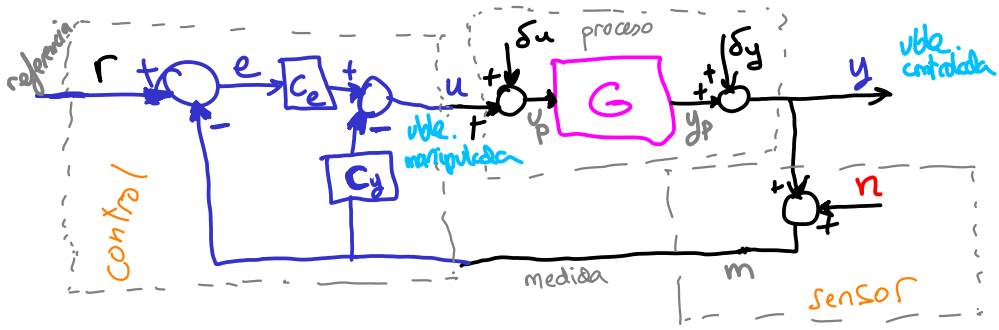

$y = G\cdot(u+\delta_u)+\delta_y$ (proceso)

$m = y+n$ (sensor)

$u = C_e\cdot e - C_y\cdot m$ (control)

$e = (r-m)$

4 ecuaciones
4 incógnitas: y, u, m, e
entradas: r, δ_u, δ_y, n
datos "constantes": G, C_e, C_y

$$y = G\cdot(u+\delta_u)+\delta_y = G\cdot(C_e e - C_y m + \delta_u)+\delta_y =$$

$$= G\cdot(C_e(r-(y+n)) - C_y(y+n)+\delta_u)+\delta_y =$$

$$= GC_e r - GC_e y - GC_e n - GC_y y - GC_y n + G\delta_u + \delta_y$$

$$(1+GC_e+GC_y)\,y = GC_e r - G(C_e+C_y)n + G\delta_u + \delta_y$$

$$y = \frac{GC_e}{(1+GC_e+GC_y)}r + \frac{-G(C_e+C_y)}{(1+GC_e+GC_y)}n + \frac{G}{(1+GC_e+GC_y)}\delta_u + \frac{1}{(1+GC_e+GC_y)}\delta_y$$

Video: https://personales.upv.es/asala/DocenciaOnline/Video/c2glblk.html

$y = G\cdot(u+\delta_u)+\delta_y$ (proceso)

$m = y+n$ (sensor)

$u = C_e\cdot e - C_y\cdot m$ (control)

$e = (r-m)$

$$e = r-(y+n) = r-\left(n+G(u+\delta_u)+\delta_y\right) = r-(n+G(C_e e - C_y m + \delta_u)+\delta_y) =$$

($r-e$)

$$= r-n-\delta_y - GC_e e + GC_y r - GC_y e - G\delta_u$$

$$(1+GC_e+GC_y)\,e = (1+GC_y)\,r - n - \delta_y - G\delta_u$$

$$e = \frac{1}{(1+GC_e+GC_y)}\cdot\left((1+GC_y)r - n - \delta_y - G\delta_u\right)$$

Control block-diagram [2DoF] simplification

```
syms G C_e C_y y u du r e u_PI dy m n e_true
EcsBC= [y==G*(u+du)+dy;
        m==y+n;
        u==C_e*e-C_y*m;
        e==r-m;
        e_true==r-y];
sol=solve(EcsBC,{y,u,m,e,e_true});
vars=[r,du,dy,n];
collect(sol.y,vars)
```

ans =

$$\frac{C_e G}{C_e G + C_y G + 1} r + \frac{G}{C_e G + C_y G + 1} \mathrm{du} + \frac{\mathrm{dy}}{C_e G + C_y G + 1} + \left(-\frac{C_e G + C_y G}{C_e G + C_y G + 1}\right) n$$

```
collect(sol.e,vars)
```

ans =

$$\frac{C_y G + 1}{C_e G + C_y G + 1} r + \left(-\frac{G}{C_e G + C_y G + 1}\right) \mathrm{du} + \left(-\frac{1}{C_e G + C_y G + 1}\right) \mathrm{dy} + \left(-\frac{1}{C_e G + C_y G + 1}\right) n$$

```
collect(sol.u,vars)
```

ans =

$$\frac{C_e}{C_e G + C_y G + 1} r + \left(-\frac{C_e G + C_y G}{C_e G + C_y G + 1}\right) \mathrm{du} + \left(-\frac{C_e + C_y}{C_e G + C_y G + 1}\right) \mathrm{dy} + \left(-\frac{C_e + C_y}{C_e G + C_y G + 1}\right) n$$

```
collect(sol.e_true,vars)
```

ans =

$$\frac{C_y G + 1}{C_e G + C_y G + 1} r + \left(-\frac{G}{C_e G + C_y G + 1}\right) \mathrm{du} + \left(-\frac{1}{C_e G + C_y G + 1}\right) \mathrm{dy} + \frac{C_e G + C_y G}{C_e G + C_y G + 1} n$$