TI-RSLK MAX

Texas Instruments Robotics System Learning Kit

Texas Instruments

Module 12

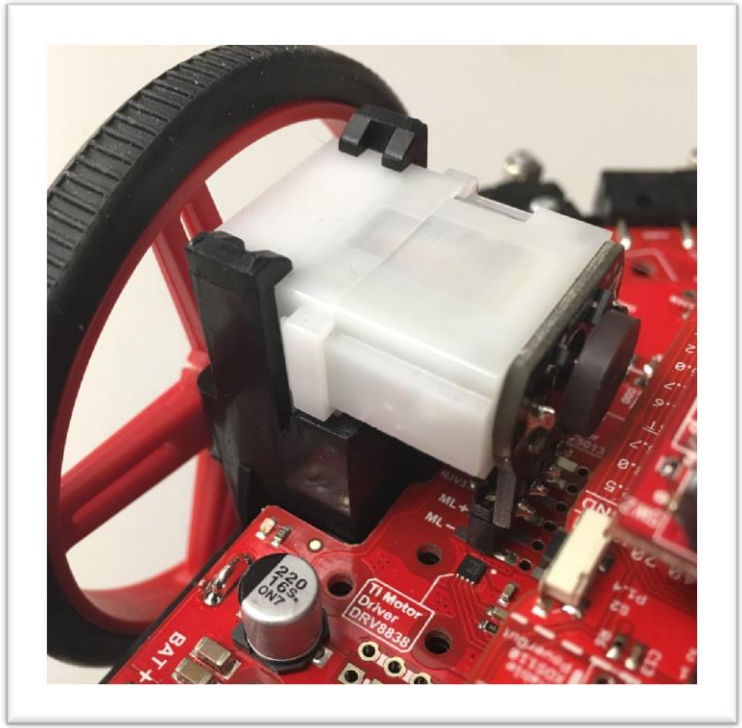
Lecture: DC motors - Physics

DC motors

You will learn in this module

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

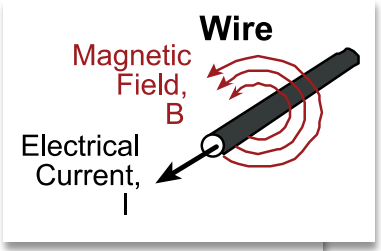
- Brushed DC Motors

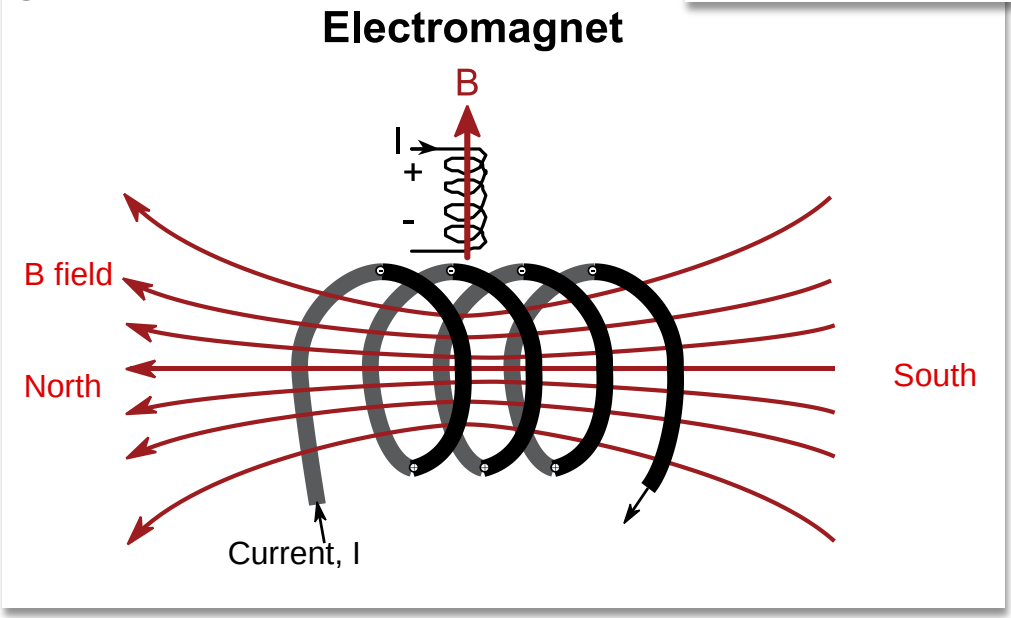


Electromagnetic Fields

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

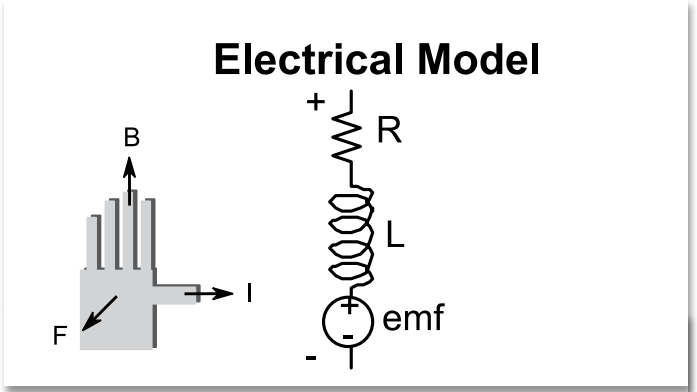
Faraday-Maxwell

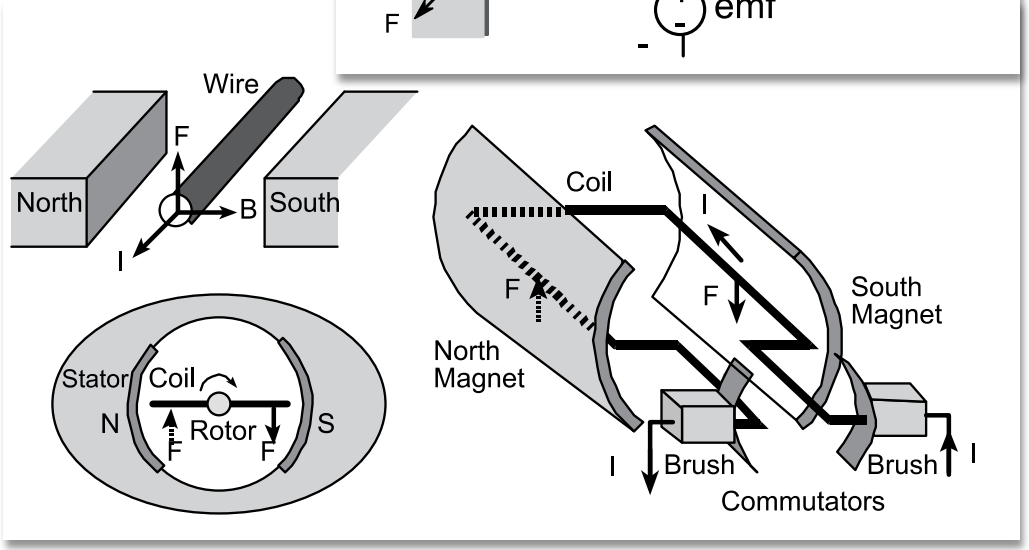
Force = Current*Length*Magnetic Field

F = I*L*B

Right hand rule

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





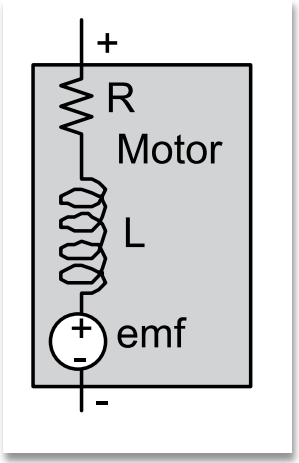
DC Motor Physics

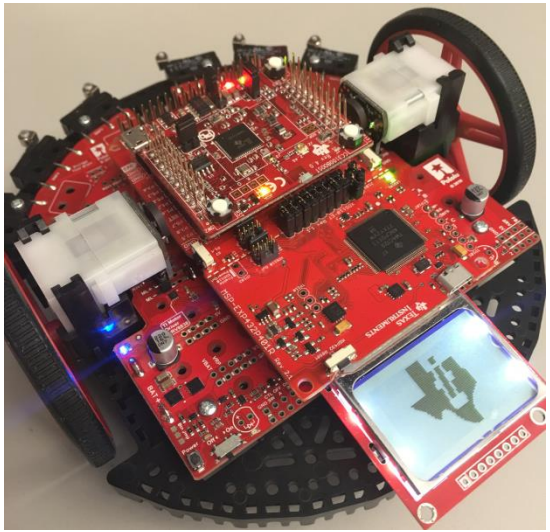
Electrical Model

R - Resistance from long wires

L - Inductance because wires are coil (electromagnet)

emf - voltage (mechanical ↔ electrical energy conversion)



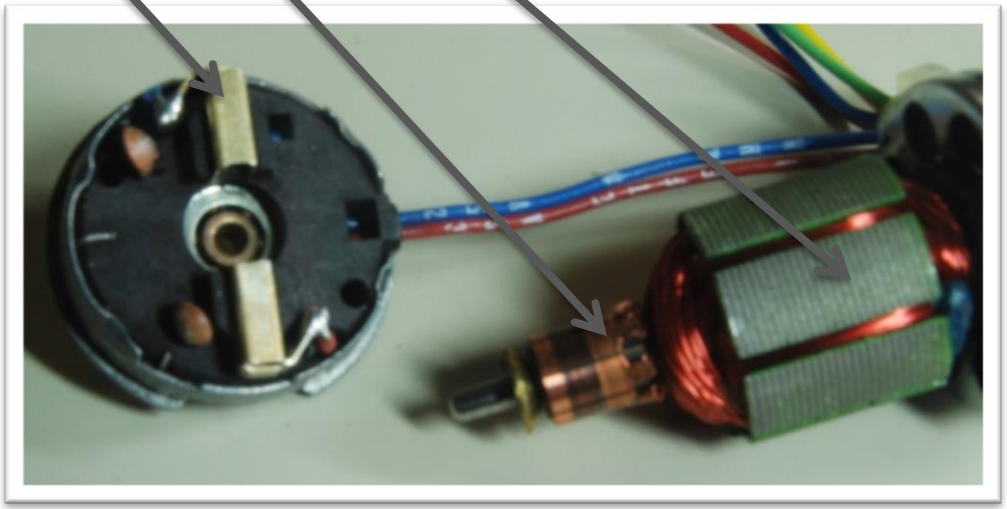


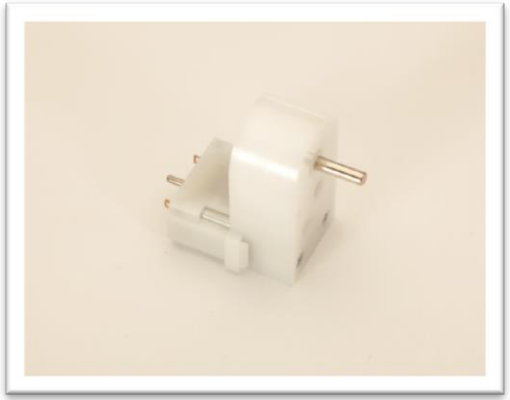
$V = L \, dI/dt$

DC Motor Physics

Components

Brushes Commutator Rotor Stator (not shown)

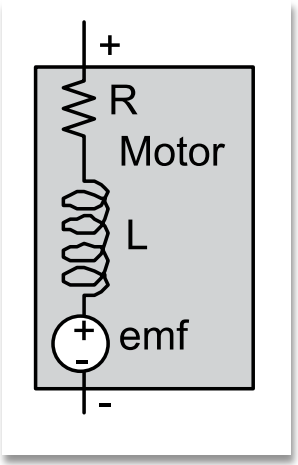




Basic Model for a DC motor

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)

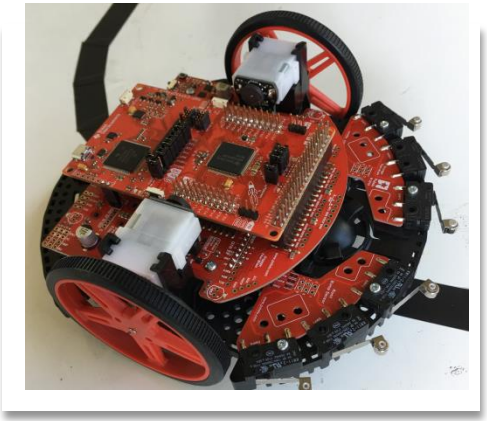


$P = V*I$

$F = m*a$

$\tau = F*d$

$V = L\ dI/dt$



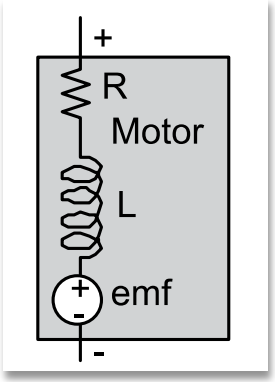
Summary

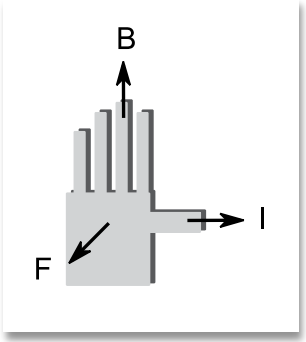
Electromagnets

- 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

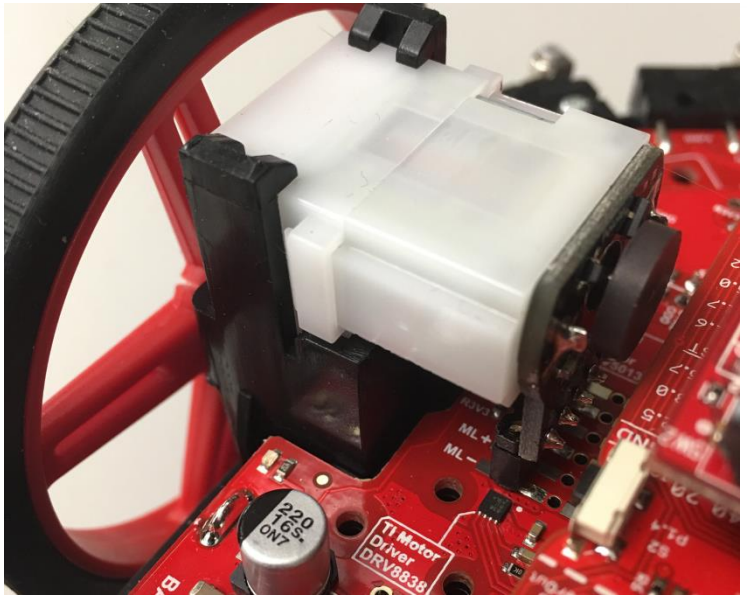
Module 12

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



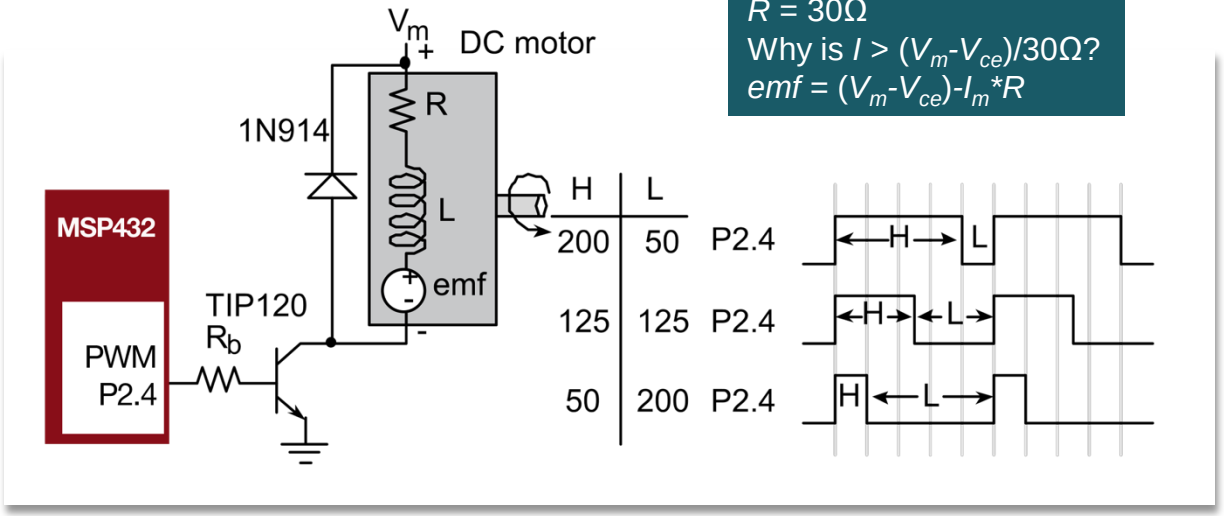
Basic Drive circuits for DC motors

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

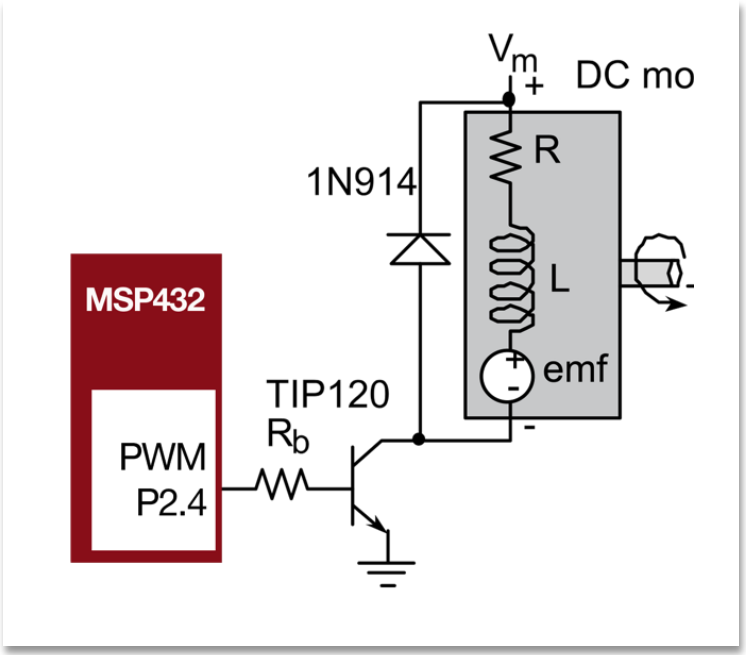


One direction, power adjusted by duty cycle

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

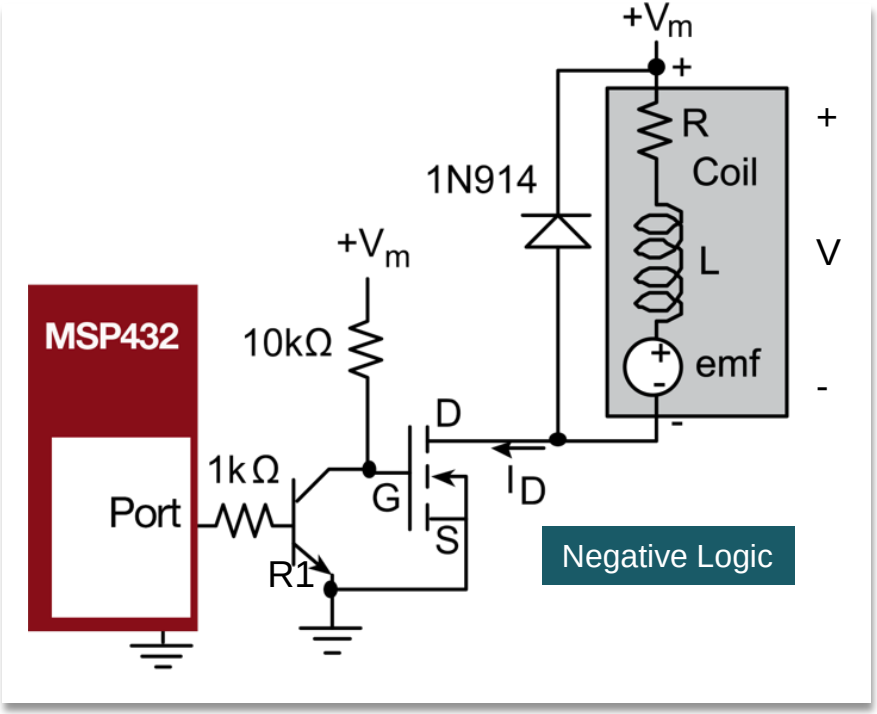
V_{CE} depends on current (0.5 to 1 V)

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

MOSFET Drive circuit for DC motor

N channel considerations

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

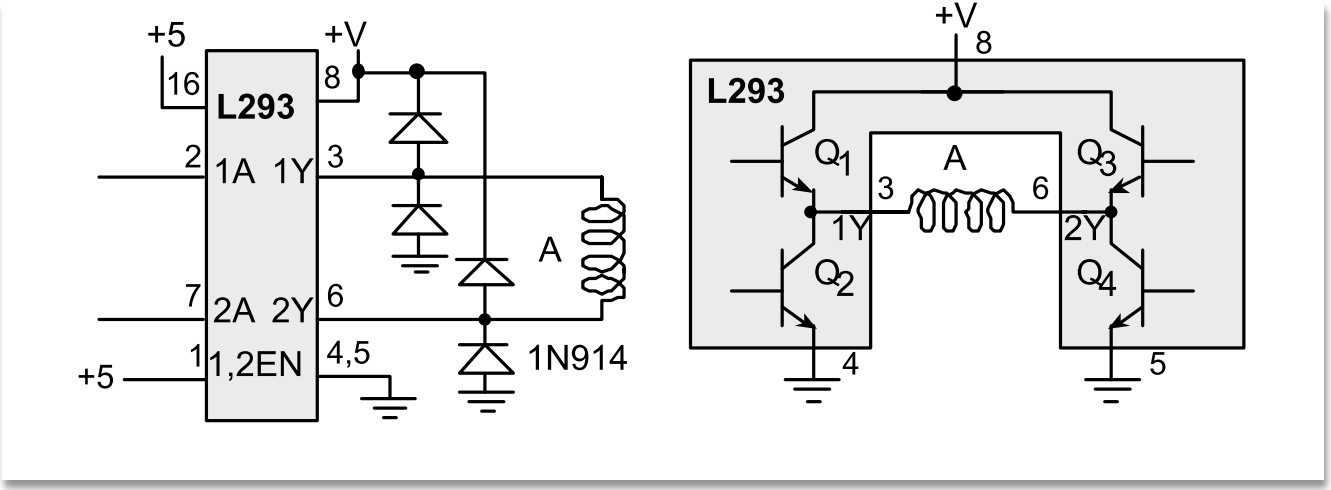


$V = V_m - V_{DS}$
$I_b = I_{ce}/h_{fe}$ (max)
$R1 < (3.3-V_{be})/I_b$

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

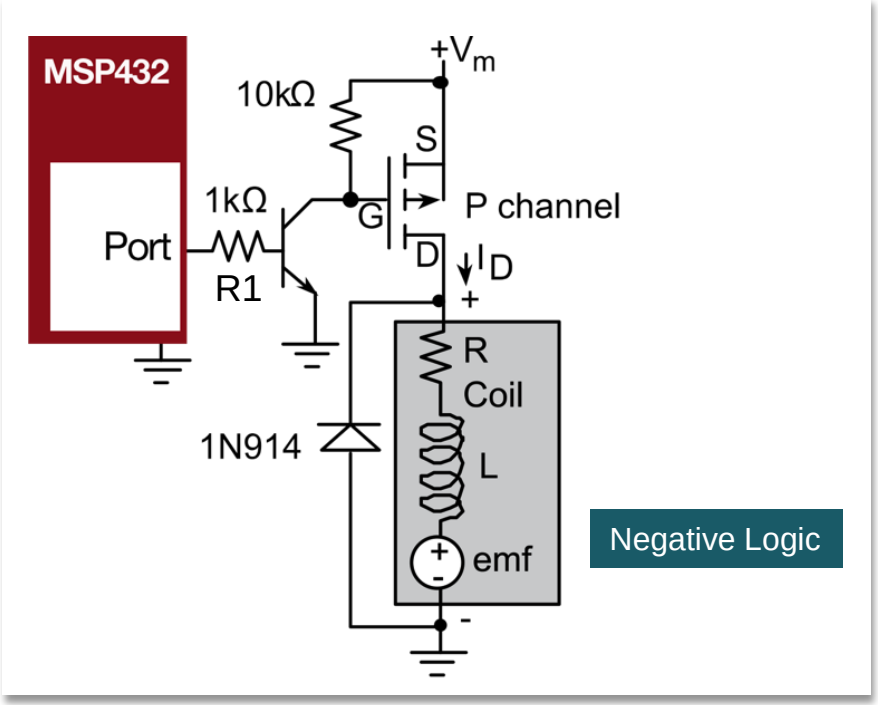


More information: http://www.ti.com/lit/ds/symlink/l293.pdf

MOSFET interface of a DC motor

P channel considerations

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

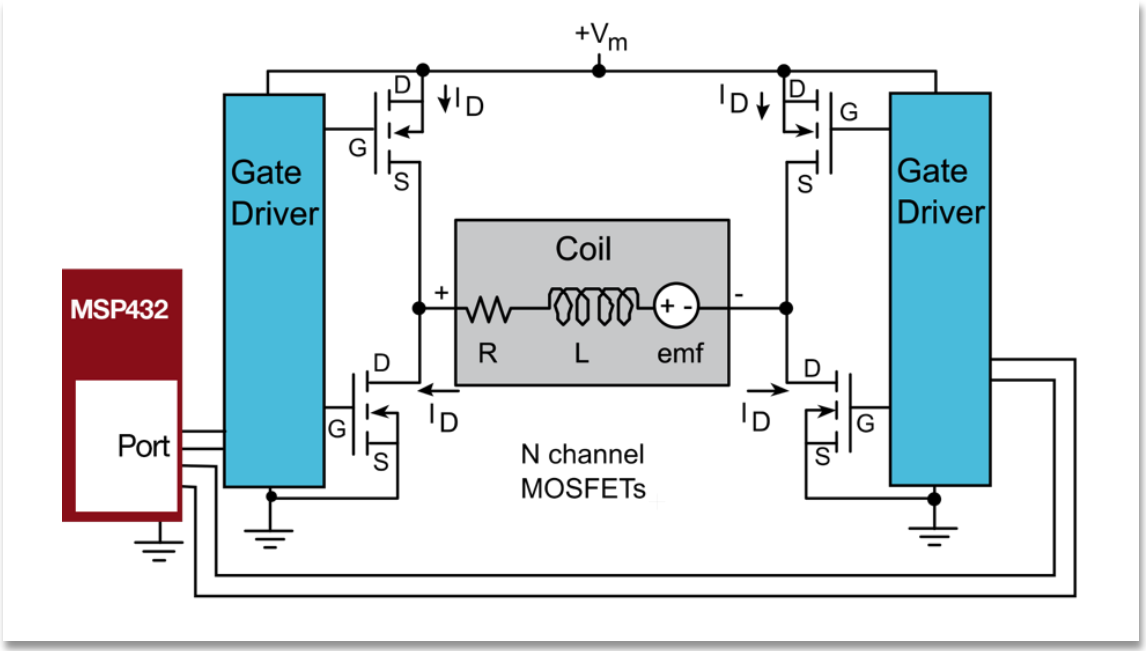


$V = V_m - V_{DS}$
$I_b = I_{ce}/h_{fe}$ (max)
$R1 < (3.3-V_{be})/I_b$

Negative Logic

MOSFET interface of a DC motor using H bridge

H bridge

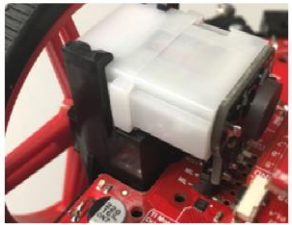


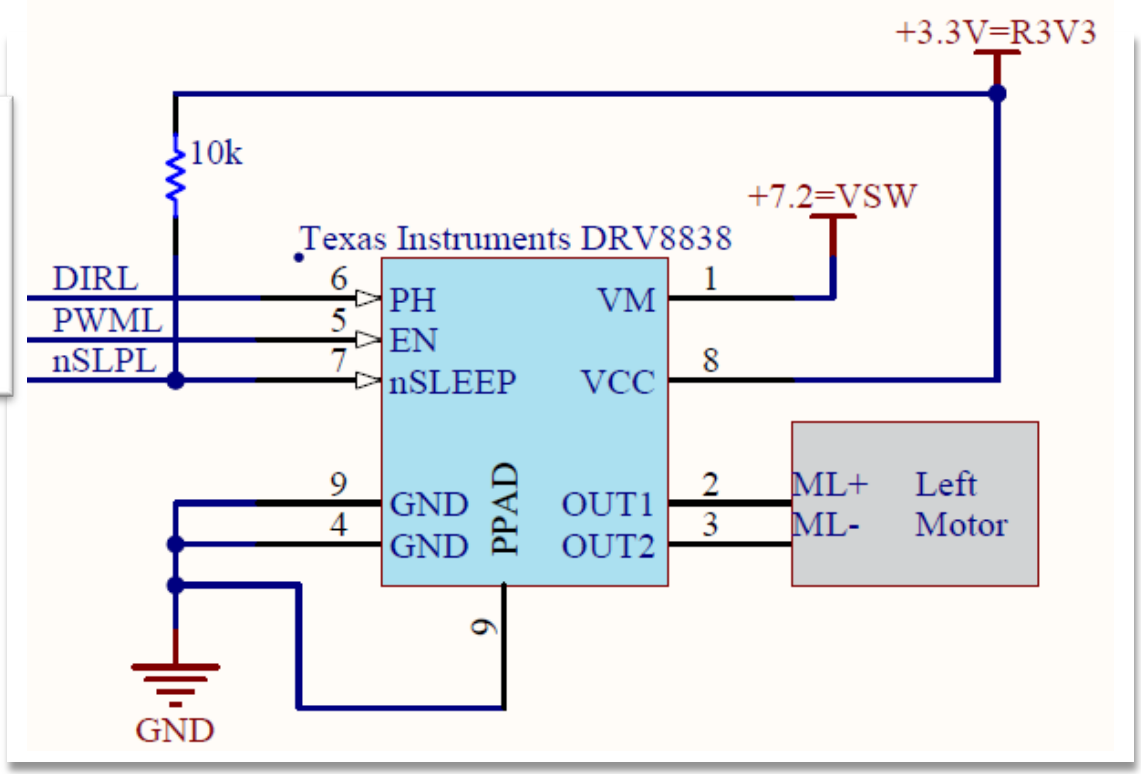
Basic circuit inside the DRV8838

Motor Drive circuit using TI DRV8838

$R_{DS} = 0.28\Omega$

TI-RSLK Chassis Board

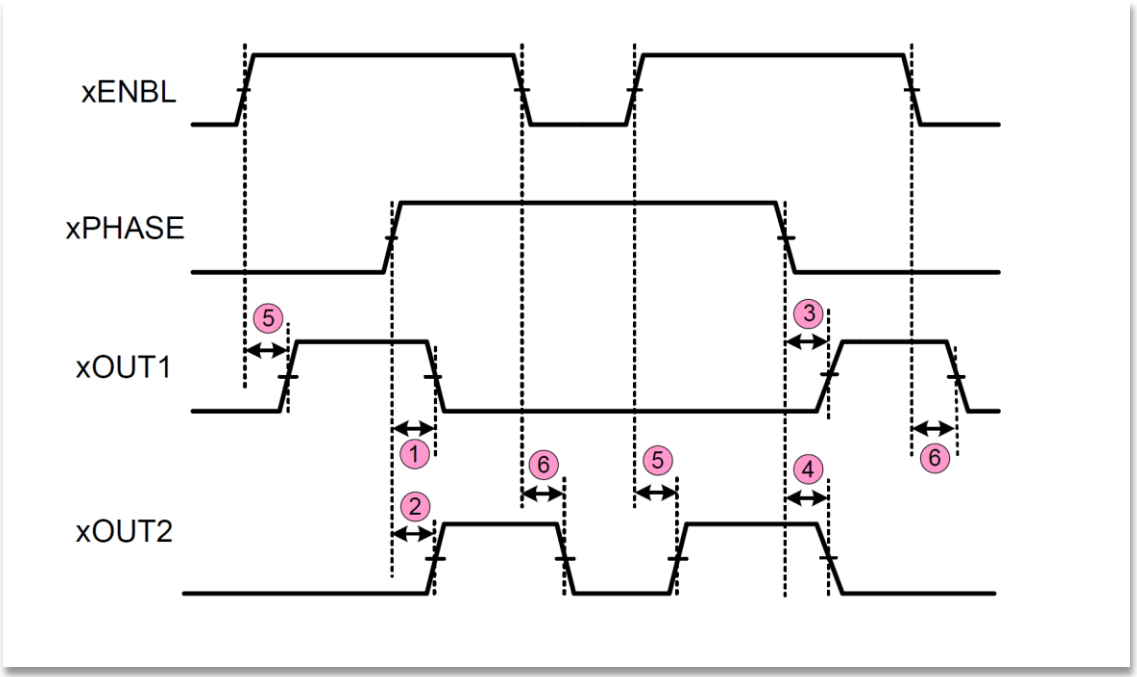




Drive circuit waveforms for DC Motors

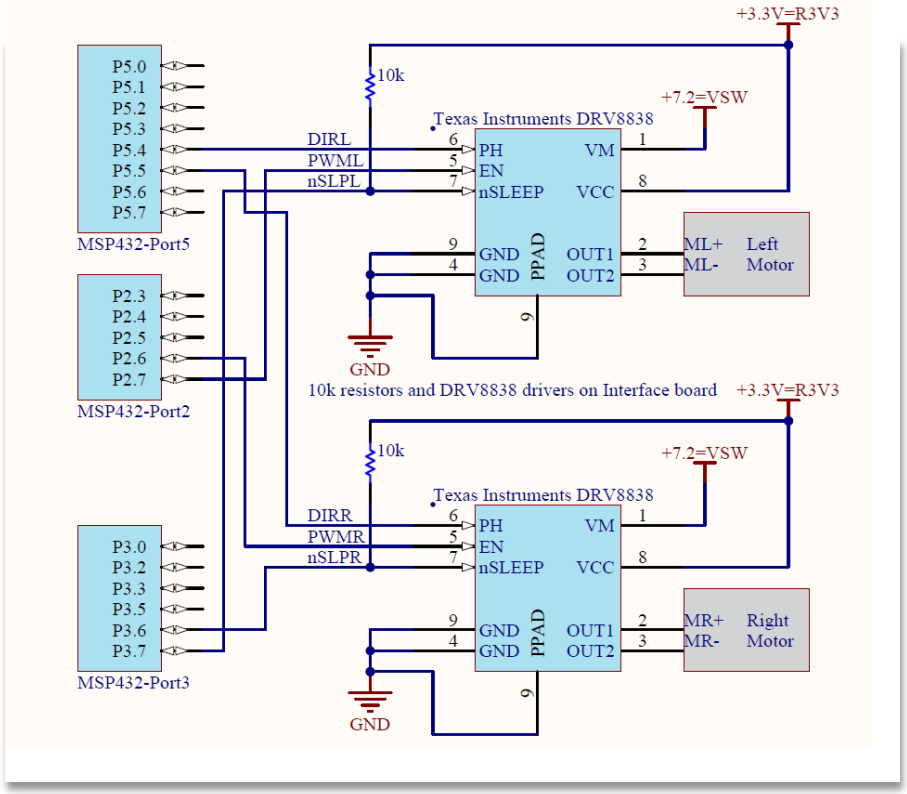
Times < 200ns

TI DRV8838



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

Motor Interface Circuit on TI-RSLK Chassis Board



PH	EN	
DIRL	PWML	
P5.4	P2.7	Left
0	0	Stop
1	0	Stop
0	1	Forward
1	1	Back

PH	EN	
DIRR	PWMR	
P5.5	P2.6	Right
0	0	Stop
1	0	Stop
0	1	Forward
1	1	Back

RSLK robot

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

Summary

Darlington interfaces

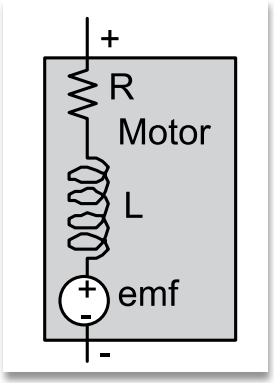
- Simple, inefficient

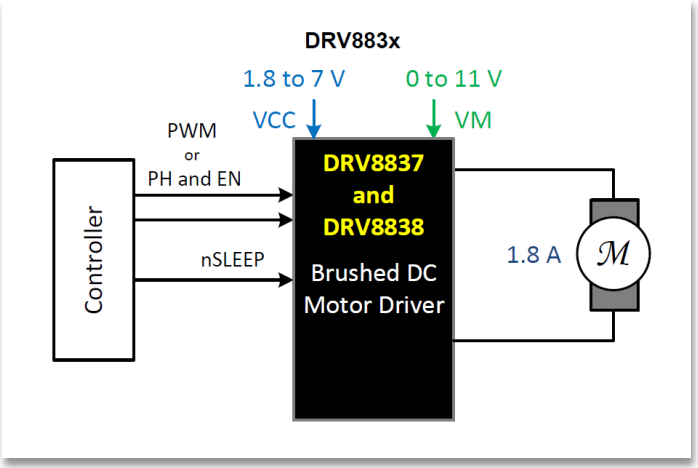
MOSFET interfaces

- Efficient, large current

H bridge Interfaces

- Both directions
- DRV8838





ti.com/rslk

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265