List of Equations

$$0°C = 273K$$

$$1\,psi = 6895\,Pa$$

$$1\,in^3 = 1.635\times10^{-5}\,m^3$$

absolute pressure = gauge pressure +101 kPa

$$\tau = \frac{Fl}{(2\pi/rev)\eta_s}$$

$$J = M\left(\frac{l}{(2\pi/rev)}\right)^2$$

$$l = (2\pi/rev)r_p$$

$$F_{out} = \frac{\tau_{in}}{r_p}\eta_{rp}$$

$$\tau_{out} = F_{in}r_p\eta_{rp}$$

$$J = Mr_p^2$$

$$\omega_{out} = \frac{1}{N_r}\omega_{in}$$

$$\dot{\omega}_{out} = \frac{1}{N_r}\dot{\omega}_{in}$$

$$\tau_{out} = N_r\tau_{in}\eta_g$$

$$\tau_{motor} = J_{motor}\dot{\omega}_{motor} + \tau_{reflected}$$
$$= \left(J_{motor} + \frac{1}{N_r^{\,2}}J_{load}\right)\dot{\omega}_{motor} + \frac{1}{N_r}\tau_{external}$$

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

$$J\dot{\omega} = K_t i_a - K_d\omega - \tau_{load}$$

$$\eta_{motor} = \frac{\text{mechanical power output}}{\text{electrical power input}}$$

$$N_{r,opt} = \sqrt{\frac{J_{load}}{J_{motor}}}$$

$$Ratio_J = \frac{J_{load}/N_r^{\,2}}{J_{motor}}$$

For $t_i \le t \le (t_i + \frac{1}{2}t_{move})$:

$x(t) = \frac{1}{2}a_{con}(t-t_i)^2 + x_i$, $v(t) = a_{con}(t-t_i)$ and

$a(t) = a_{con}$

For $(t_i + \frac{1}{2}t_{move}) < t \le (t_i + t_{move})$:

$x(t) = x_i + x_{move} - \frac{1}{2}a_{con}(t_i + t_{move} - t)^2$,

$v(t) = a_{con}\left(t_i + t_{move} - t\right)$ and

$a(t) = -a_{con}$

$$x_{move} = \tfrac{1}{4}a_{con}t_{move}^{\,2}$$

$$v_{\max} = \tfrac{1}{2}a_{con}t_{move}$$

$$\tau_{motor,RMS} = \sqrt{\sum_{i=1}^{n}\tau_{motor,i}^2 t_i \Big/ \sum_{i=1}^{n} t_i}$$

$$I_{RMS} = \sqrt{\sum_{i=1}^{n} I_i^2 t_i \Big/ \sum_{i=1}^{n} t_i}$$

$$I_{RMS} = \frac{\tau_{RMS}}{K_t}$$

$$P_j = I^2 R_{Hot}$$

$$R_{Hot} = R_{25}\left(1 + 0.00392(T_{Hot} - 25)\right)$$

$$T_w(t) = T_{initial} + \left(P_j R_{th} + T_a - T_{initial}\right)\left(1 - e^{\frac{-t}{\tau_w}}\right)$$

$$T_w = T_a + P_j R_{th}$$

$$F_{extend} = P_{extend}A_{extend} - P_{retract}A_{retract}$$

$$F_{retract} = P_{retract}A_{retract} - P_{extend}A_{extend}$$

$$v = \frac{Q}{A}$$

$$C_V = \left(4.22\times10^4\ m^{-2}\right)Q\sqrt{\frac{\rho}{\Delta P}}$$

$$Q = \left(2.37\times10^{-5}\ m^2\right)C_V\sqrt{\frac{\Delta P}{\rho}}$$

$$\rho = \frac{P_2}{R_g T} = \frac{P_1 - \Delta P}{R_g T}$$

$$R_g = 287\,J/kgK = 287\,m^2/s^2K$$