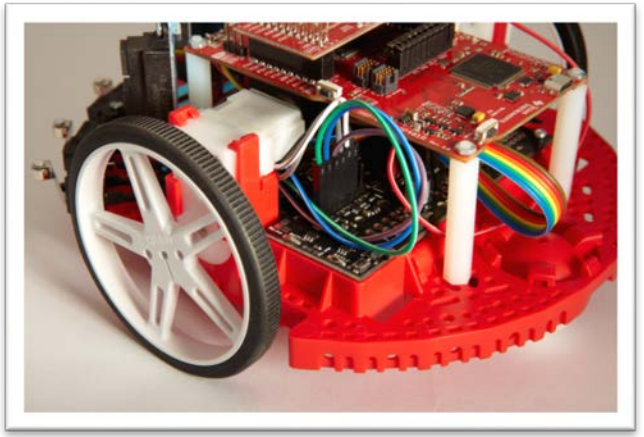
Lecture: DC motors - Physics

DC motors

You will learn in this module

- Fundamentals of Electromagnetic Fields
  - Ampere's Law
  - Faraday-Maxwell

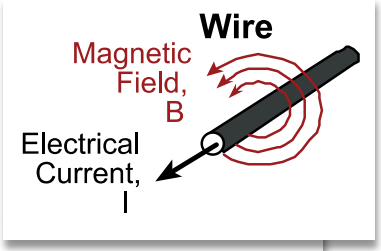
- Brushed DC Motors

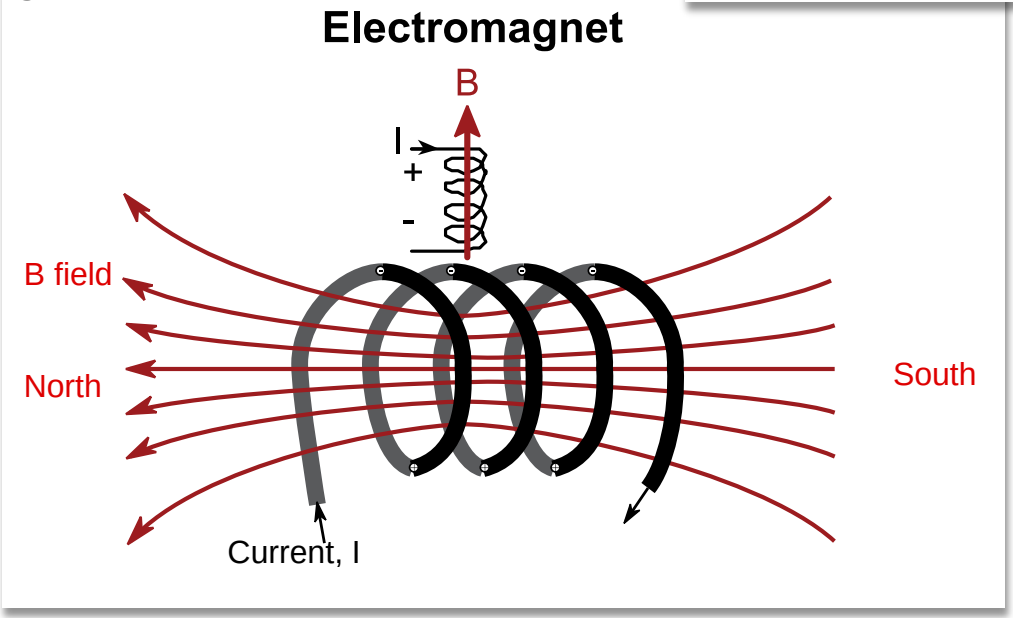


Electromagnetic Fields

Current induces a magnetic field

- Derived from Ampere's Law: B = NIμ/L
- I is current
- L is the length of the coil
- N is the number of turns
- μ is the permeability
- B is magnetic field





DC Motor Physics

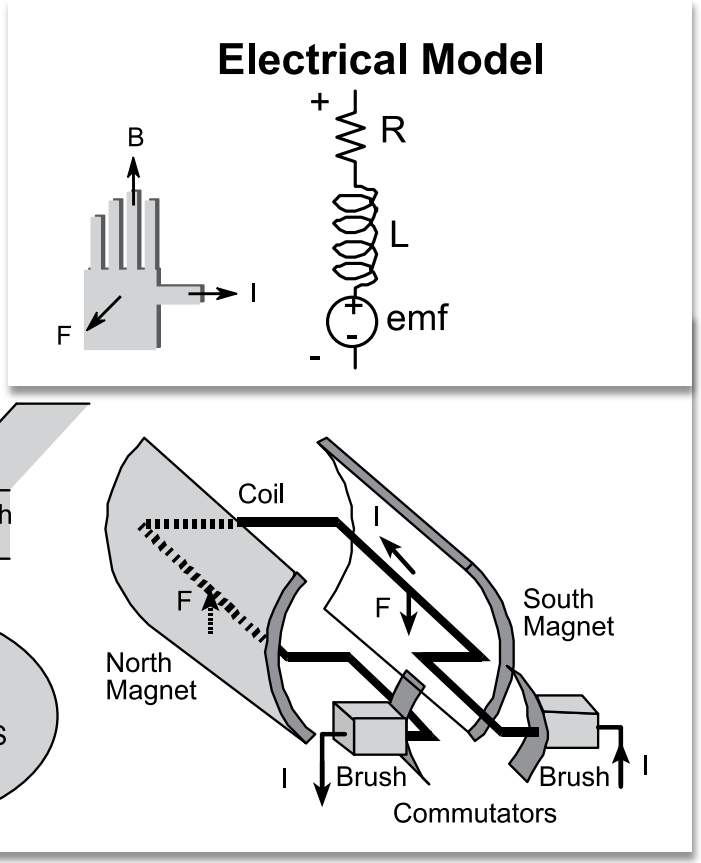
Faraday-Maxwell

Force = Current*Length*Magnetic Field

F = I*L*B

Right hand rule

- **Thumb = direction of current**
- **Fingers = direction of magnetic field**
- **Palm = direction of force**



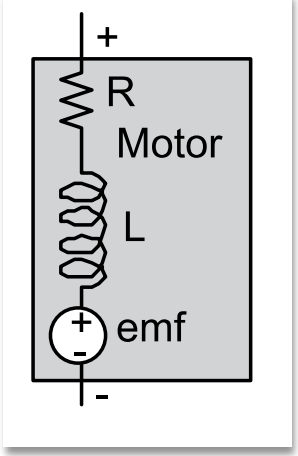
DC Motor Physics

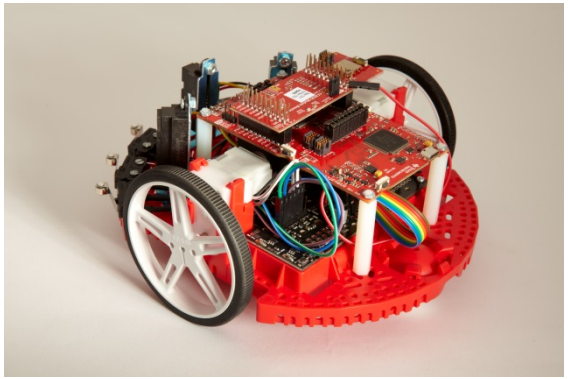
Electrical Model

R - Resistance from long wires

L - Inductance because wires are coil (electromagnet)

emf - voltage (mechanical ↔ electrical energy conversion)



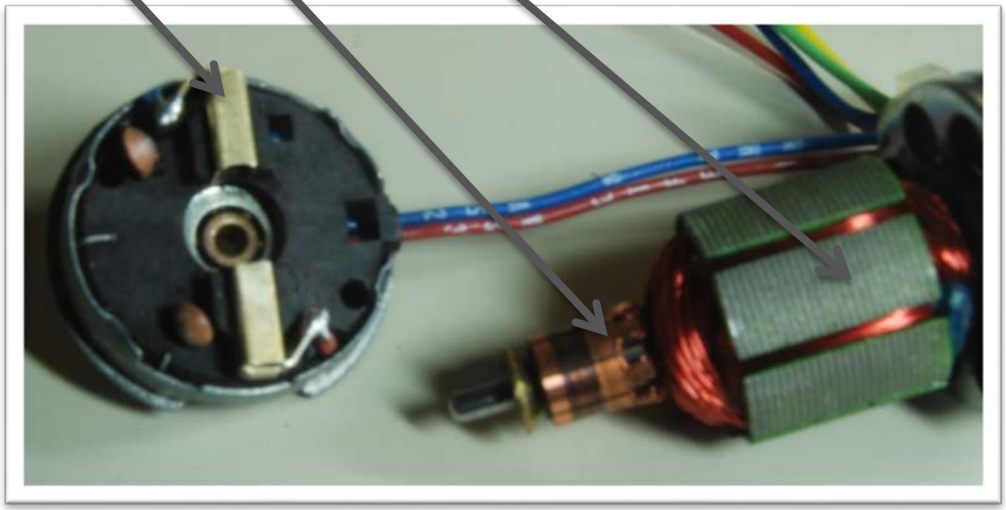


$V = L \, dI/dt$

DC Motor Physics

Components

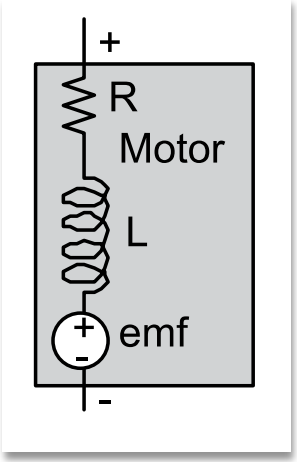
Brushes Commutator Rotor Stator (not shown)



Basic Model for a DC motor

Considerations

- Voltage (V)
- Current (A)
- Power (W = V*A = J/sec)
- Force (N=kg*m/sec^2)
- Torque (N-m)
- Inductance (H)
- emf (V)
- Friction (coefficient)
- Speed (rps)

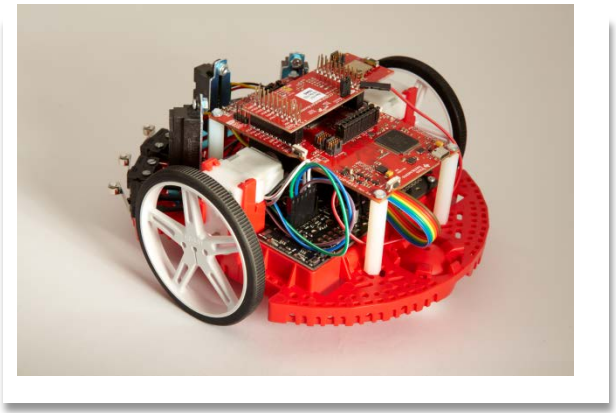


$P = V*I$

$F = m*a$

$\tau = F*d$

$V = L\ dI/dt$



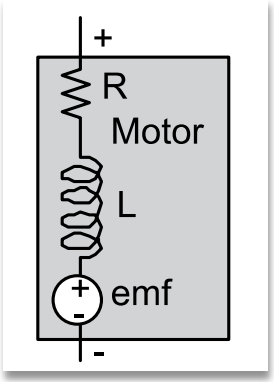
Summary

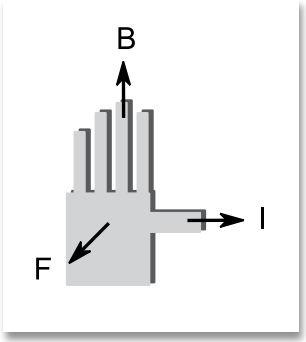
Electromagnets

- B = NIμ/L

DC Motor

- F = I*L*B
- R, L, emf
- Brush, commutator, coil, stator
- Power, force, torque





Right hand rule

Thumb = direction of current
Fingers = direction of magnetic field
Palm = direction of force

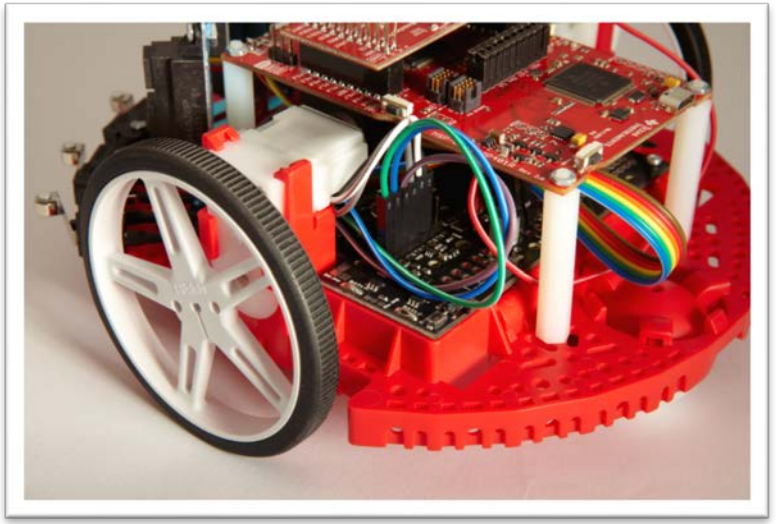
Module 12

Lecture: DC motors - Interface

DC motors

You will learn in this module

- Drive circuits for DC Motors
  - Darlington Pair, H bridge
  - TI DRV8838 driver
  - Interfacing motors with TI’s LaunchPad



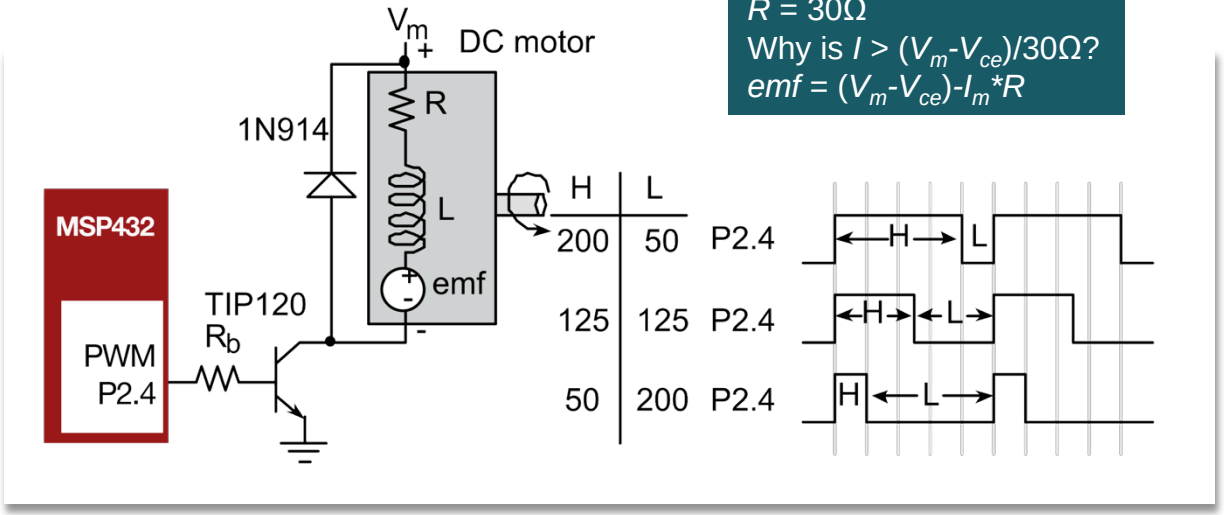
Basic Drive circuits for DC motors

Design considerations

- Peak voltage
- Peak current
- Speed
- Back emf

$V = V_m - V_{ce}$
$I_b = I_{ce}/h_{fe}$ (max)
$R < (3.3 - V_{be})/I_b$

$R = 30\Omega$
Why is $I > (V_m - V_{ce})/30\Omega$?
$emf = (V_m - V_{ce}) - I_m * R$

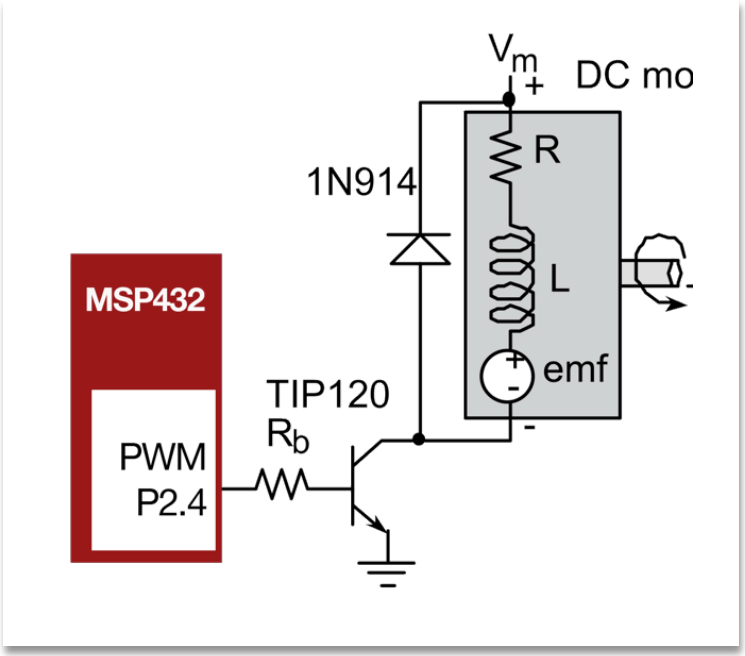


One direction, power adjusted by duty cycle

Basic Drive circuit – Unidirectional

Design: 6V, 1A

- TIP120 (NPN)
- h_{fe} = 1000 (typical)
- I_{ce} = 3A (max)
- back emf (1N914)



$I_b = I_{coil} / h_{fe}$ = 1A/1000 = 1mA

$R_b \leq (V_{OH}\text{-}V_{be})/I_b$ = (3-2.5)/1mA = 0.5 kΩ

R_b = 100 Ω

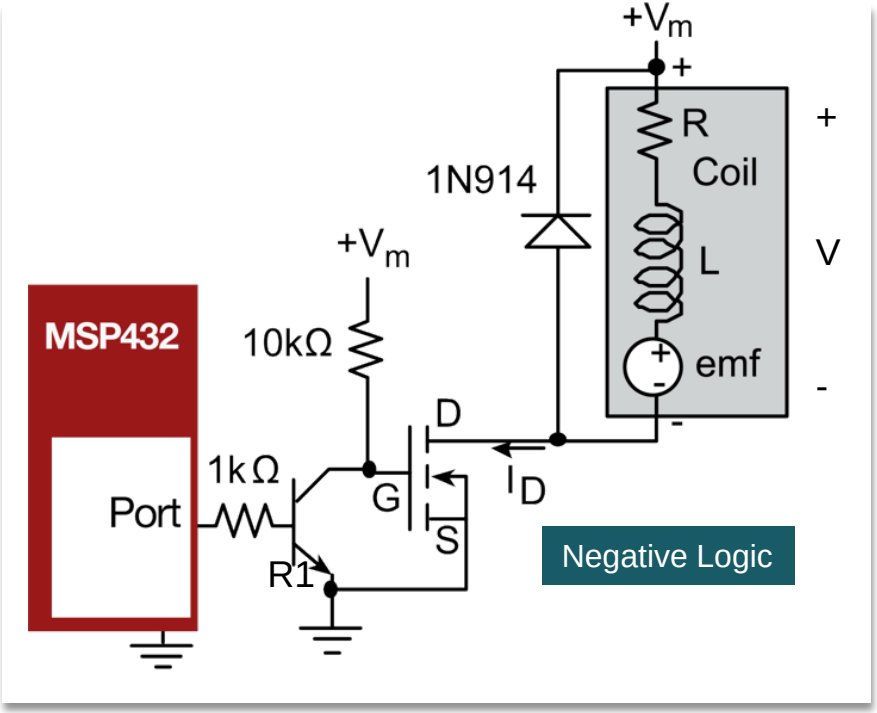
V_{CE} depends on current (0.5 to 1 V)

$$V = L \frac{dI}{dt}$$

MOSFET Drive circuit for DC motor

N channel considerations

- V_{GS} turns on
- V_{DS} small
- I_{DS} large

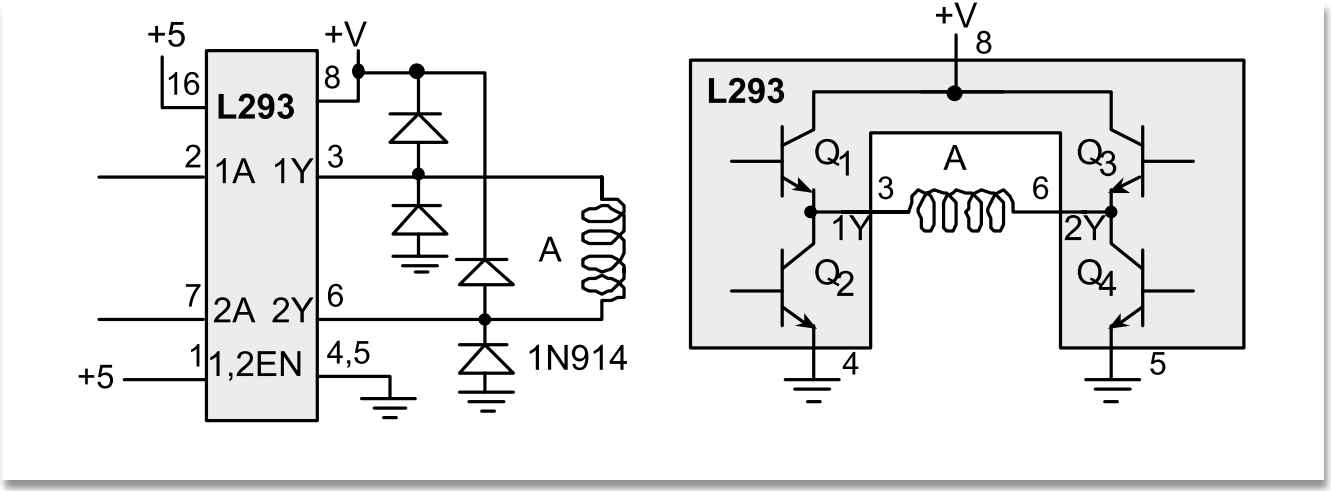


$V = V_m - V_{DS}$
$I_b = I_{ce}/h_{fe}$ (max)
$R1 < (3.3 - V_{be})/I_b$

Motor-Drive Circuits for Bidirectional Control

H bridge using Two-phase Motor Driver (TI L293)

- Can spin motors in both directions
- Can lose 1 to 2 V in transistors

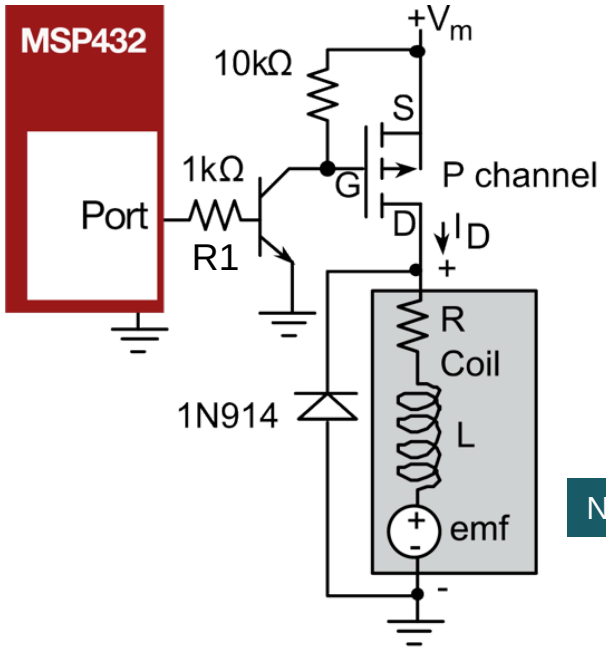


More information: http://www.ti.com/lit/ds/symlink/l293.pdf

MOSFET interface of a DC motor

P channel considerations

- V_{GS} turns on
- V_{DS} small
- I_{DS} large

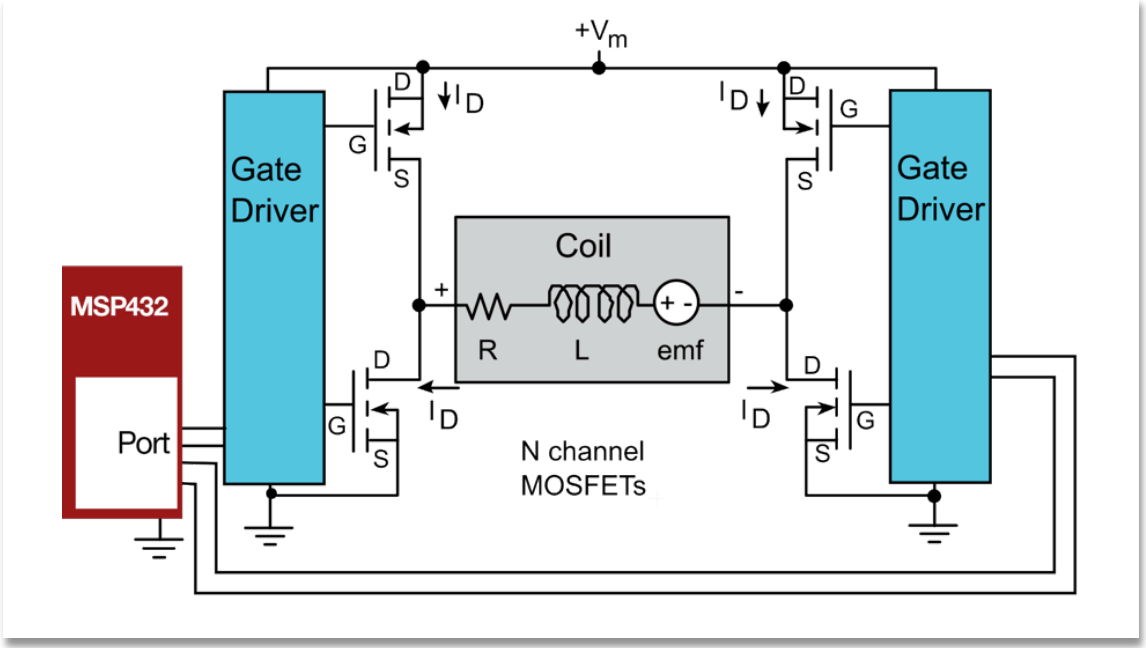


$V = V_m - V_{DS}$
$I_b = I_{ce}/h_{fe}$ (max)
$R1 < (3.3-V_{be})/I_b$

Negative Logic

MOSFET interface of a DC motor using H bridge

H bridge



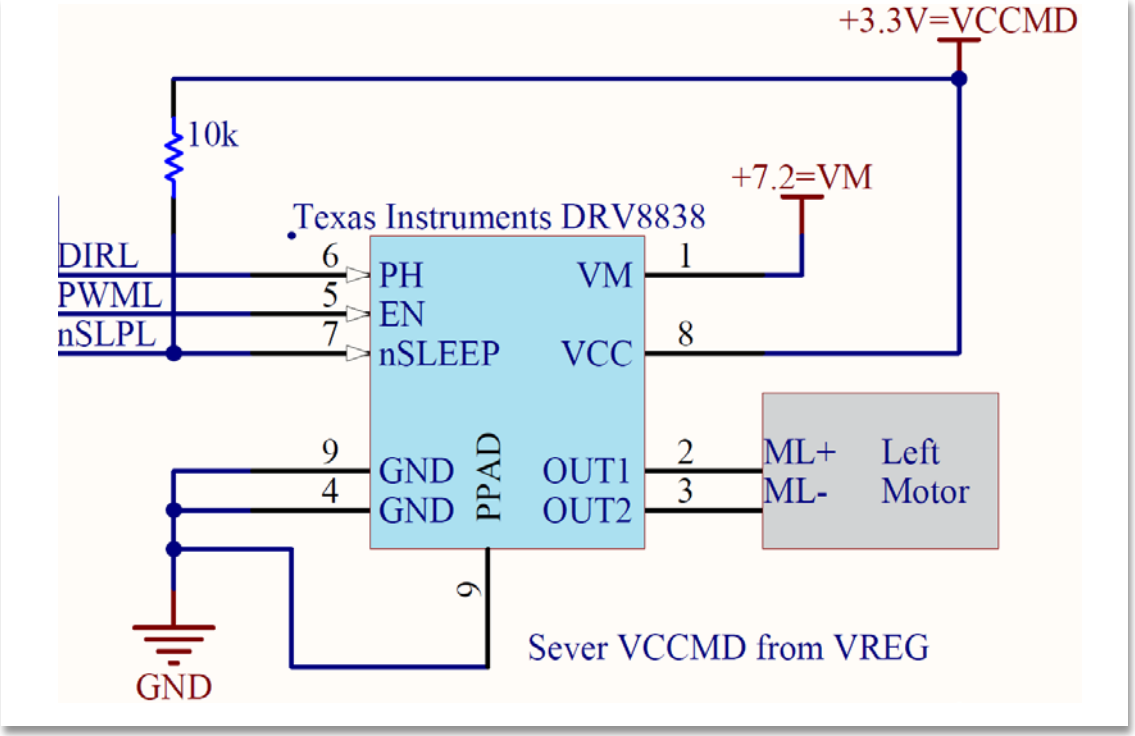
Basic circuit inside the DRV8838

More info: http://www.ti.com/product/drv8838/description?keyMatch=DRV8838&tisearch=Search-EN-Everything

Drive circuit using TI DRV8838

$R_{DS} = 0.28\Omega$

Pololu Board

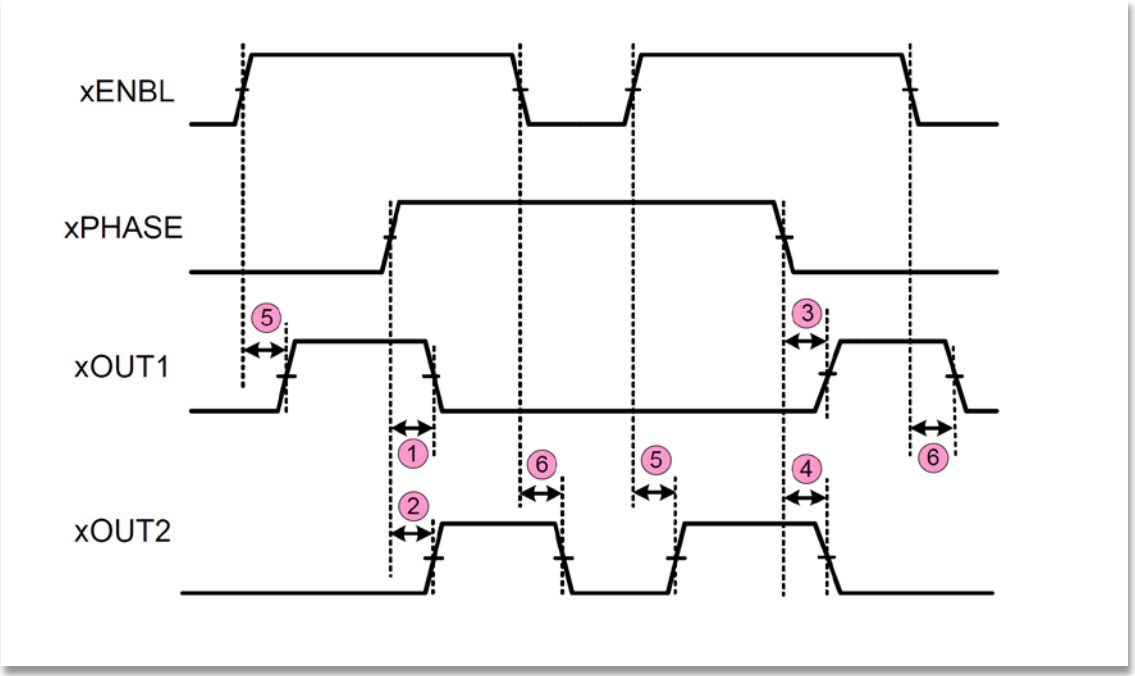


More info: http://www.ti.com/product/drv8838/description?keyMatch=DRV8838&tisearch=Search-EN-Everything

Drive circuit waveforms for DC Motors

Times < 200ns

DRV8838



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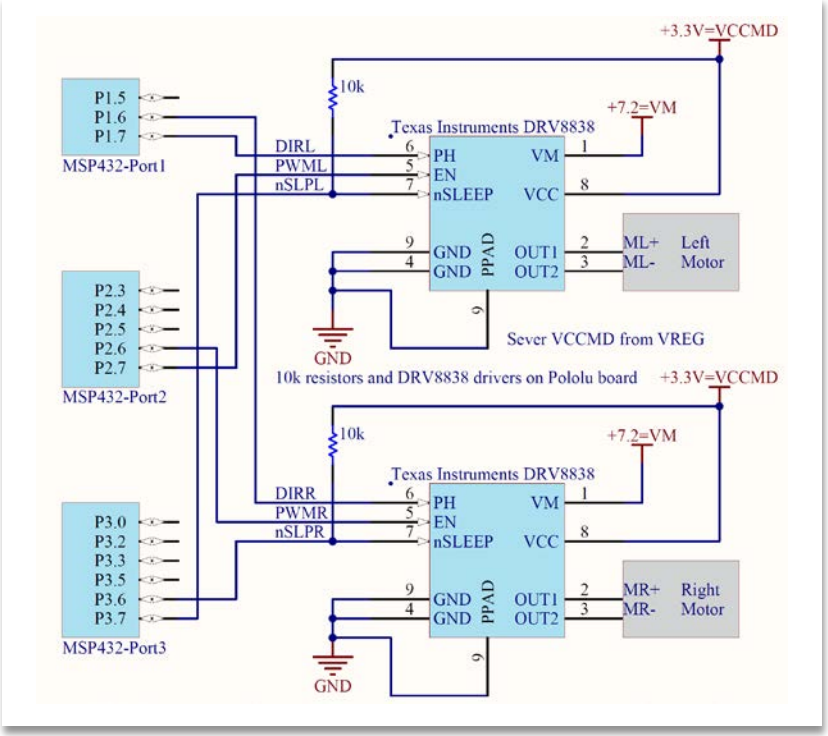
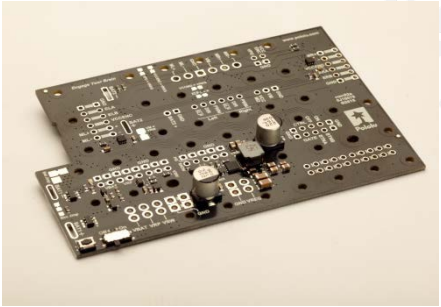
Motor Drive and Power distribution board interface with TI's Launchpad Development board



PH	EN	
DIRL	PWML	
P1.7	P2.7	Left
0	0	Stop
1	0	Stop
0	1	Forward
1	1	Back

PH	EN	
DIRR	PWMR	
P1.6	P2.6	Right
0	0	Stop
1	0	Stop
0	1	Forward
1	1	Back

Pololu Board



P3.6=P3.7=1 to activate, not sleep

Summary

Darlington interfaces

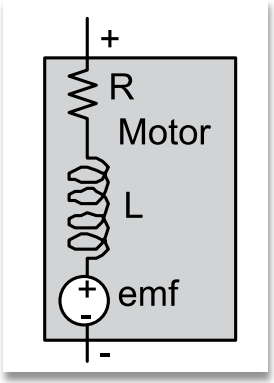
- Simple, inefficient

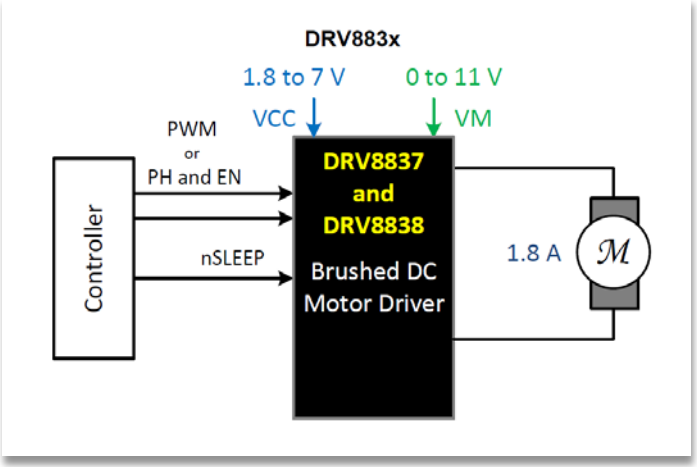
MOSFET interfaces

- Efficient, large current

H bridge Interfaces

- Both directions
- DRV8838





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