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FAQ: What's the difference between torque constant, back EMF constant, and motor constant?

APRIL 5, 2017 BY [DANIELLE COLLINS](#) — [LEAVE A COMMENT](#)

A DC motor's [output torque](#) is directly proportional to the current through the windings, and the motor's [angular speed](#) is directly proportional to the back EMF that it generates. These simple relationships are typically given by the equations:

$$T = I \cdot k_T$$

Where:

T = torque (Nm)

I = current (A)

k_T = torque constant (Nm/A)

And

$$\omega = \frac{V_E}{k_E}$$

Where:

ω = angular velocity (rad/s)

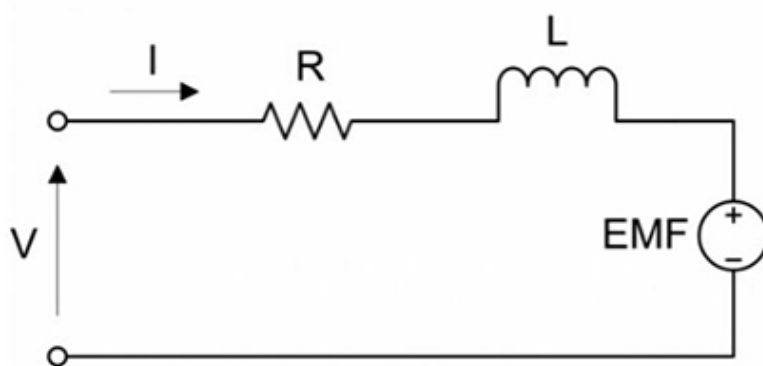
V_E = back EMF voltage (V)

k_E = back EMF constant (V-s/rad)

The torque constant, k_T , is specific to motor's design, including its magnetic strength, number of wire turns, and armature length. The slope of the motor's torque-current curve is determined by the torque constant.

The back EMF constant, k_E , represents the relationship between the motor's back EMF and its speed. It has an often-used inverse, referred to as the voltage constant, k_V . The back EMF constant, k_E , is given in units of volt-seconds per radian (V-s/rad), and conversely, the voltage constant, k_V is given in units of radians per volt-second (rad/V-s).

Interestingly, the torque constant, k_T and the back EMF constant, k_E are equal. This can be demonstrated by applying the law of conservation of energy: electrical power in must be equal to mechanical power out plus motor electrical losses.



Typical DC motor circuit

Image credit: Precision Microdrives Limited

Electrical power in is equal to voltage times current.

$$\text{Electrical power in} = V \cdot I$$

According to [Kirchhoff's Voltage Law](#), the applied voltage is given as:

$$V_{in} = I \cdot R + V_E$$

Where:

R = motor resistance (ohms)

Substituting for V_E (from above)

$$V_{in} = I \cdot R + k_E \cdot \omega$$

Now, multiplying voltage by current, we get:

$$\text{Electrical power in} = (I^2 \cdot R) + (k_E \cdot I \cdot \omega)$$

Mechanical power out is equal to torque times rotational speed:

$$\text{Mechanical power out} = T \cdot \omega$$

Substituting for T (from above):

$$\text{Mechanical power out} = k_T \cdot I \cdot \omega$$

Electrical losses are caused by the resistance in the circuit:

$$\text{Losses} = I^2 \cdot R$$

Now, setting electrical power in equal to mechanical power out plus losses, we get:

$$(I^2 \cdot R) + (k_E \cdot I \cdot \omega) = (k_T \cdot I \cdot \omega) + (I^2 \cdot R)$$

Shares

You can see that all terms cancel out, except the back EMF constant and the torque constant, which must be equal:

$$k_E = k_T$$

Also related to the torque constant is the motor constant, k_m , which represents the motor's ability to convert electrical power to mechanical power. The motor constant is given by:

$$k_m = \frac{T}{\sqrt{P}}$$

Where:

k_m = motor constant (Nm/ $\sqrt{\text{Watt}}$)

T = torque (Nm)

P = resistive power losses (also known as I^2R losses) (W)

Substituting for T (from above) and resistive power losses, P , we get:

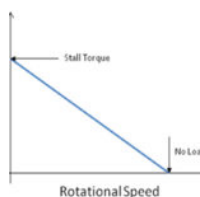
$$k_m = \frac{(I \cdot k_T)}{\sqrt{I^2 \cdot R}}$$

Which simplifies to:

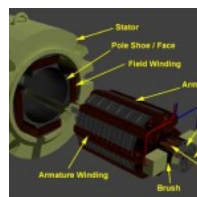
$$k_m = \frac{k_T}{\sqrt{R}}$$

The motor constant is supplied by the manufacturer, and is useful for comparing the relative outputs, or efficiencies, of different motors.

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The Torque Equation and the Relationship with DC Motors

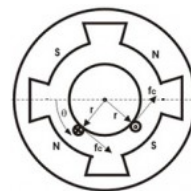


FAQ: What are rotational losses in DC motors?

Lenz's Law

$$\epsilon = -N \left(\frac{\Delta \Phi}{\Delta t} \right)$$

Lenz's Law and Back EMF



FAQ: What's the relationship between current and DC motor output...



The relationship between voltage and DC motor output speed

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Lisa (Elisabeth) Eitel is an editor at Design World and its network of sites. She got her engineering degree from Fenn (now Washkewicz) College at Cleveland State University and has 15 years of experience as a technical writer.

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