Motor Equations

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No load speed at applied Voltage

n_0' = no load speed at applied voltage (rpm)

V_A = Applied Voltage (V)

k_n = speed constant (rpm/V)

$$\boxed{n_0' = V_A \cdot k_n}$$

Speed loss under load

n_L = speed loss under load (rpm)

T_M = Motor torque (mNm)

S_T = Speed - torque gradient (rpm/mNm)

$$\boxed{n_L = T_M \cdot S_T}$$

Output Speed - no gear

$$\boxed{n_{output} = n_0' - n_L}$$

n_{output} = output speed, no gear (rpm)

n_0' = no load speed at applied voltage (rpm)

n_L = speed loss under load (rpm)

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n_{output} = output speed, no gear (rpm)

$$\boxed{n_{output} = \left(\frac{V_A}{V_N} \cdot n_0\right) - S_T \cdot T_M}$$

T_M = Motor torque (mNm)

S_T = Speed - torque gradient (rpm/mNm)

V_A = Applied Voltage (V)

V_N = Nominal Voltage (V)

n_0 = no load speed at nominal voltage (rpm)

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Voltage applied, no gear

n_{output} = output speed, no gear (rpm)

T_M = Motor torque (mNm)

S_T = Speed - torque gradient (rpm/mNm)

k_n = speed constant (rpm/V)

V_A = Voltage applied, no gear (V)

$$\boxed{V_A = \frac{n_{output} + T_M \cdot S_T}{k_n}}$$

Min. motor Torque Required w/ gear

T_M = motor torque required w/ gear (mNm)

T_{out} = output torque desired (mNm)

R_R = Reduction Ratio

eff = gearhead efficiency

$$\boxed{T_M = \frac{T_{out}}{R_R \cdot eff}}$$

Voltage applied w/ gear

V_A = applied voltage (V)

n_0 = no load speed at V_N (rpm)

V_N = nominal voltage (V)

R_R = Reduction ratio

S_T = speed - torque gradient (rpm/mNm)

T_M = motor torque required w/ gear (mNm)

n_{output} = output speed w/ gear (rpm)

$$\boxed{V_A = \frac{V_N \cdot \left(n_{output} \cdot R_R + S_T \cdot T_M\right)}{n_o}}$$

Output speed w/ gear

$$\boxed{n_{output} = \frac{1}{R_R} \cdot \left[\left(\frac{n_0 \cdot V_A}{V_N}\right) - S_T \cdot T_M\right]}$$

Current under load

i_L = current under load (A)
T_M = motor torque (mNm)
k_m = torque constant (mNm/A)
i_0 = no load current (A)

$$\boxed{i_L = \frac{T_M}{k_m} + i_0}$$

Output Power

P_{out} = output power (mW)
n = speed (rpm)
T_M = motor torque (mNm)

$$\boxed{P_{out} = \frac{\pi}{30} \cdot n \cdot T_M}$$

Max power output at V_N

$$\boxed{P_{\max} = \left(\frac{V_N}{4}\right) \cdot \left[\left(\frac{V_N}{R}\right) - i_0\right]}$$

$P_{\max}$ = max power output at V_N (W)
V_n = nominal voltage (V)
R = terminal resistance (Ω)
i_0 = no load current (A)

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Time to thermal overload of a cold motor at 25°C

$$\boxed{t_{on} = \tau_{th} \cdot \ln \frac{K^2}{K^2 - 1}}$$

t_{on} = time to thermal overload at 25°C (s)

τ_{th} = thermal time contant of winding (s)

$$K = \frac{i}{i_{\max}} \cdot \sqrt{\frac{R_{th1}}{R_{th1} + R_{th2}}} = \frac{T_M}{T_{\max}} \cdot \sqrt{\frac{R_{th1}}{R_{th1} + R_{th2}}}$$

i = current (mA)

$i_{\max}$ = max continuous current (mA)

T_M = motor torque (mNm)

$T_{\max}$ = max continous torque (mNm)

R_{th1} = thermal resistance winding - housing (K/W)

R_{th2} = thermal resistance housing - ambient (K/W)

Impedance

X_L = impedance (Ω)

ω = frequency of PWM ($\frac{1}{\mathrm{s}}$)

L = inductance (H)

$$\boxed{X_L = \omega \cdot L}$$

Average current - pulsed cycle

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i_{avg} = average current (mA)

t_{on} = on time (s)

t_{off} = off time (s)

i = pulsed current (mA)

$$i_{avg} = \sqrt{i^2 \cdot \frac{t_{on}}{t_{on} + t_{off}}}$$

Average current - working cycle

i_{avg} = average current (mA)

t_{tot} = total time (s)

i_1 = current during t_1 (mA)

i_2 = current during t_2 (mA)

i_3 = current during t_3 (mA)

$$i_{avg} = \sqrt{\frac{1}{t_{tot}} \cdot \left(i_1^2 \cdot t_1 + i_2^2 \cdot t_2 + i_3^2 \cdot t_3 + \ldots\right)}$$

Arcminutes

$0.05 \text{ degrees} = 3'$

$0.1 \text{ degrees} = 6'$

$1 \text{ degree} = 60'$