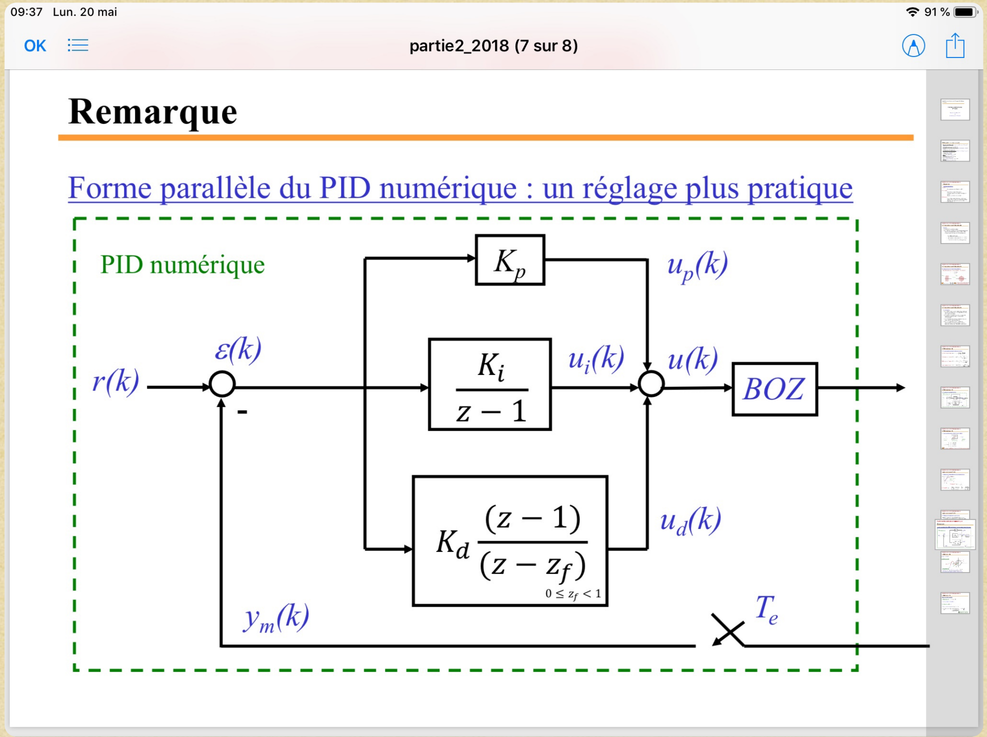

PID structure

$$u_p(k) = K_p\,\varepsilon(k)$$

$$U_i(z) / \varepsilon(z) = K_i / (z-1) = \frac{K_i z^{-1}}{1 - z^{-1}} = \frac{U_i(z)}{\varepsilon(z)}$$

$$\Rightarrow K_i\,\varepsilon(k-1) = u_i(k) - u_i(k-1)$$

$$\Rightarrow u_i(k) = u_i(k-1) + K_i\,\varepsilon(k-1)$$

Rem: for forward Euler approximation of the integral:

$$u_i(k) = u_i(k-1) + K_i\,\varepsilon(k)$$

$$\frac{U_d(z)}{\varepsilon(z)} = K_d \frac{(1-z^{-1})}{1-f z^{-1}} \qquad (zf = f)$$

$$u_d(k) - f u_d(k-1) = K_d\left(\varepsilon(k) - \varepsilon(k-1)\right)$$

$$u_d(k) = f u_d(k-1) + K_d\left(\varepsilon(k) - \varepsilon(k-1)\right)$$

$$\Rightarrow u_0(k) = u_p(k) + u_i(k) + u_d(k)$$

$$\text{If } |u_0(k)| > Sat \Rightarrow \bar{u}_i(k) = u_i(k-1)$$

$$\text{If } |u_0(k)| \leq Sat \Rightarrow \bar{u}_i(k) = u_i(k)$$

$$u(k) = u_p(k) + \bar{u}_i(k) + u_d(k)$$