$$C(s) = K_p + \frac{K_i}{s} + \frac{K_d N s}{s+N}$$

Bilinear transform

$$s \rightarrow \frac{2(z-1)}{T(z+1)}$$

$$C(z) = K_p + \frac{K_i T(z+1)}{2(z-1)} + \frac{\frac{2K_d N}{T}\frac{(z-1)}{(z+1)}}{\frac{2(z-1)}{T(z+1)} + N}$$

$$C(z) = K_p + \frac{0.5K_i T(z+1)}{(z-1)} + \frac{2K_d N(z-1)}{2(z-1)+NT(z+1)}$$

$$U(z) = C(z)e(z) = \overbrace{K_p e(z)}^{u_p(z)} + \overbrace{\frac{0.5K_i T(z+1)}{(z-1)} e(z)}^{u_i(z)} + \overbrace{\frac{2K_d N(z-1)}{2(z-1)+NT(z+1)} e(z)}^{u_d(z)}$$

$$U(z) = U_p(z) + U_i(z) + U_d(z)$$

$$U_p(z) = K_p e(z) \longrightarrow \boxed{U_p(k) = K_p e(k)} \quad *$$

$$2z - 2 + NTz + NT$$
$$(2+NT)z - 2 + NT$$

$$U_i(z) = \frac{0.5K_i T(1+z^{-1})}{1-z^{-1}} e(z)$$

$$U_i(z) - z^{-1}U_i(z) = 0.5K_i T(e(z) + z^{-1}e(z))$$

$$u_i(k) - u_i(k-1) = 0.5K_i T(e(k) + e(k-1))$$

$$\boxed{u_i(k) = u_i(k-1) + 0.5K_i T(e(k) + e(k-1))} \quad *$$

$$u_d(z) = \frac{2K_d N(e(z) - z^{-1}e(z))}{(2+NT) + (NT-2)z^{-1}}$$

$$(2+NT)u_d(z) + (NT-2)z^{-1}u_d(z) = 2K_d N(e(z) - z^{-1}e(z))$$

$$\boxed{u_d(k) = -\frac{(NT-2)}{2+NT}u_d(k-1) + \frac{2K_d N}{2+NT}(e(k) - e(k-1))} \quad *$$