

$$-\frac{(2K_d(pos-prevpos)+(2*\tau-T)diff)}{2*\tau*T}$$

$$P+I\frac{T_s}{2}\frac{z+1}{z-1}+D\frac{N}{1+N\frac{T_s}{2}\frac{z+1}{z-1}}$$

$$P+I\frac{T_s}{2}\left(\frac{z}{z-1}+\frac{1}{z-1}\right)+D\frac{2}{T_s}\frac{1}{\frac{2}{NT_s}+\frac{z+1}{z-1}}$$

$$P+I\frac{T_s}{2}\left(\frac{z}{z-1}+\frac{1}{z-1}\right)+D\frac{2}{T_s}\frac{1}{\frac{2(z-1)+NT_s(z+1)}{NT_s(z-1)}}$$

$$P+I\frac{T_s}{2}\left(\frac{z}{z-1}+\frac{1}{z-1}\right)+D\frac{2}{T_s}\frac{NT_s(z-1)}{2(z-1)+NT_s(z+1)}$$

$$P+I\frac{T_s}{2}\left(\frac{z}{z-1}+\frac{1}{z-1}\right)+D2N\frac{(z-1)}{2(z-1)+NT_s(z+1)}$$

$$P+I\frac{T_s}{2}\left(\frac{z}{z-1}+\frac{1}{z-1}\right)+D2N\frac{(z-1)}{2(z-1)+NT_s(z+1)}$$

P

$$u_p(z)=Pe(z)$$

$$u_p(kT+t)=Pe(kT+T)$$

I

$$u_i(z)=I\frac{T}{2}\frac{z+1}{z-1}e(z)$$

$$u_i(z)(z-1)=I\frac{T}{2}(z+1)e(z)$$

$$u_i(z)(1-z^{-1})=I\frac{T}{2}(1+z^{-1})e(z)$$

$$u_i(kT+T)-u_i(kT)=I\frac{T}{2}(e(kT+T)+e(kT))$$

$$u_i(kT+T)=I\frac{T}{2}(e(kT+T)+e(kT))+u_i(kT)$$

D

$$u_d(z) = D \frac{N}{1 + N \frac{T}{2} \frac{z+1}{z-1}} e(z)$$

$$u_d(z) \left(1 + N \frac{T}{2} \frac{z+1}{z-1} \right) = DN e(z)$$

$$u_d(z) \left(z - 1 + N \frac{T}{2} (z+1) \right) = DN (z-1) e(z)$$

$$u_d(z) \left(z - 1 + N \frac{T}{2} z + N \frac{T}{2} \right) = DN (z-1) e(z)$$

$$u_d(z) \left(z \left(1 + N \frac{T}{2} \right) + N \frac{T}{2} - 1 \right) = DN (z-1) e(z)$$

$$u_d(z) \left(\left(1 + N \frac{T}{2} \right) + \left(N \frac{T}{2} - 1 \right) z^{-1} \right) = DN (1 - z^{-1}) e(z)$$

$$u_d(kT + T) \left(1 + N \frac{T}{2} \right) + u_d(kT) \left(N \frac{T}{2} - 1 \right) = DN (e(kT + T) - e(kT))$$

$$u_d(kT + T) \left(1 + N \frac{T}{2} \right) = DN (e(kT + T) - e(kT)) - u_d(kT) \left(N \frac{T}{2} - 1 \right)$$

$$u_d(kT + T) = \frac{DN (e(kT + T) - e(kT)) - u_d(kT) (N \frac{T}{2} - 1)}{1 + N \frac{T}{2}}$$

$$u_d(kT + T) = \frac{2DN (e(kT + T) - e(kT)) - u_d(kT) (NT - 2)}{1 + NT}$$