Accuracy = ± (max(abs(Y_{actual} - Y_{sensor}))+ $3\sigma_y$)

Linearity = ± (max(abs(Y_{actual} – Y_{sensor})))

Repeatability = ± $3\sigma_y$

$$A = \frac{\sum xy}{\sum x^2}$$

$$A = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{n\sum x^2 - \left(\sum x\right)^2}$$

$$B = \left(\sum y - A\sum x\right)/n$$

$$Y_{sensor} = \frac{Y_{volts}}{A}$$

$$Y_{sensor} = \frac{\left(Y_{volts} - B\right)}{A}$$

$$\frac{\Delta R}{R} = G\varepsilon$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$V_{in} = V_S\left(\frac{R_{in}}{R_{in} + R_S}\right)$$

If $R = \frac{XYZ}{P}$ then $\Delta R = |R|\left(\left|\frac{\Delta X}{X}\right| + \left|\frac{\Delta Y}{Y}\right| + \left|\frac{\Delta Z}{Z}\right| + \left|\frac{\Delta P}{P}\right|\right)$

If $R = X + Y - Z$ then

$$\Delta R = |\Delta X| + |\Delta Y| + |\Delta Z|$$

$$a_{ADC} = \pm\frac{V_{FS}}{2^{ENOB}}$$

$$\frac{Y_{out}(s)}{Y_{true}(s)} = \frac{K_s}{\tau_s s + 1}$$

$$\tau_s = 0.455 t_r$$

$$\tau_s = \frac{1}{\omega_b} = \frac{1}{2\pi f_b}$$

$$y_{out}(t) = y_{out}(0)e^{-\frac{t}{\tau_s}} + K_s\left(1 - e^{-\frac{t}{\tau_s}}\right)y_{true}$$

$$t \geq -\tau_s \ln\left(\frac{0.1|a_y|}{\max\left(y_{max} - y_{out}(0), y_{out}(0) - y_{min}\right)}\right)$$

$$\Delta y_{out}(t) = |a_y| + \max\left(y_{max} - y_{out}(0), y_{out}(0) - y_{min}\right)e^{-\frac{t}{\tau_s}}$$

$$\begin{aligned} y_{out}(t) &= A_{out}(\omega)\sin\left(\omega t + \phi(\omega)\right) \\ &= K_s M(\omega) A_{true}\sin\left(\omega t + \phi(\omega)\right) \end{aligned}$$

$$M(\omega) = \frac{1}{\sqrt{1 + \omega^2\tau_s^2}}$$

$$\phi(\omega) = -\tan^{-1}(\omega\tau_s)$$

$$t_d = -\frac{\phi}{\omega}$$

$$\Delta A_{out}(\omega) = |a_y| + \left(1 - \frac{1}{\sqrt{1 + \omega^2\tau_s^2}}\right)A_{out}(\omega)$$

$$v_{est}(kT) = \frac{p\left(kT\right) - p((k-1)T)}{T}$$

$$\Delta v_{est} = \frac{T}{2}\max\left(|a_{true}|\right) + \frac{2\Delta p}{T}$$

$$T_{opt} = \sqrt{\frac{4\Delta p}{\max\left(|a_{true}|\right)}}$$

$$\Delta v_{est} = \frac{T}{2}\max\left(|a_{true}|\right) + \frac{\text{encoder's position resolution}}{T}$$

$$\Delta v_{est} = \frac{T}{2}\max\left(|a_{true}|\right) + \frac{6\sigma_p}{T}$$

$$F = ma$$

$$\tau = J\alpha$$

$$0°C = 273K$$

$$1\,psi = 6895Pa$$

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

absolute pressure = gauge pressure +101 kPa

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

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

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

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

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

$$J = Mr_p^2$$

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

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

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

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

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

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

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

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

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

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 $(t_i + \frac{1}{2}t_{move}) < t \le (t_i + t_{move})$:
$x(t) = x_i + x_{move} - \frac{1}{2}a_{con}(t_i + t_{move} - t)^2$,
$v(t) = a_{con}\ \ t_i + t_{move} - t$ and
$a(t) = -a_{con}$

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

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

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

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

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

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

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

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

$$T_w = T_a + P_jR_{th}$$

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

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

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

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

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

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

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

$$F = kx$$

$$F = cv$$

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

$$i = C\frac{dV}{dt}$$

$$V = iR$$

$$P_1 - P_2 = RQ$$

$$Q_1 - Q_2 = C\frac{d(P_2 - P_1)}{dt}$$

$$C = \frac{A}{\rho g}$$

$$C = \frac{A^2}{k}$$

$$P_1 - P_2 = I\frac{dQ}{dt}$$

$$I = \frac{L\rho}{A}$$

$$P_1 - P_2 = R\dot{m}$$

$$\dot{m}_1 - \dot{m}_2 = C\frac{dP}{dt}$$

$$C = \frac{V}{R_g T}$$

$$P_1 - P_2 = I\frac{d\dot{m}}{dt}$$

$$I = \frac{L}{A}$$

$$T_1 - T_2 = Rq$$

$$R = \frac{L}{Ak}$$

$$R = \frac{1}{Ah}$$

$$q_1 - q_2 = C\frac{dT}{dt}$$

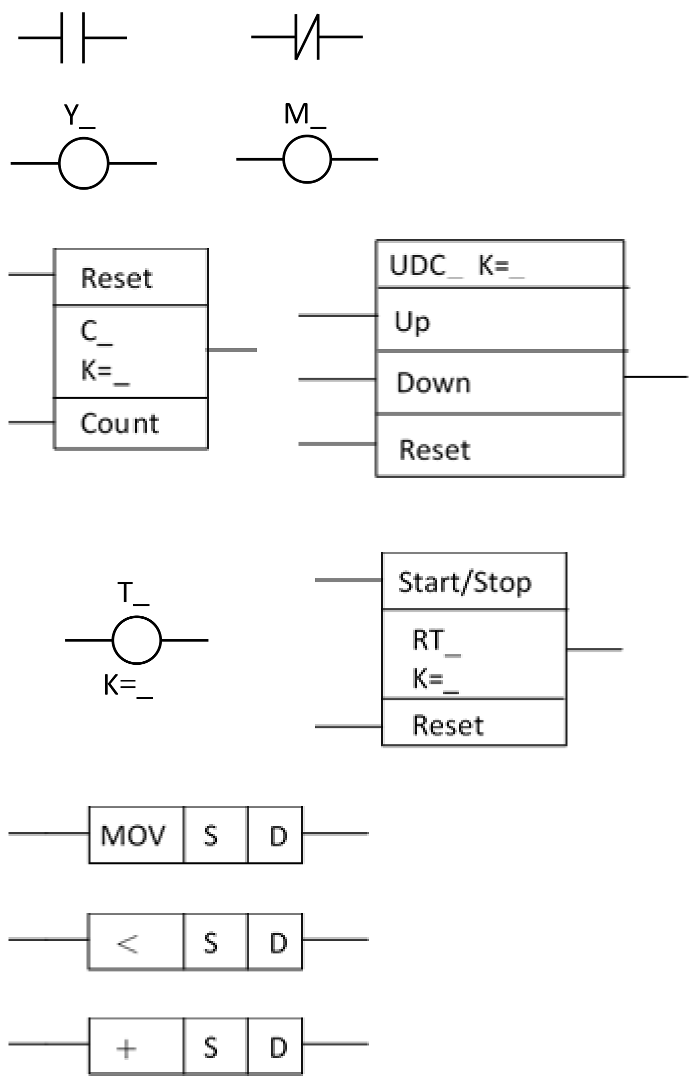
$$C = mc$$

$$\Delta y = \left(\left.\frac{\partial f}{\partial a}\right|_{a=a_0}\right)\Delta a + \left(\left.\frac{\partial f}{\partial b}\right|_{b=b_0}\right)\Delta b + \left(\left.\frac{\partial f}{\partial c}\right|_{c=c_0}\right)\Delta c + \ldots$$

Rules:

(1) Each rung must begin with an input instruction, or a series of input instructions, and end with an output instruction or a special instruction.

(2) Each output instruction should occur once in a program.



$$\frac{U(s)}{E(s)} = K_P(1+\frac{1}{s}K_I + sK_D)$$

$$\frac{U(z)}{E(z)} = K_P(1+K_I\frac{Tz}{z-1}+K_D\frac{z-1}{Tz})$$

<u>Stability Rules:</u>

1) The poles of H(z) must not lie outside the unit circle.

2) H(z) must contain as zeros all of the zeros of G(z) that lie outside the unit circle.

3) 1-H(z) must contain as zeros all of the poles of G(z) that lie outside the unit circle.

$$D(z) = \frac{U(z)}{E(z)} = \frac{1}{G(z)}\frac{H(z)}{1-H(z)}$$

$$e(\infty) = \sum_{i=1}^{n}\frac{T}{1-p_i} - \sum_{j=1}^{m}\frac{T}{1-q_j}$$

$$z = e^{Ts}$$

$$z = e^{aT+jbT} = e^{aT}\left(\cos(bT) + j\sin(bT)\right)$$