Control of DC Motors

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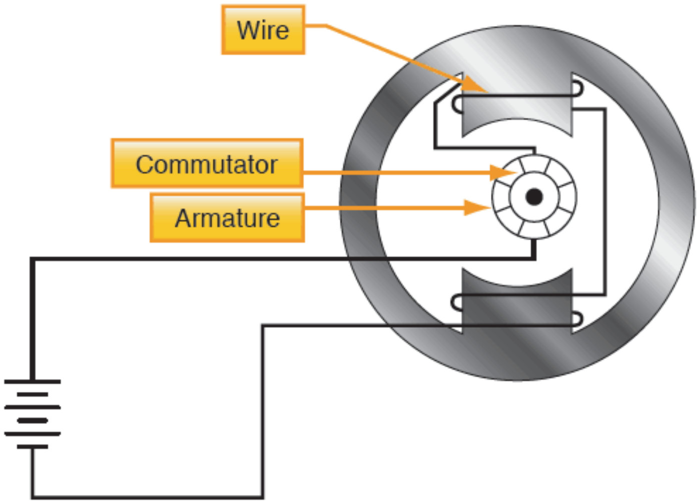
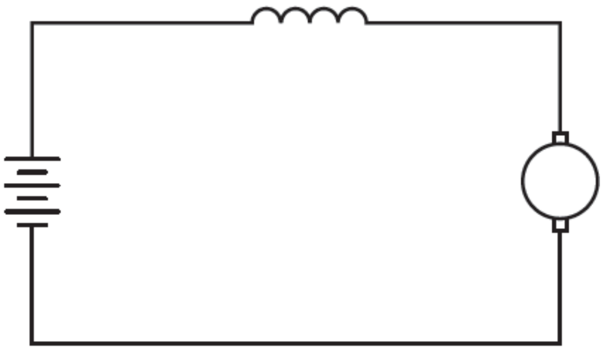
DC Machine

Would field

Series | Compound | Shunt

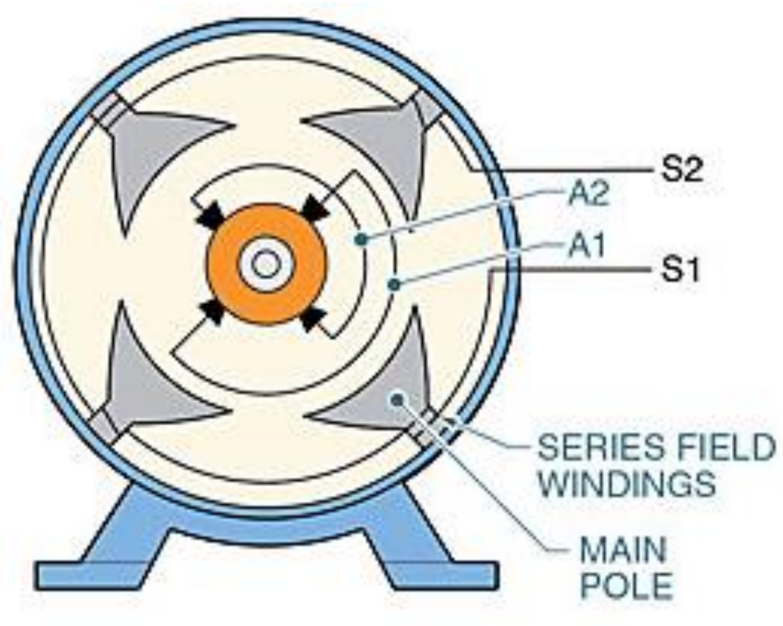


Pictorial drawing

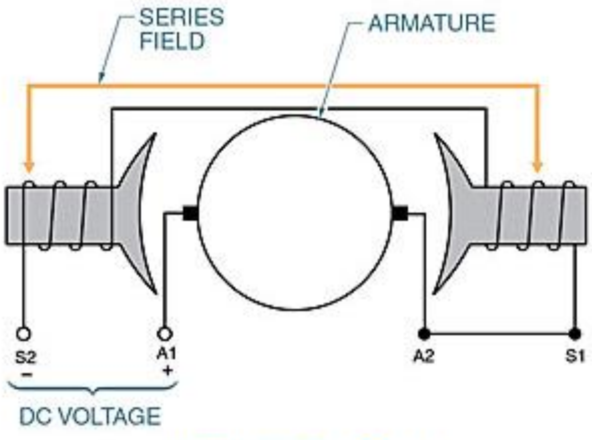


Schematic diagram

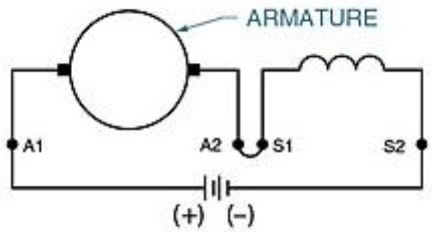
DC series motor



Pictorial drawing

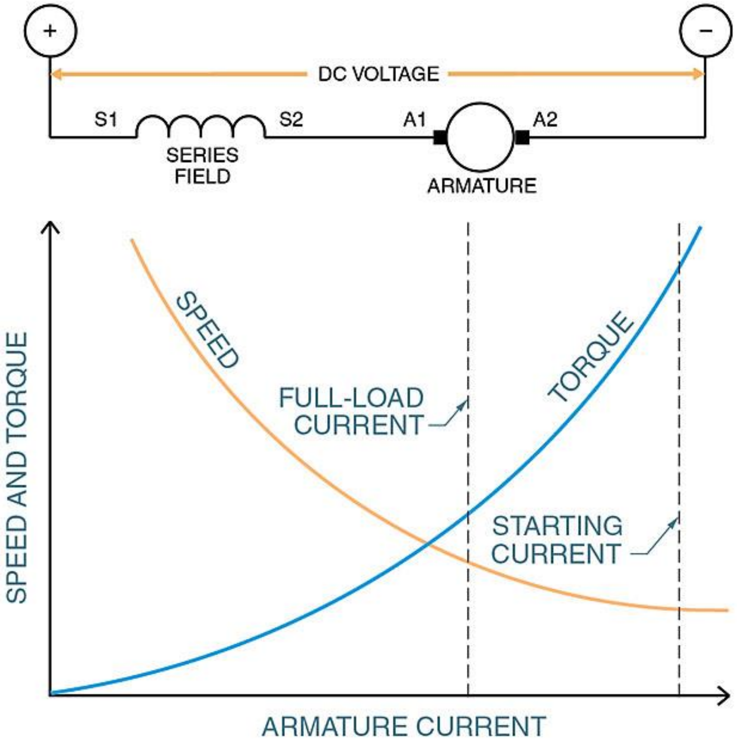


Wiring diagram



Schematic diagram

DC series motor



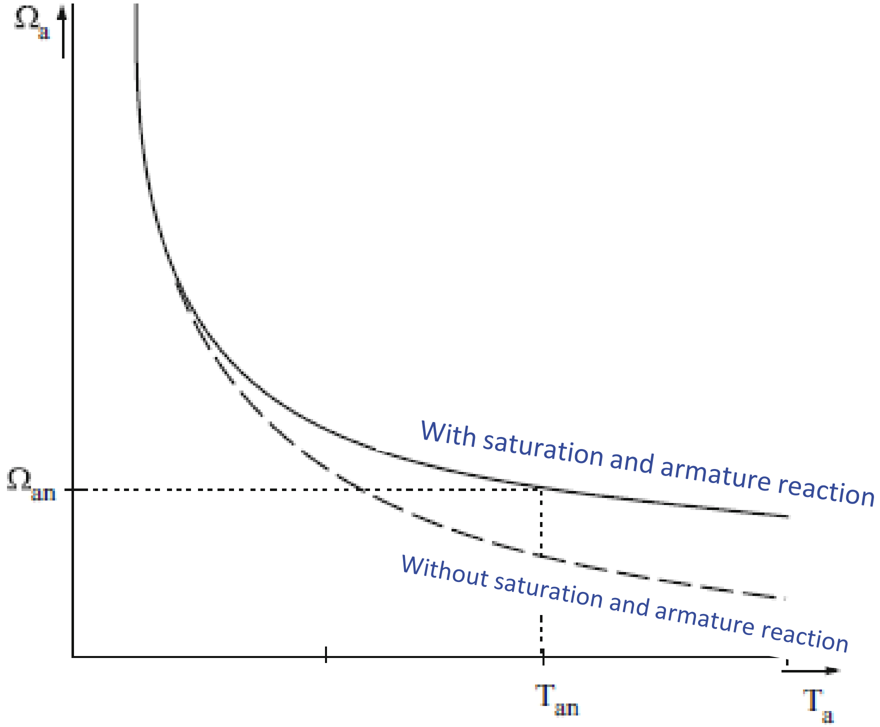
$$k \cdot \Phi_m(I_a) = k' \cdot I_a$$

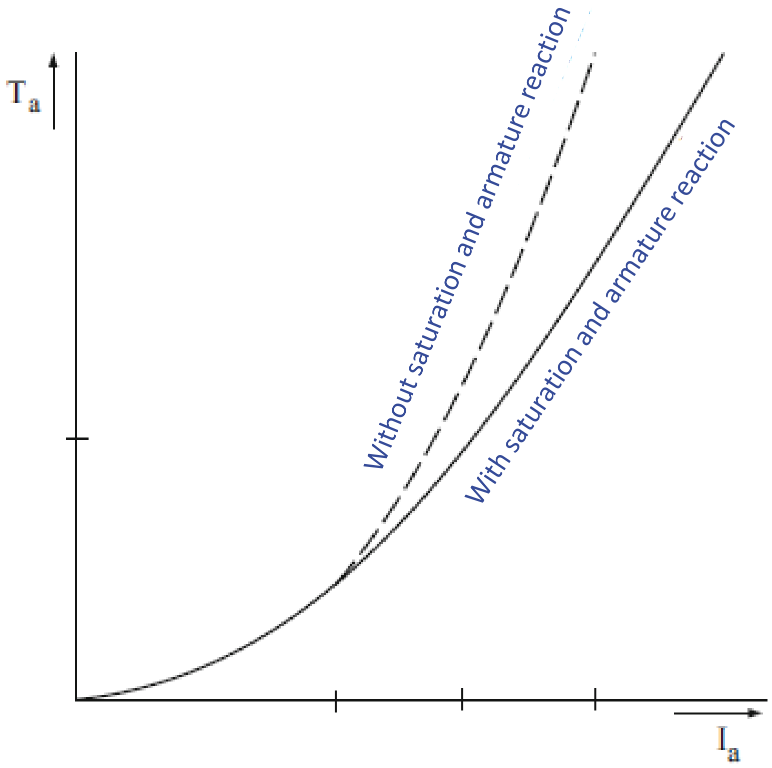
$$I_a = V_a / (R_a + R_u + k'\Omega_a)$$

$$T_a = k' \cdot I_a^2$$

$$T_a = \frac{k' V_a^2}{(R_a + R_u + k'\Omega_a)^2}$$

DC series motor



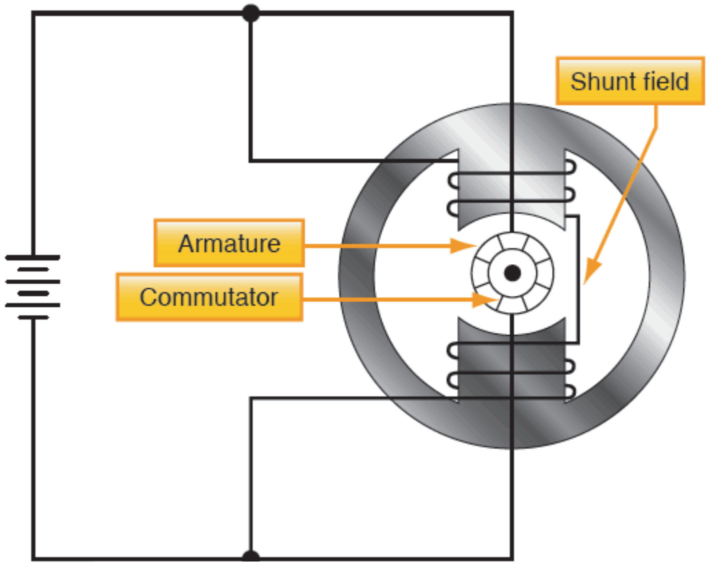


DC shunt motor

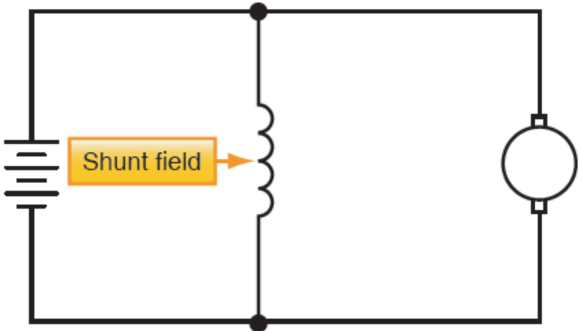
DC Machine

Would field

Series | Compound | Shunt

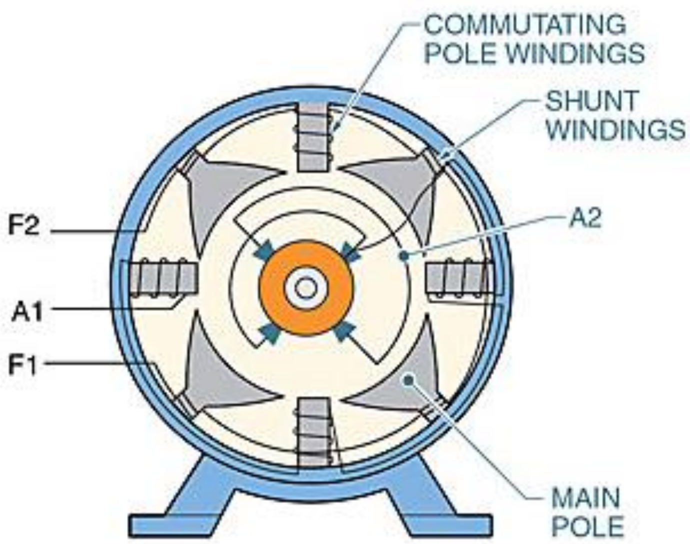


Pictorial drawing

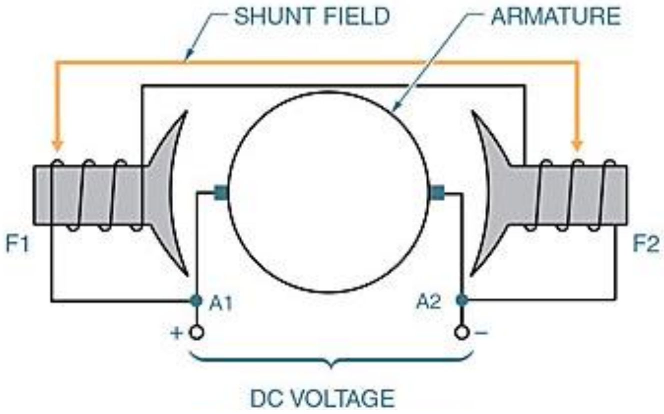


Schematic diagram

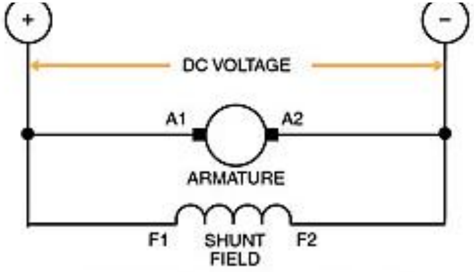
DC shunt motor



Pictorial drawing

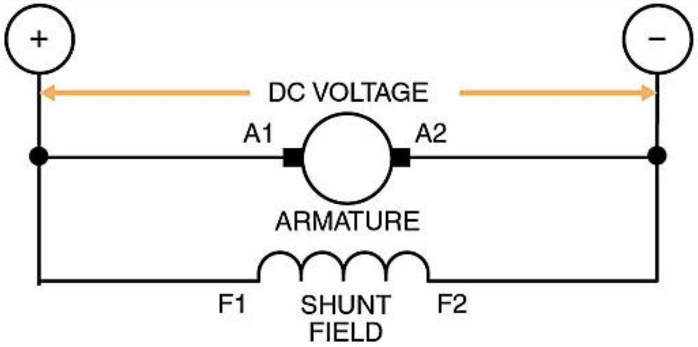


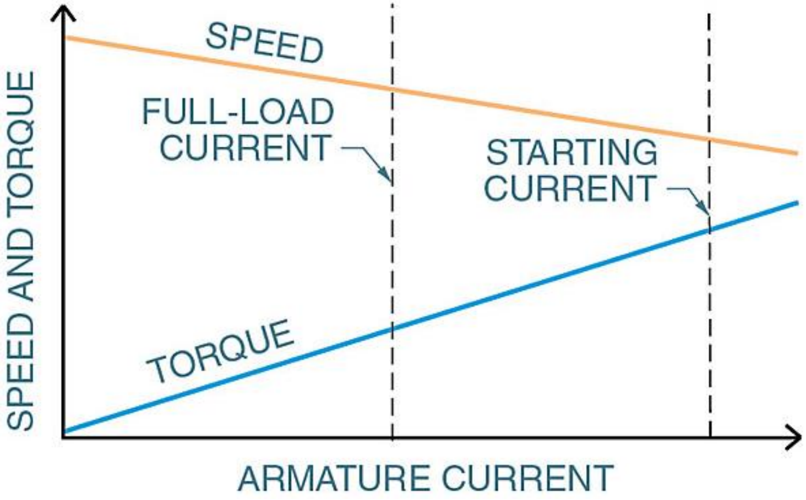
Wiring diagram

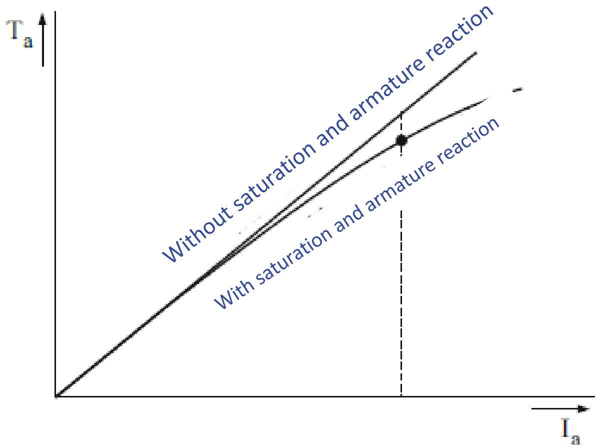


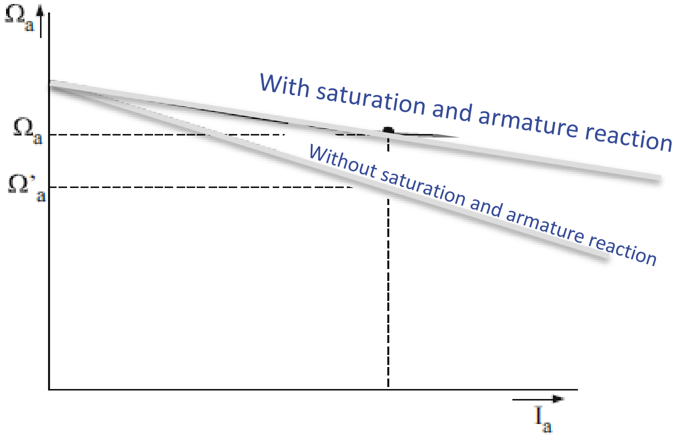
Schematic diagram

DC shunt motor





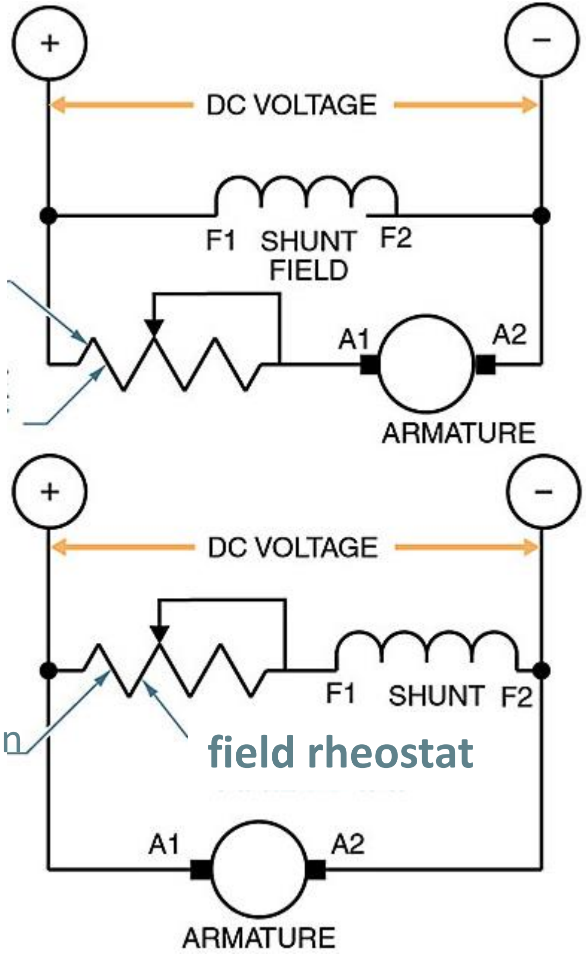




DC shunt motor

decreasing armature voltage decreases motor speed because of decreasing magnetic repulsion between armature and stator magnetic fields

armature rheostat



A field rheostat or armature rheostat is used to adjust the speed of a DC shunt motor

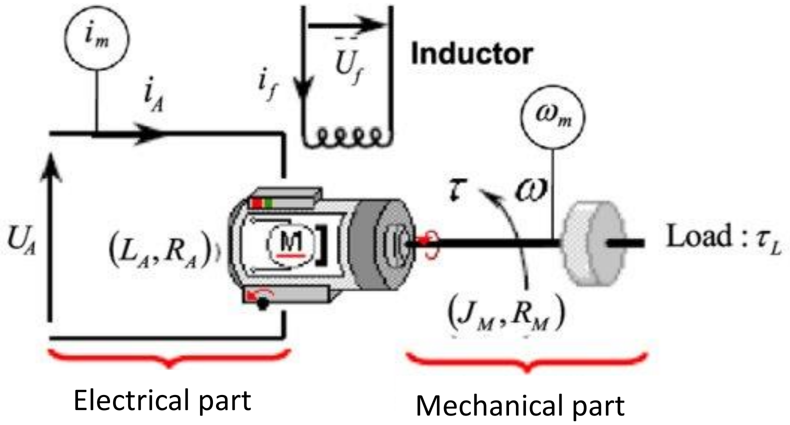
decreasing field voltage increases motor speed because of decreasing EMF in armature

DC separately motor

DC Machine

Would field

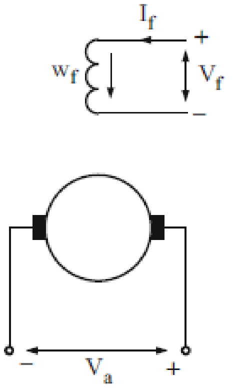
Series	Compound	Separately Shunt



Pictorial drawing

$$\Omega_a = \frac{V_a}{k \cdot \Phi_m} - \frac{(R_a + R_u)}{(k \cdot \Phi_m)^2} T_a$$

$$\Omega_{a0} = \frac{V_a}{k \cdot \Phi_m}$$ no-load speed



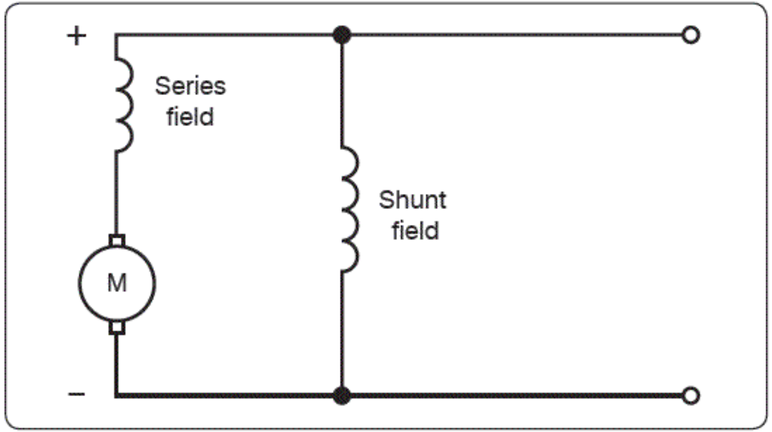
Schematic diagram

DC compound motor

DC Machine

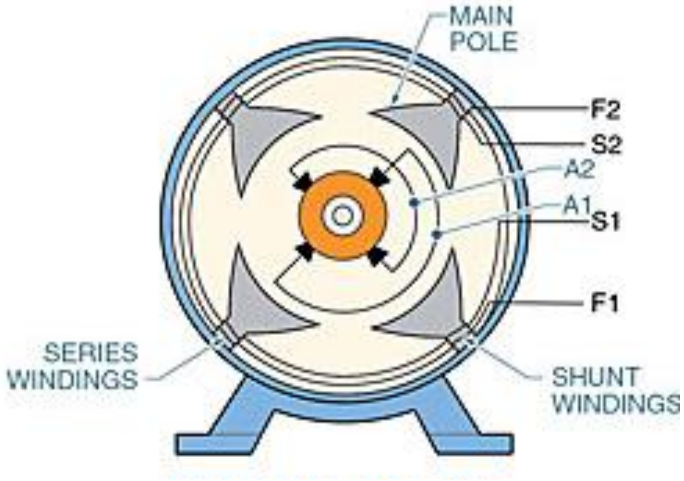
Would field

Series | Compound | Shunt

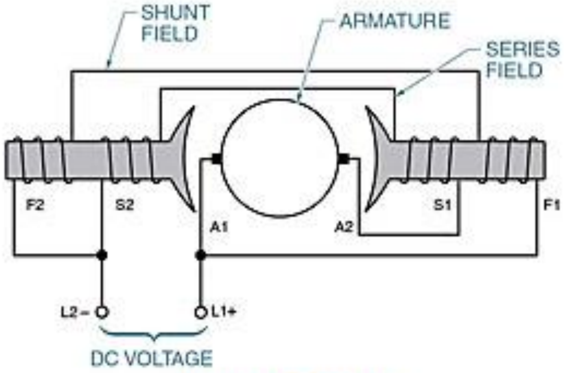


Schematic diagram

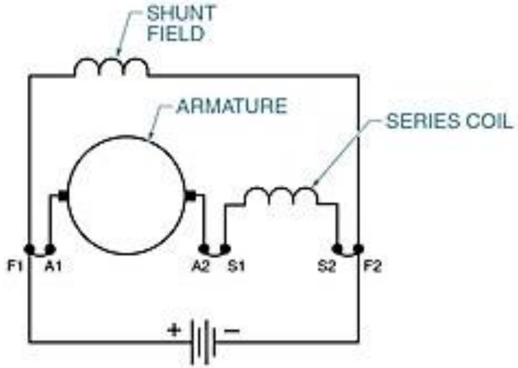
DC compound motor



Pictorial drawing



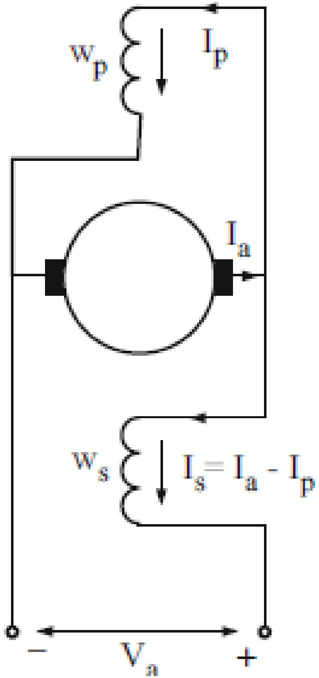
Wiring diagram



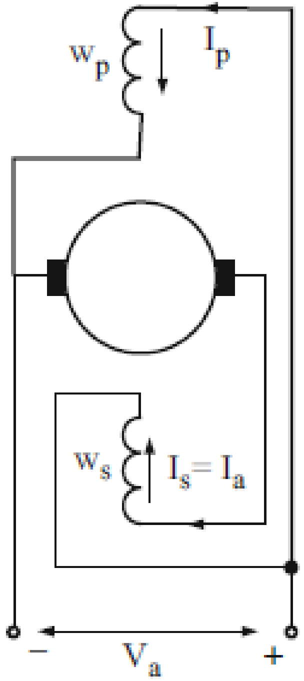
A1 TO F1 TO DC+
A2 TO S1
S2 TO F2 TO DC-

Schematic diagram

DC compound motor

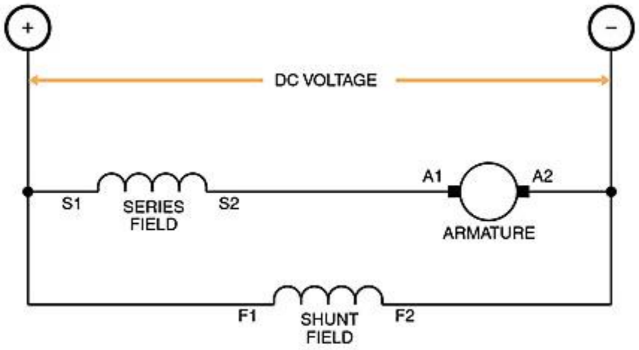


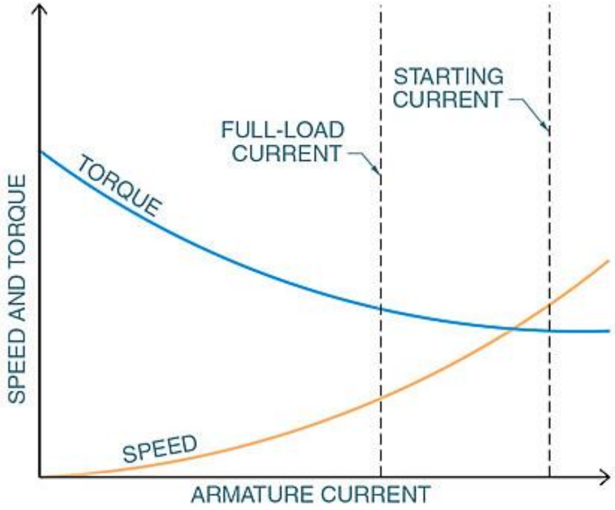
Cumulative compound motor



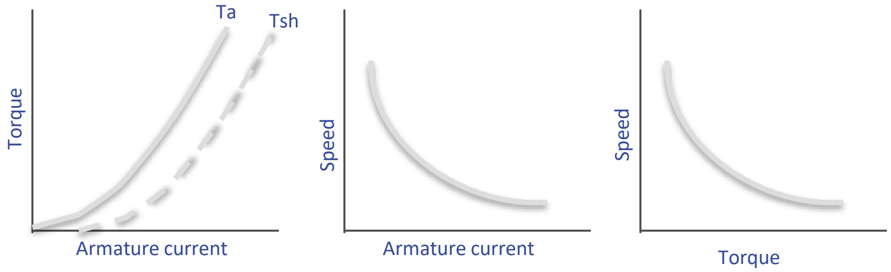
Differential compound motor

DC compound motor

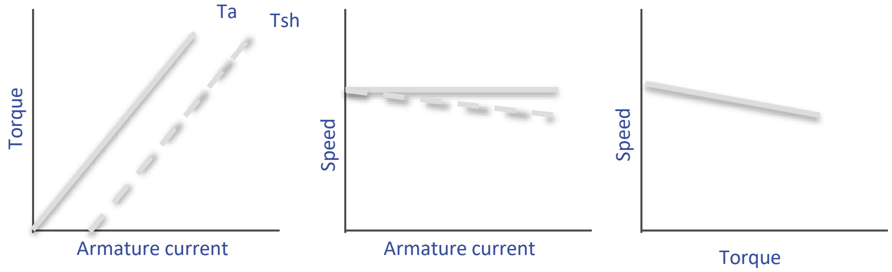




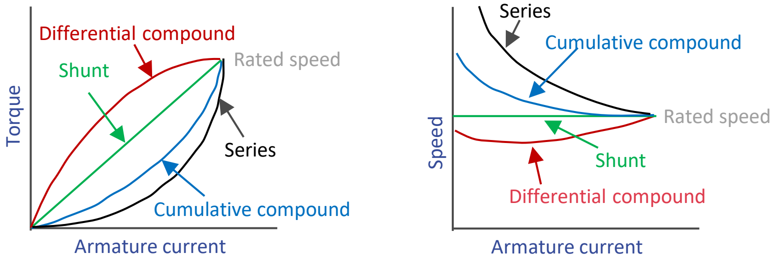
Series DC motor

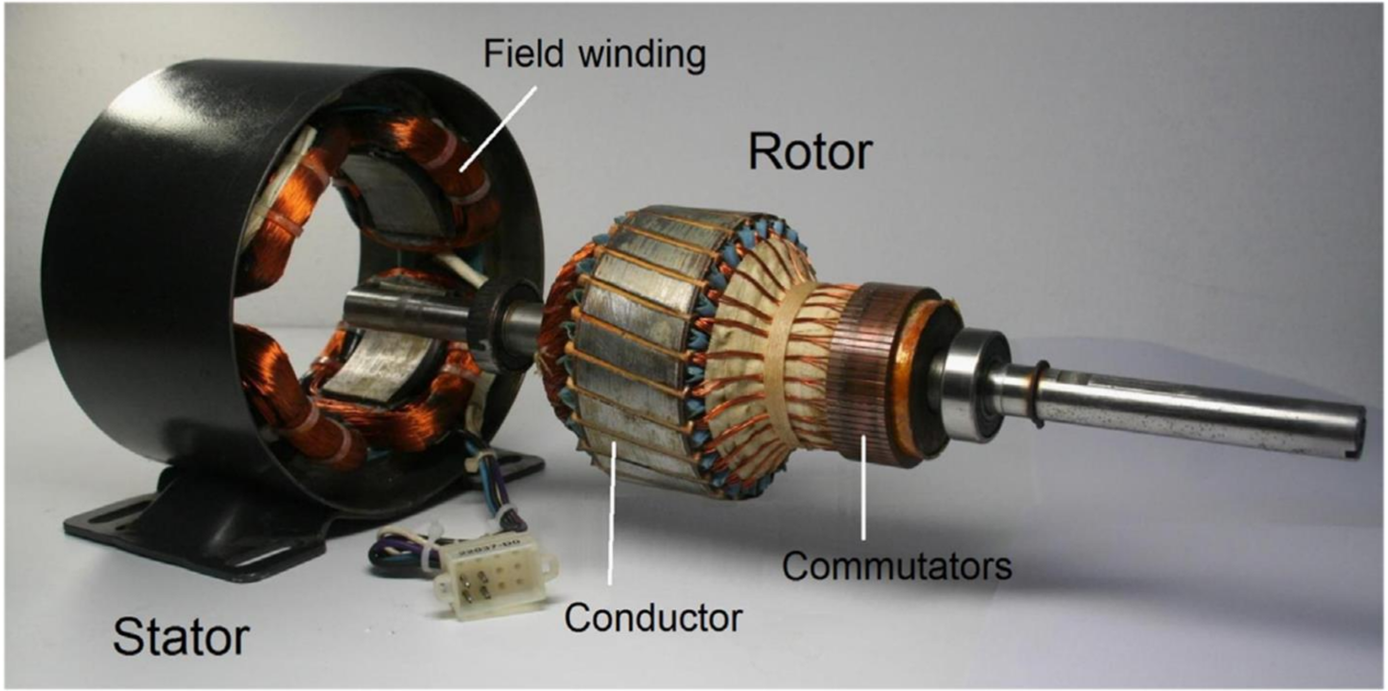


Shunt DC motor



Compound DC motor



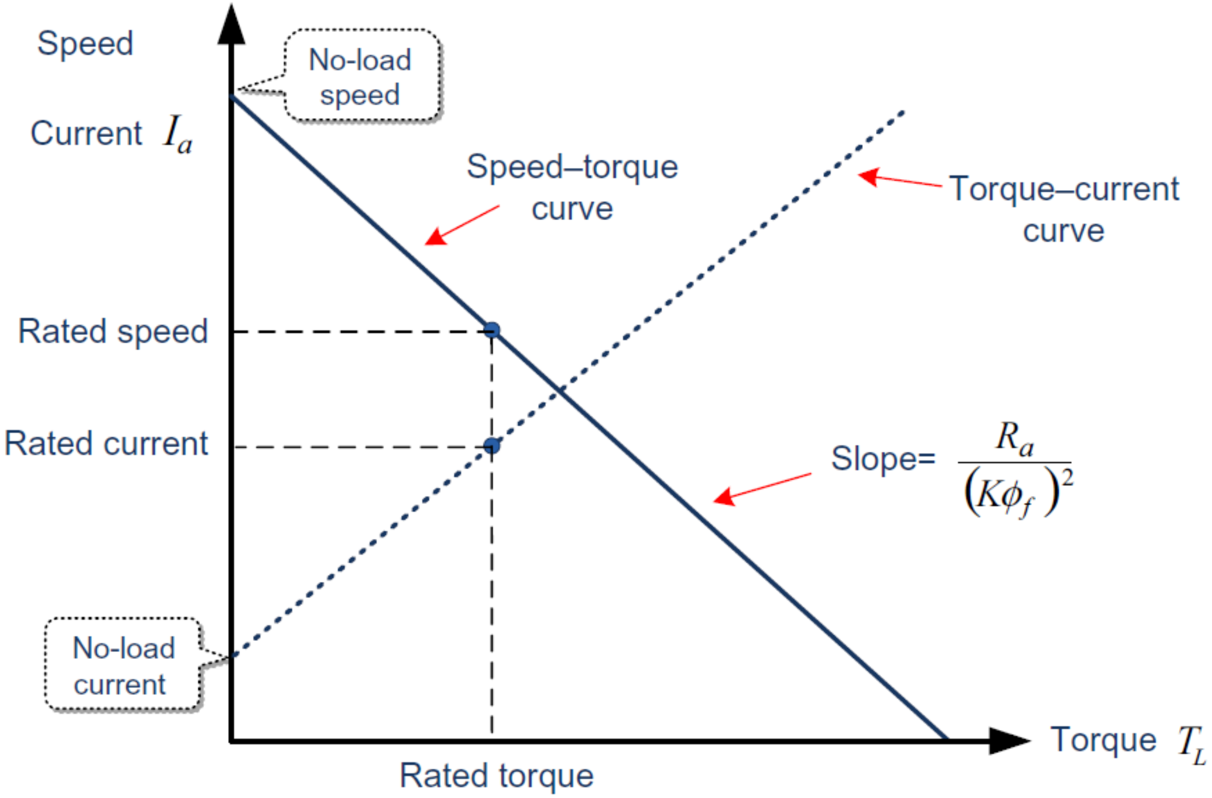

Field winding
Rotor
Commutators
Conductor
Stator

$$V_a = R_a i_a + L_a \frac{di_a}{dt} + e_a$$

where i_a is winding current,
L_a is winding inductance,
R_a is winding resistance,
e_a is back-EMF induced by the rotation of the armature winding in a magnetic field.

$di_a/dt = 0$

$$\omega_m = \frac{V_a}{k\phi_f} - \frac{R_a}{(k\phi_f)^2} T_L \quad (k = k_T = k_e)$$



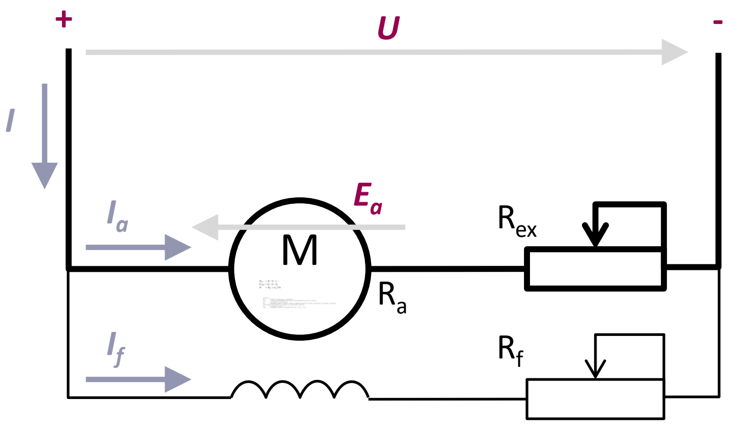
Speed
Current I_a
No-load speed
Speed–torque curve
Torque–current curve
Rated speed
Rated current
Slope= $\frac{R_a}{(K\phi_f)^2}$
No-load current
Torque T_L
Rated torque

Steady-state characteristics of DC motor with shunt field coil

$$E_a = k \cdot \Phi \cdot \omega$$

$$T_{em} = k \cdot \Phi \cdot I_a$$

$$U = E_a + I_a \cdot \Sigma R$$



where:

E_a - EMF of anchor winding;

T_{em} - electromagnetic torque developed by the motor;

I_a - armature current;

k - design gain of the motor determined by the number of poles, anchor windings and the number of parallel tracks;

Φ - magnet flow;

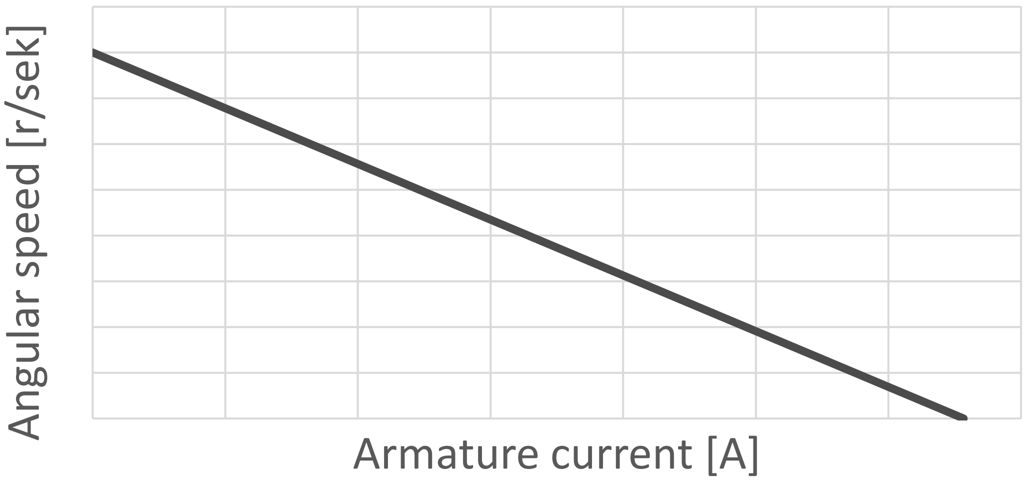
ΣR- anchor chain resistance $\Sigma R = R_a + R_{ex}$.

Steady-state characteristics of DC motor with shunt field coil

- DC motor current-speed characteristic:

$$\boldsymbol{\omega} = \boxed{\frac{U}{k\cdot\Phi}} - \frac{I_a\cdot\Sigma R}{k\cdot\Phi}$$

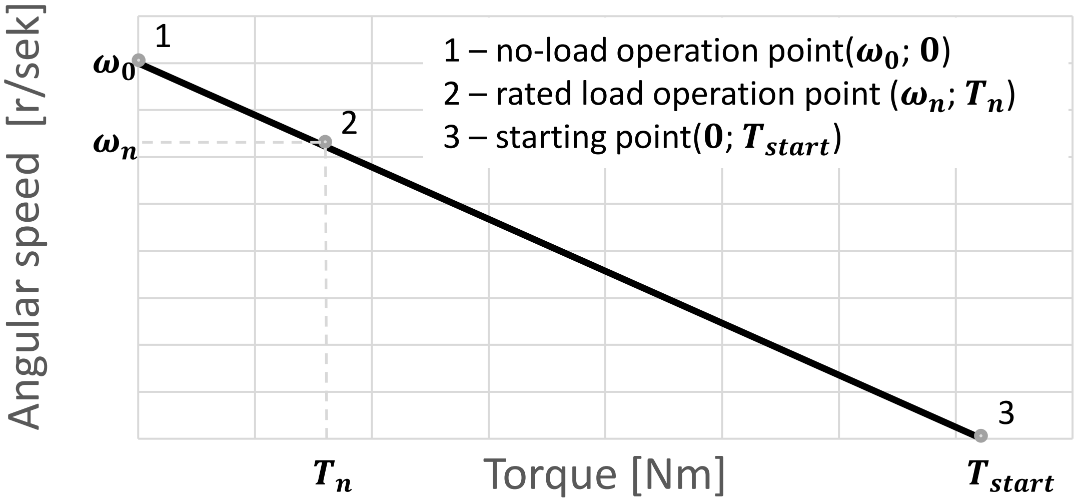
No load speed



Steady-state characteristics of DC motor with shunt field coil

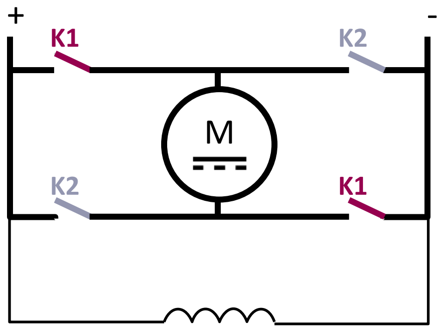
- DC motor torque-speed characteristic:

$$\omega = \frac{U}{k \cdot \Phi} - \frac{T_{em} \cdot \Sigma R}{(k \cdot \Phi)^2}$$



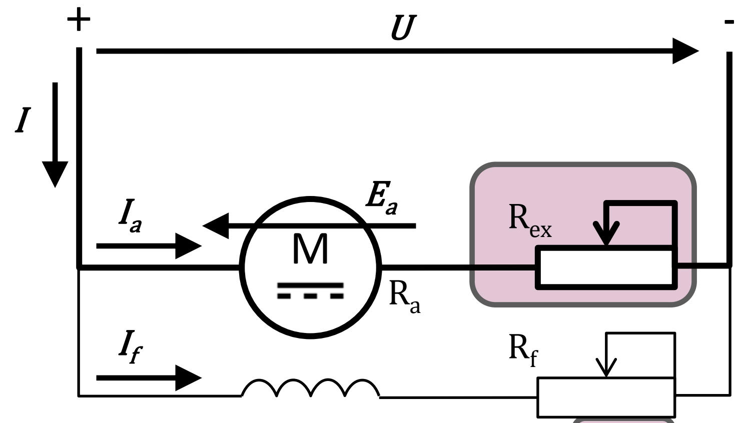
DC motor revers

- To **reverse** the DC motor, the direction of the armature or field current should be changed.
- Usually, the direction of the **armature current** is changed because the lower inductance of the armature winding ensures a shorter duration of the transient operation and avoids commutative overvoltage.
- To change the direction of the armature current, the **polarity** of the armature terminals should be changed.



Speed control of DC motor with shunt field coil

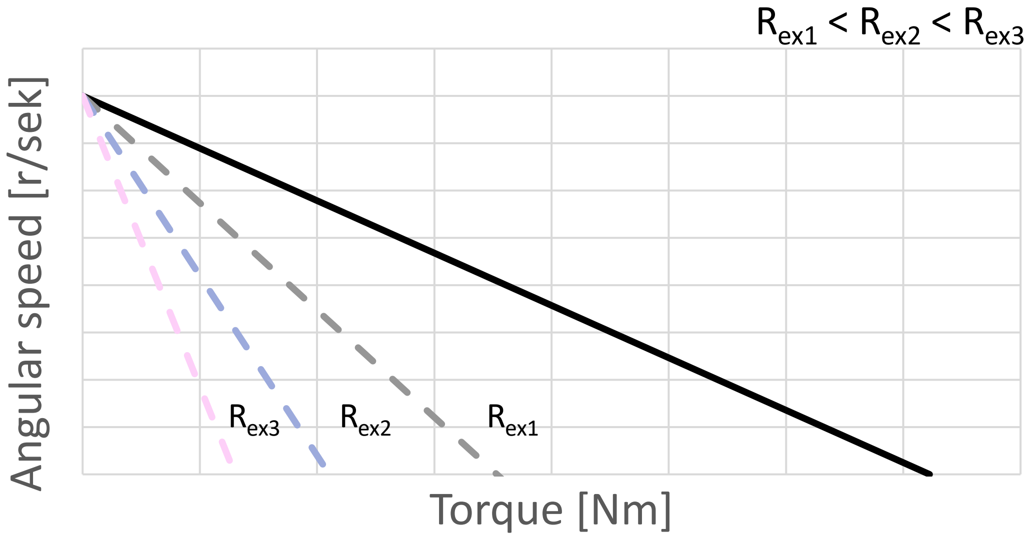
❑ The external **resistance** in armature circuit



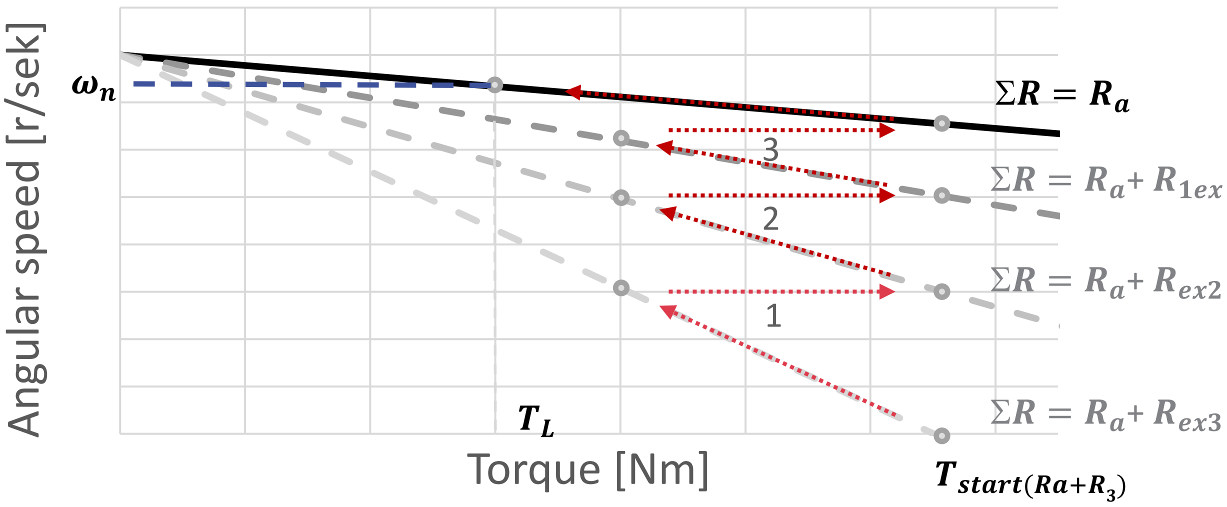
$$\omega = \frac{U}{k \cdot \Phi} - \frac{T_{em} \cdot \boxed{\Sigma R}}{(k \cdot \Phi)^2}$$

Speed control of DC motor with shunt field coil

- The external **resistance** in armature circuit



Starting of the DC motor with shunt field coil



Starting of DC motor

- At the moment a DC motor is started the armature is stationary and there is no counter EMF being generated.

$$E_a = 0$$

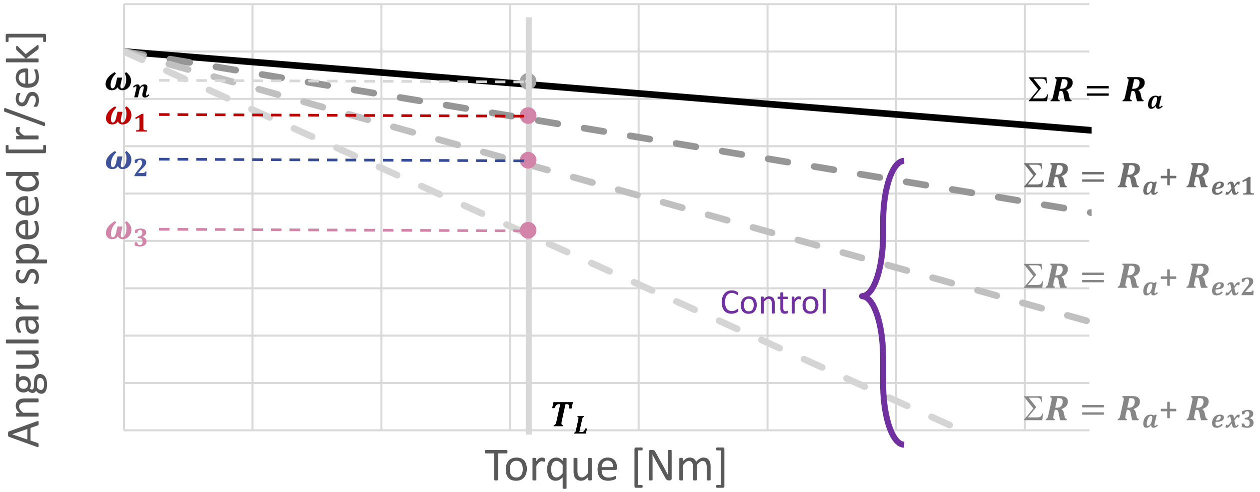
- The only component to limit starting current is the armature resistance, which, in most DC motors is a very low value (approximately one ohm or less)

$$U = E_a + \boldsymbol{I_a} \cdot R_{\boldsymbol{a}} \;=>\; \boldsymbol{I_a} = \frac{\boldsymbol{U-0}}{R_{\boldsymbol{a}}}$$

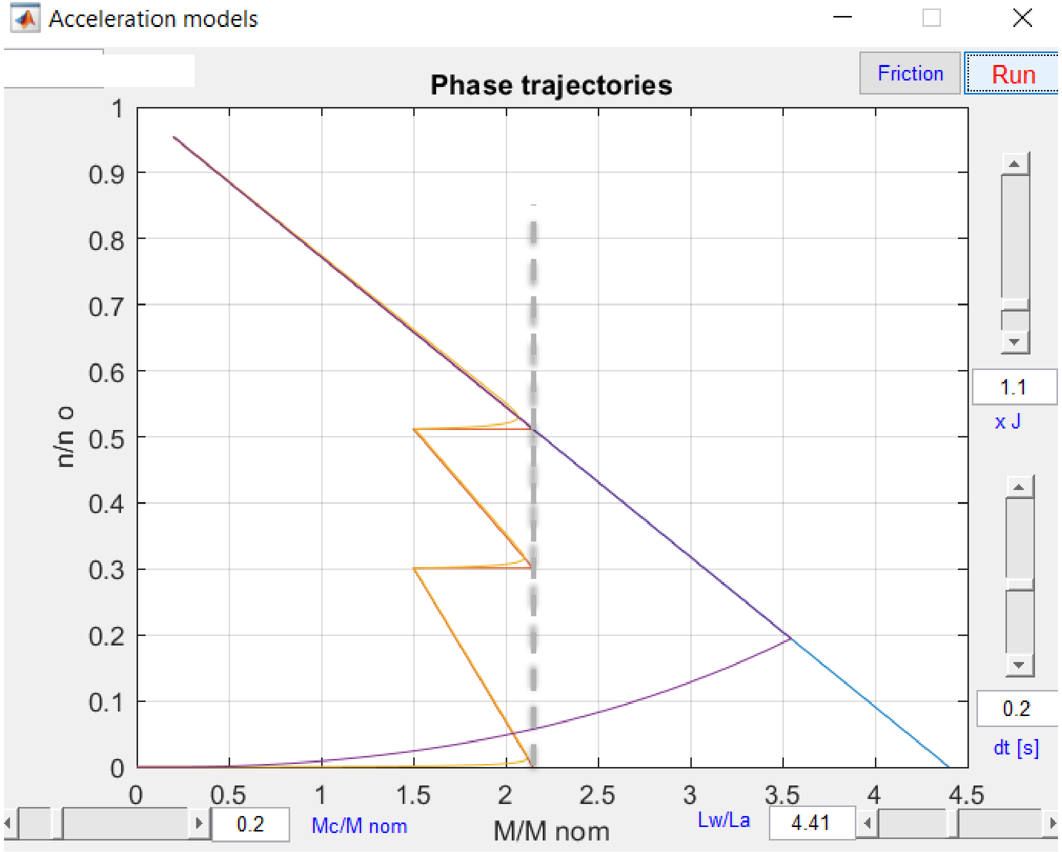
- Usually, **starting current** of the DC motor 10..20 times higher than rated current

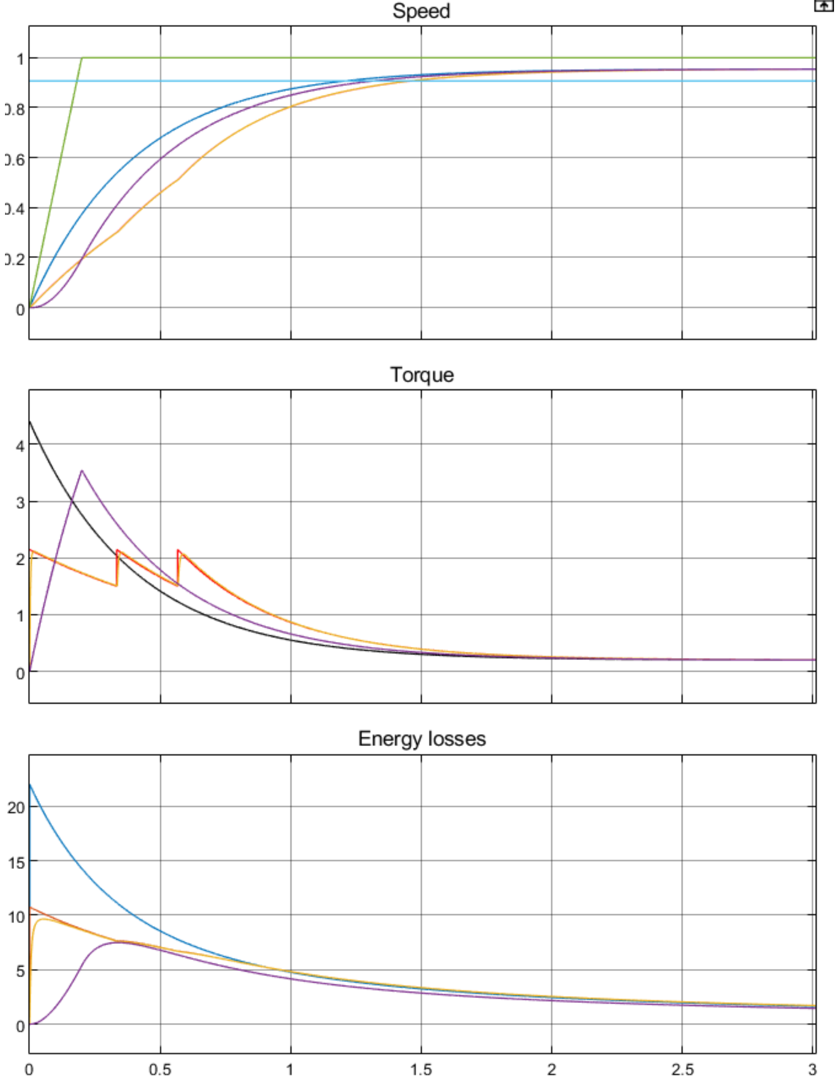
- In order to reduce this very high starting current, an external resistance must be placed in series with the armature during the starting period.

Speed control of DC motor



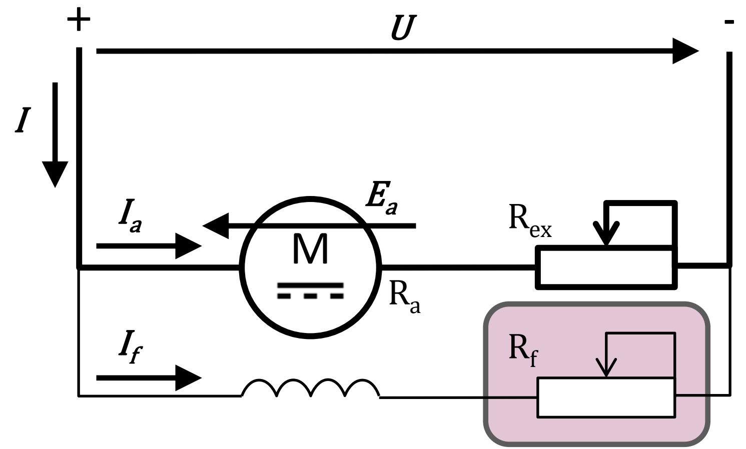
Speed control of DC motor





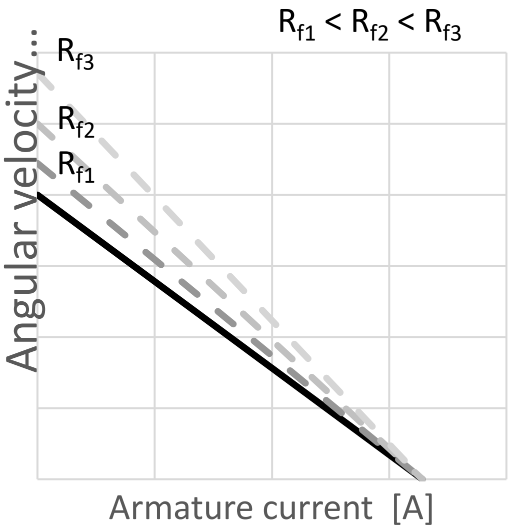
Speed control of DC motor

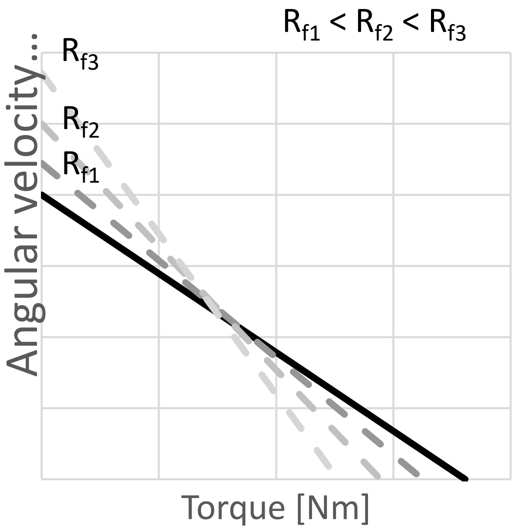
- The external resistance in **flux** circuit



$$\boldsymbol{\omega} = \frac{\boldsymbol{U}}{\boldsymbol{k}\cdot\boxed{\Phi}} - \frac{\boldsymbol{T_{em}}\cdot\Sigma\boldsymbol{R}}{(\boldsymbol{k}\cdot\boxed{\Phi})^{2}}$$

Speed control of DC motor

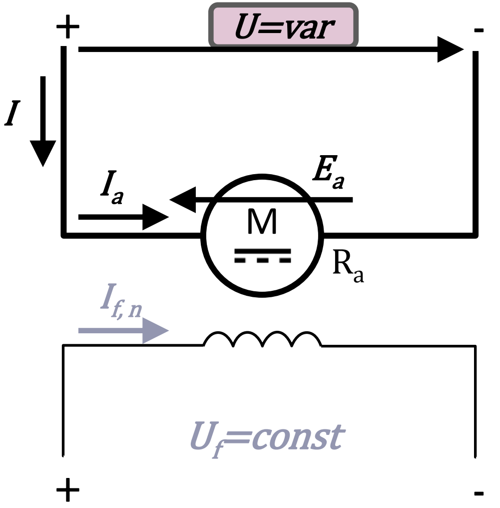


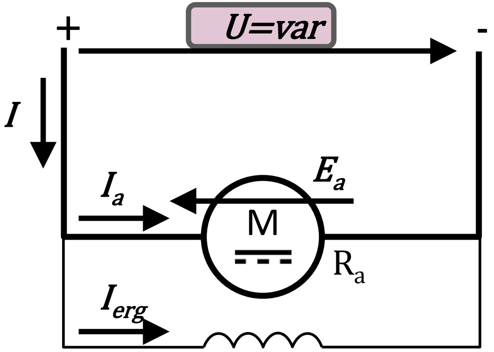


$$\boldsymbol{T_{em} = k \cdot \Phi \cdot I_a}$$

Speed control of DC motor

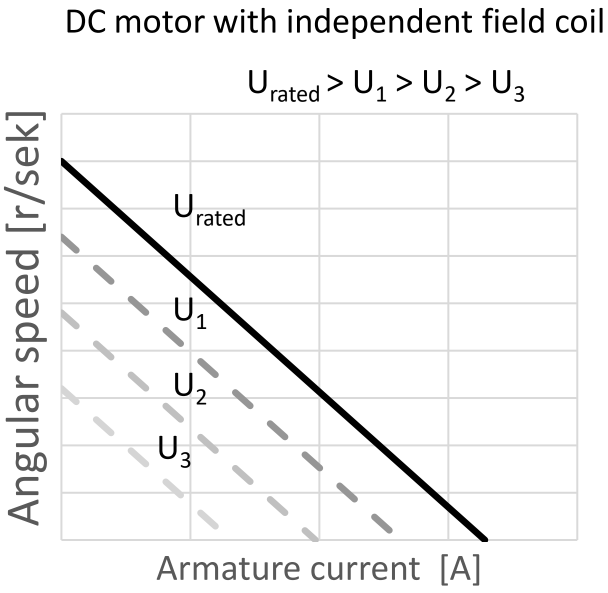
- ❑ The reduction of terminal **voltage**

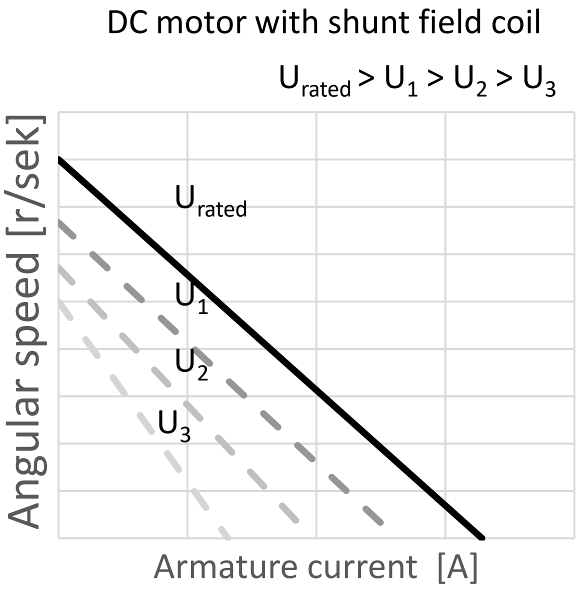




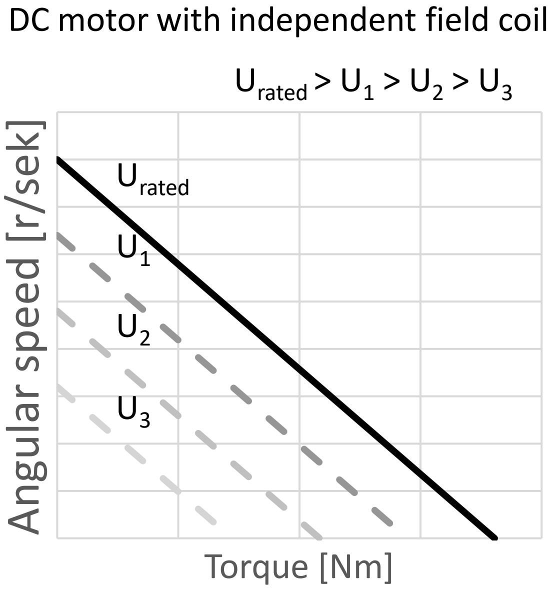
$$\boldsymbol{\omega} = \frac{\boxed{\boldsymbol{U}}}{\boldsymbol{k} \cdot \Phi} - \frac{\boldsymbol{T}_{\boldsymbol{em}} \cdot \Sigma \boldsymbol{R}}{(\boldsymbol{k} \cdot \Phi)^2}$$

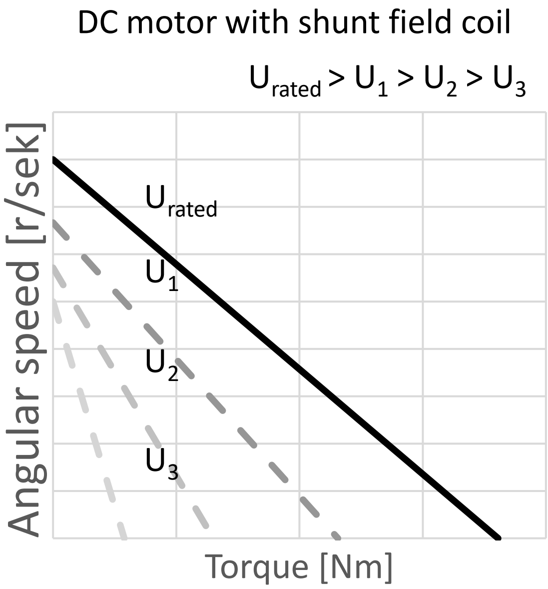
Speed control of DC motor





Speed control of DC motor

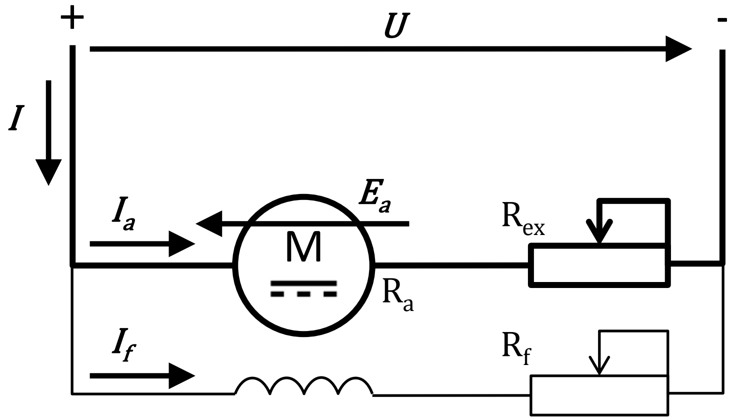




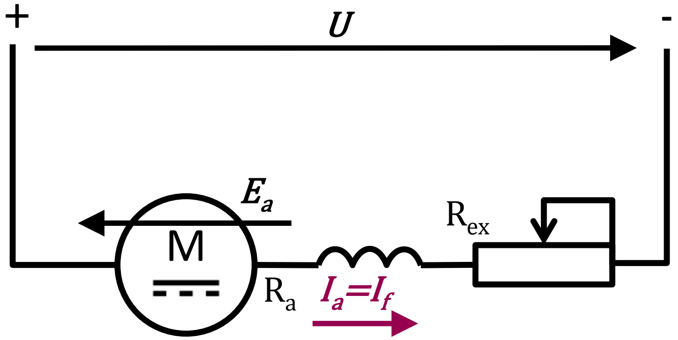
Speed control of DC motor

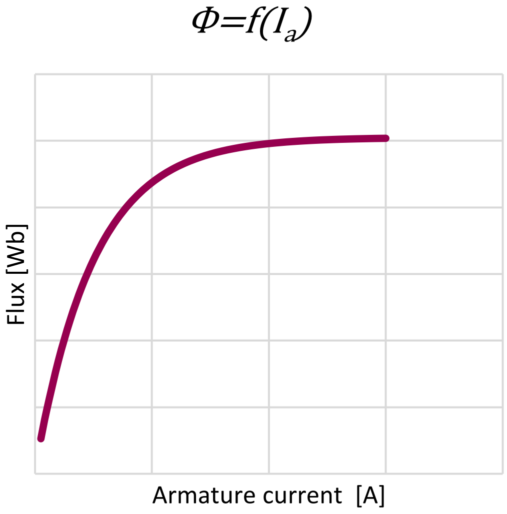
Ways to control DC motor speed:

- ❑ The external **resistance** in armature circuit
- ❑ The external resistance in **flux** coil circuit
- ❑ The reduction of terminal **voltage**



Series DC motor

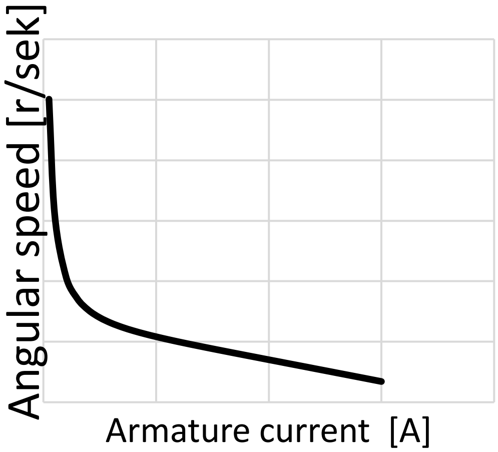


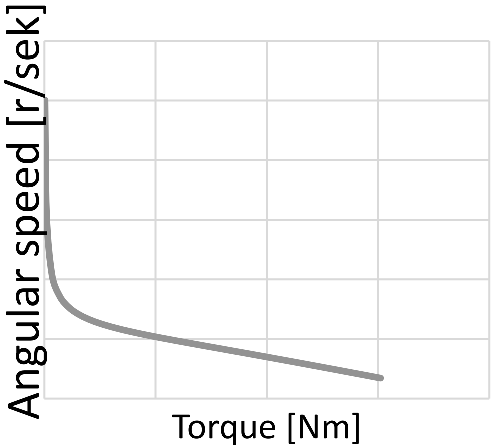


$$\omega = \frac{U}{k \cdot \boxed{\Phi}} - \frac{I_a \cdot \Sigma R}{k \cdot \boxed{\Phi}}$$

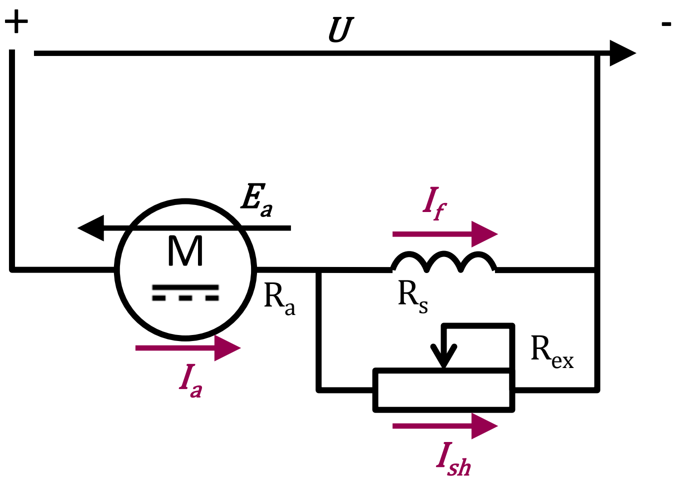
$$\omega = \frac{U}{k \cdot \boxed{\Phi}} - \frac{T_{em} \cdot \Sigma R}{(k \cdot \boxed{\Phi})^2}$$

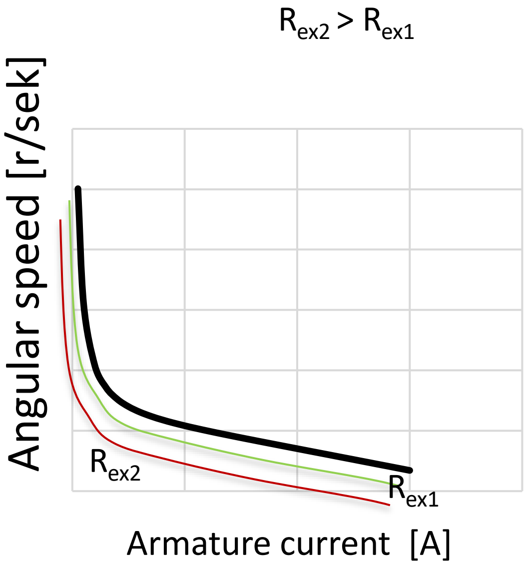
Series DC motor





Speed control of series DC motor





$$\omega = \frac{U}{\sqrt{k_a \cdot k_s \cdot T_{em}}} - (R_a + R_s + R_{ex})\sqrt{T_{em}/k_a \cdot k_s}$$

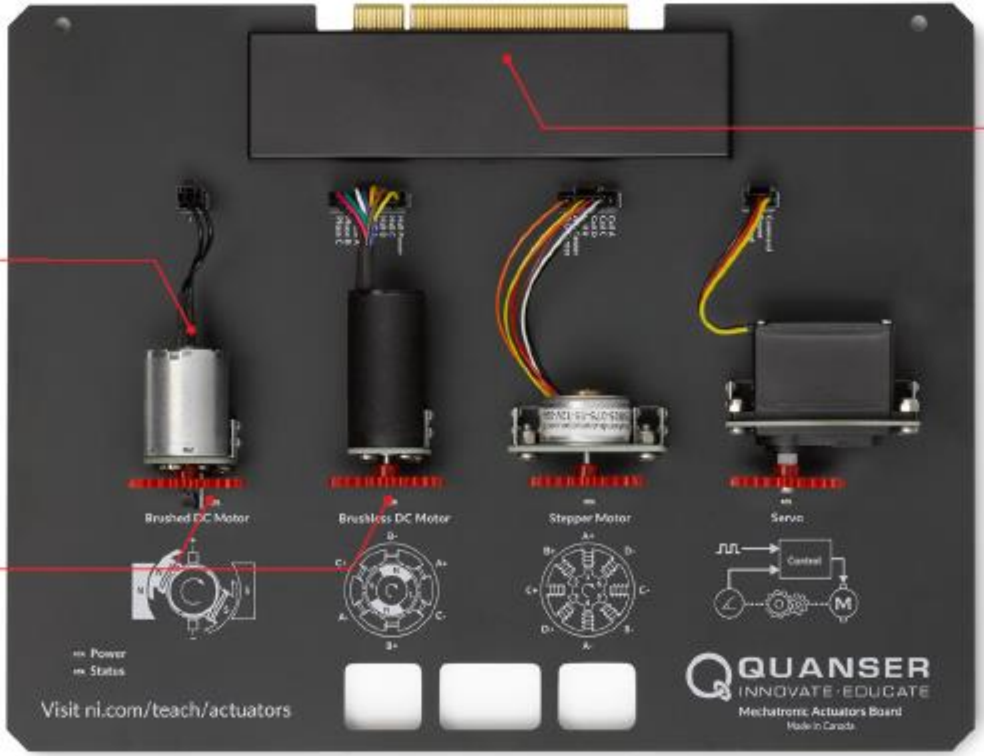
Four Complete Actuator Systems

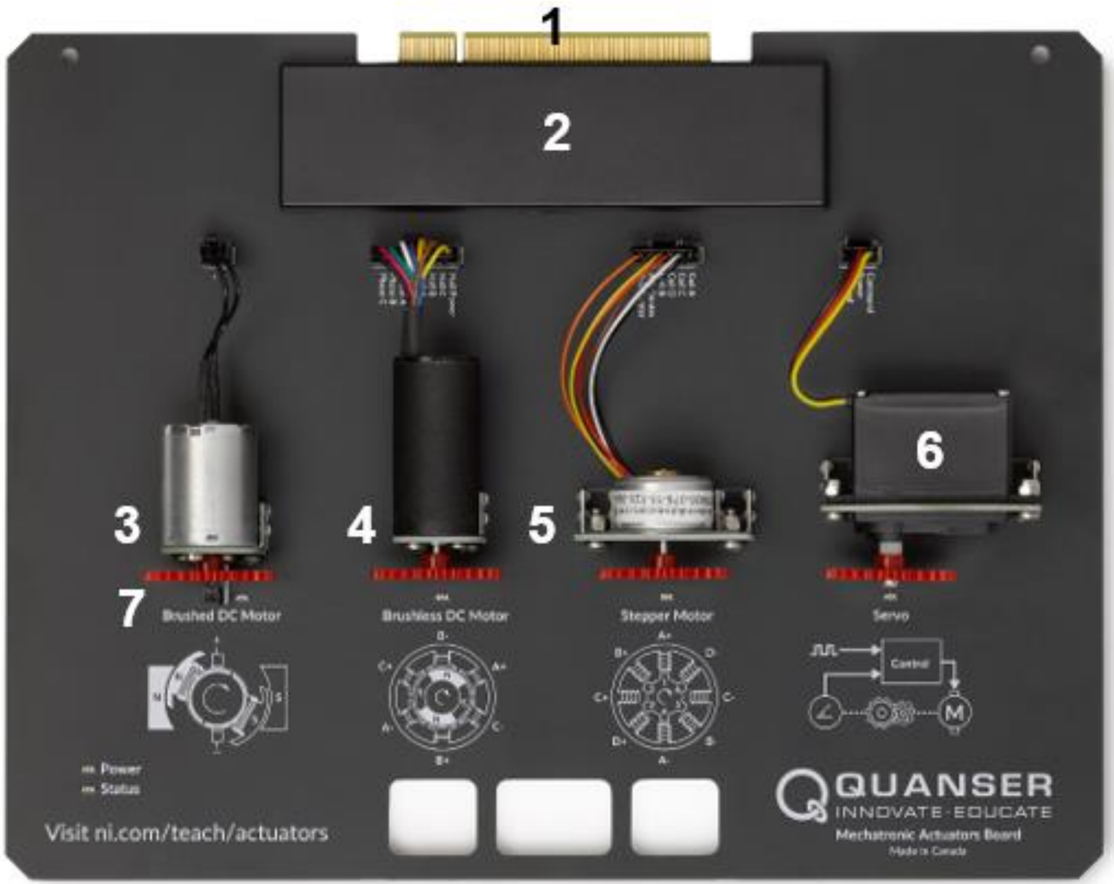
Brushed DC motor with linear and PWM amplifier, brushless DC motor, stepper motor, and servo motor

Access full system I/O including sensor data and commands

Linear and PWM amplifiers for brushed DC motor

Easily compare design alternatives



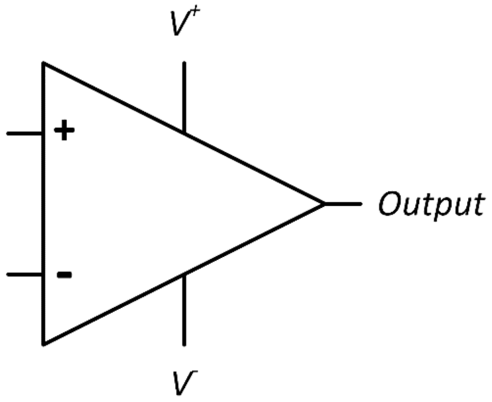


3 - Brushed DC Motor

The Mechatronic Actuators board features a direct drive 24 V DC motor. This motor can be driven either by a linear or PWM amplifier. The included motor is a Kinmore Motor RF-370CHV-13455.

7 - Photomicrosensor

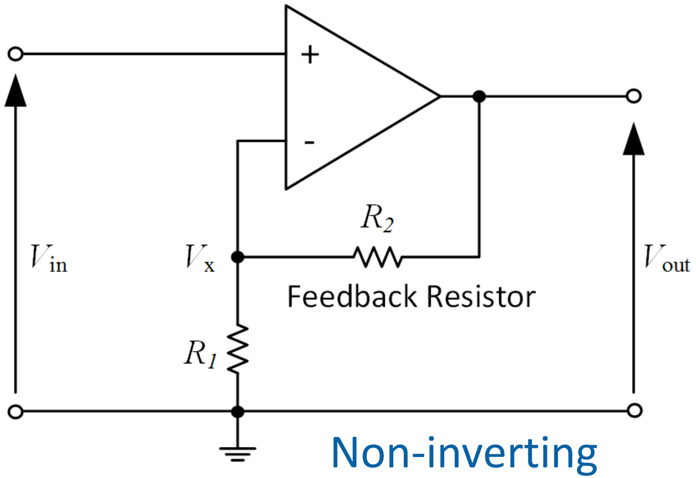
The speed of the brushed DC motor is measured using an onboard photomicrosensor which detects the teeth on the motor-mounted gear. The included sensor is a Omron EE-SX1081.



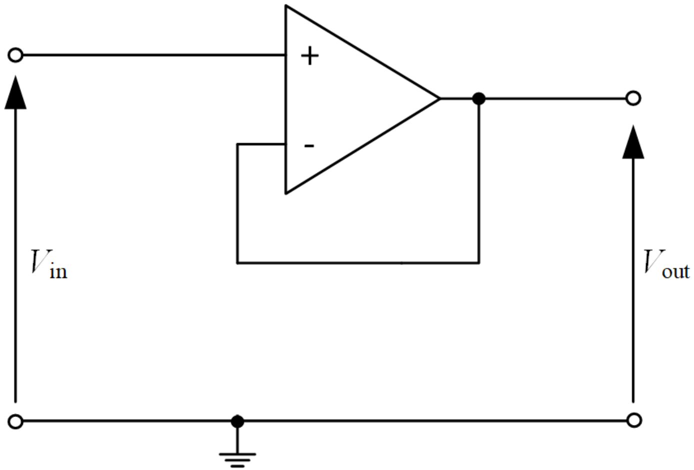
Operational amplifier
(op-amp) symbol

$$V_x = \frac{R_1}{R_1 + R_2} V_{\text{out}}$$

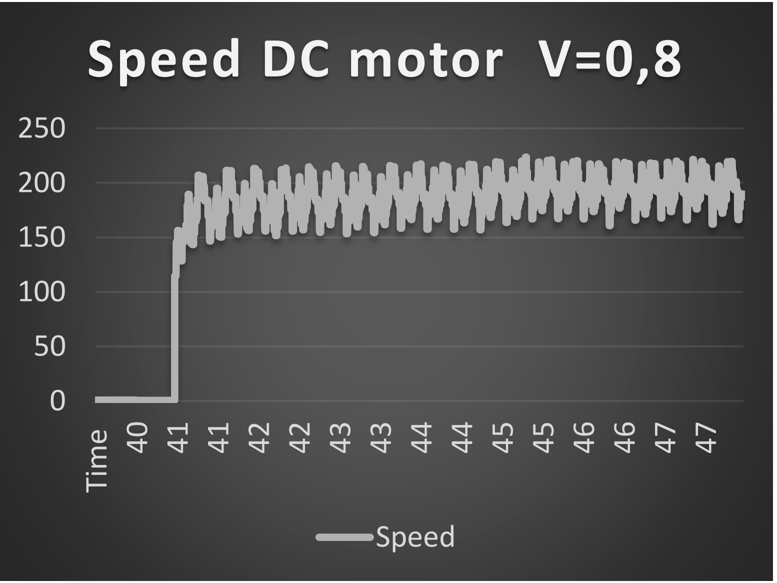
$$\text{Voltage Gain} = \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$$

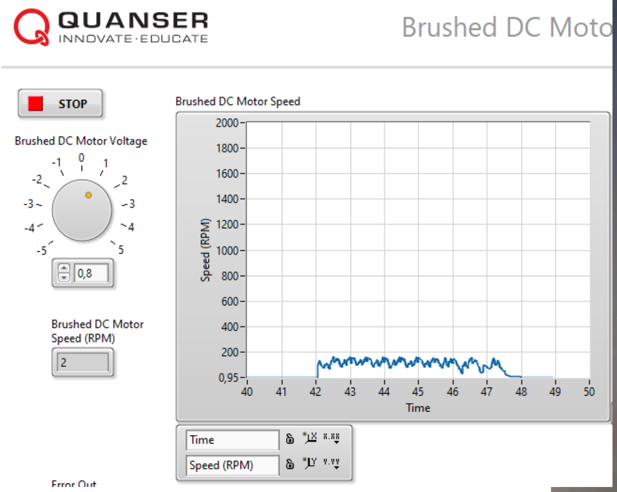


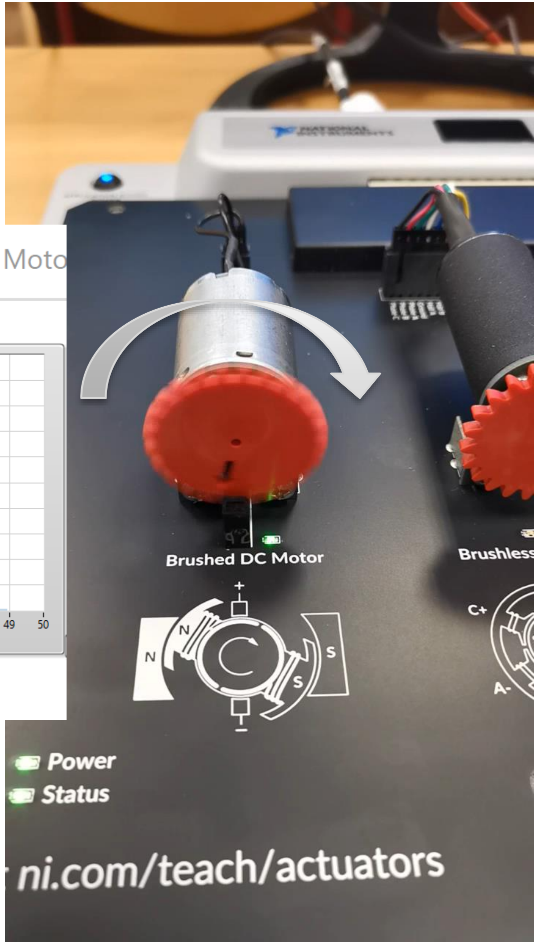
Non-inverting amplifier

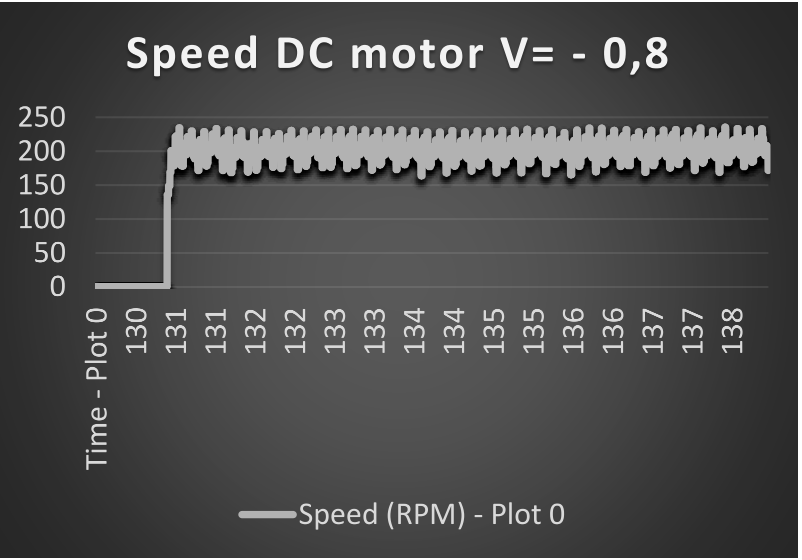


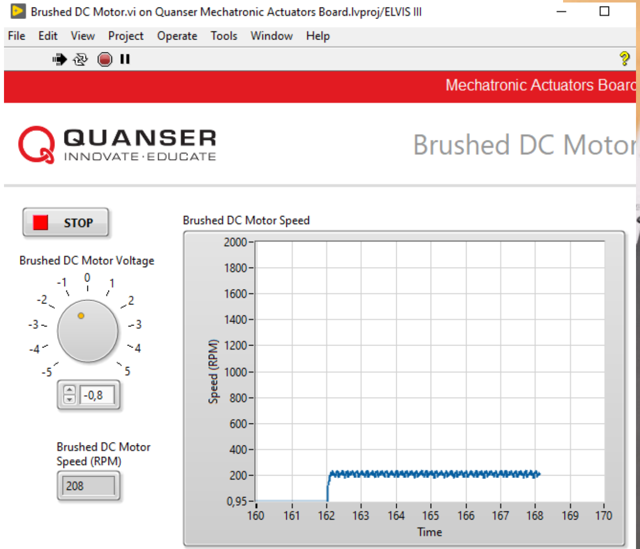
Voltage follower


Speed DC motor V=0,8
250
200
150
100
50
0
Time
40
41
41
42
42
43
43
44
44
45
45
46
46
47
47
Speed


QUANSER
INNOVATE·EDUCATE
Brushed DC Moto
STOP
Brushed DC Motor Voltage
0,8
Brushed DC Motor Speed (RPM)
2
Error Out
Brushed DC Motor Speed
Speed (RPM)
Time
Speed (RPM)


Brushed DC Motor
Brushless
Power
Status
ni.com/teach/actuators


Speed DC motor V= - 0,8
250
200
150
100
50
0
Time - Plot 0
130
131
131
132
132
133
133
134
134
135
135
136
136
137
137
138
Speed (RPM) - Plot 0


Brushed DC Motor.vi on Quanser Mechatronic Actuators Board.lvproj/ELVIS III
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Mechatronic Actuators Board
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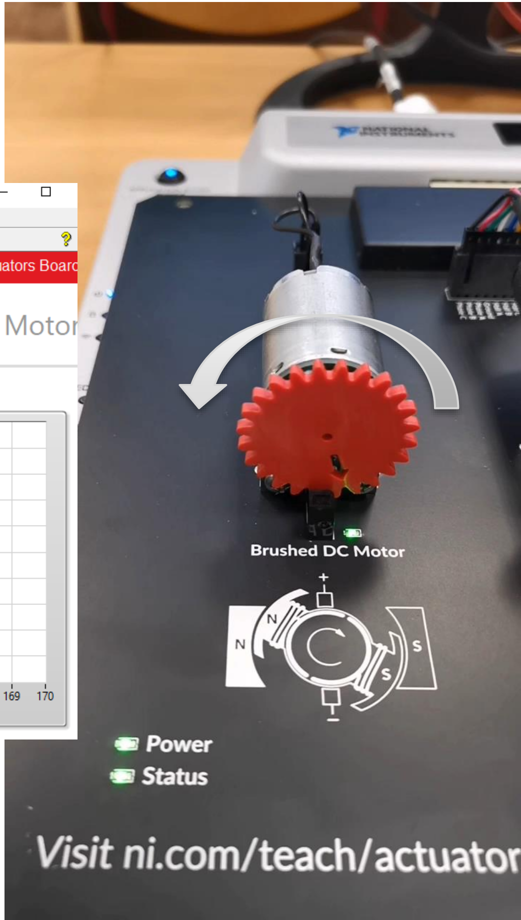
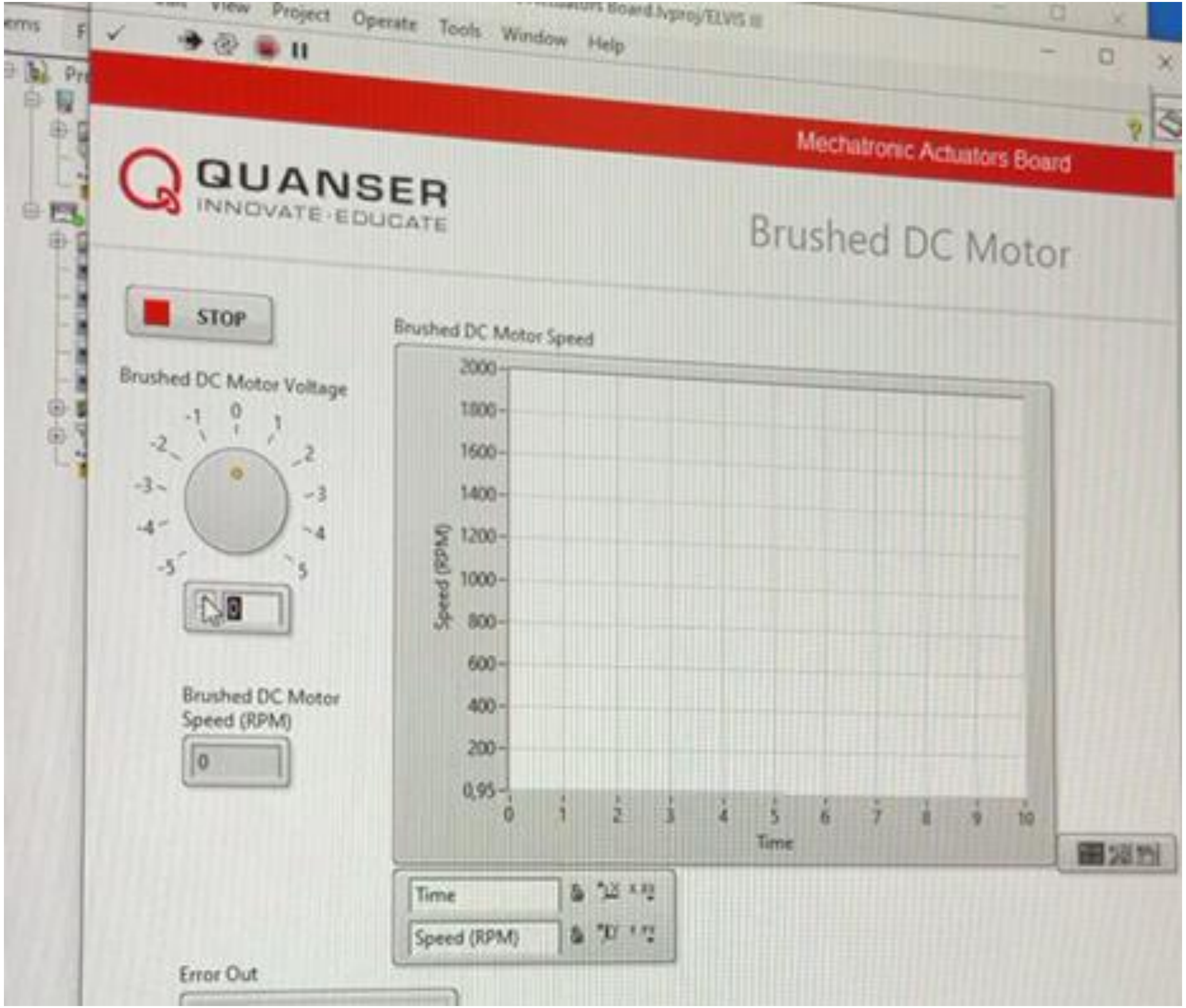
Brushed DC Motor
STOP
Brushed DC Motor Voltage
-0,8
Brushed DC Motor Speed (RPM)
208
Brushed DC Motor Speed
Speed (RPM)
Time


Brushed DC Motor
N
S
Power
Status
Visit ni.com/teach/actuator



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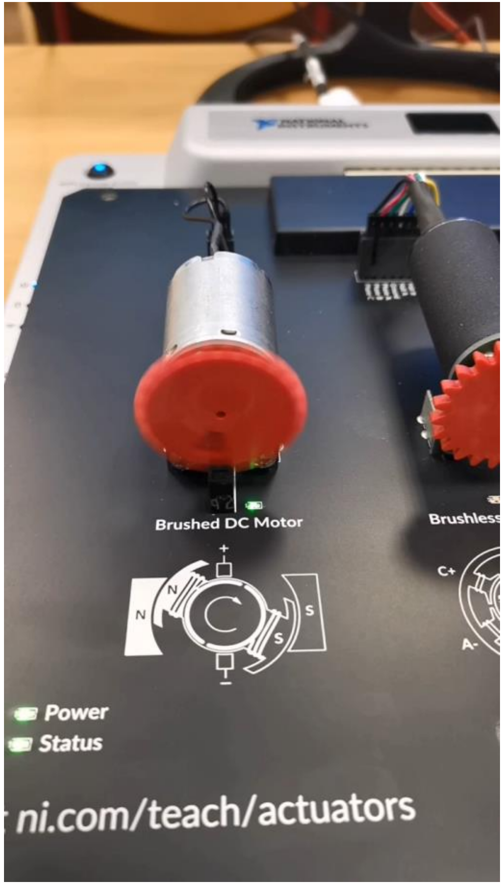
Brushed DC Motor
STOP
Brushed DC Motor Voltage
Brushed DC Motor Speed
Brushed DC Motor
Speed (RPM)
Speed (RPM)
Time
Error Out



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Power
Status
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