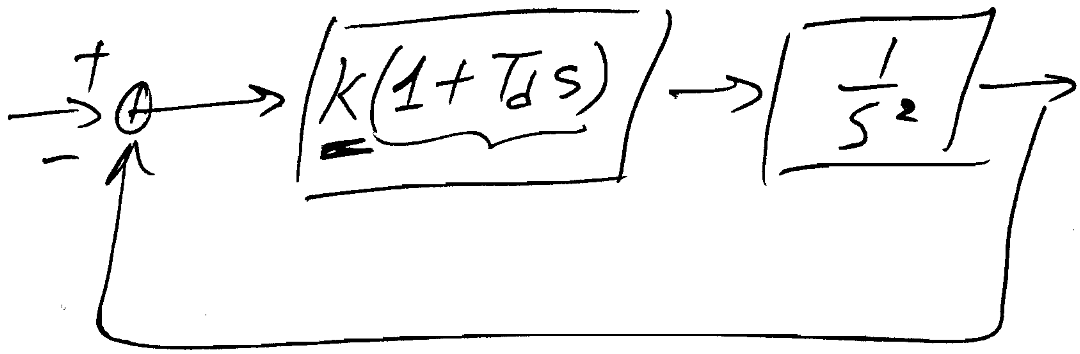
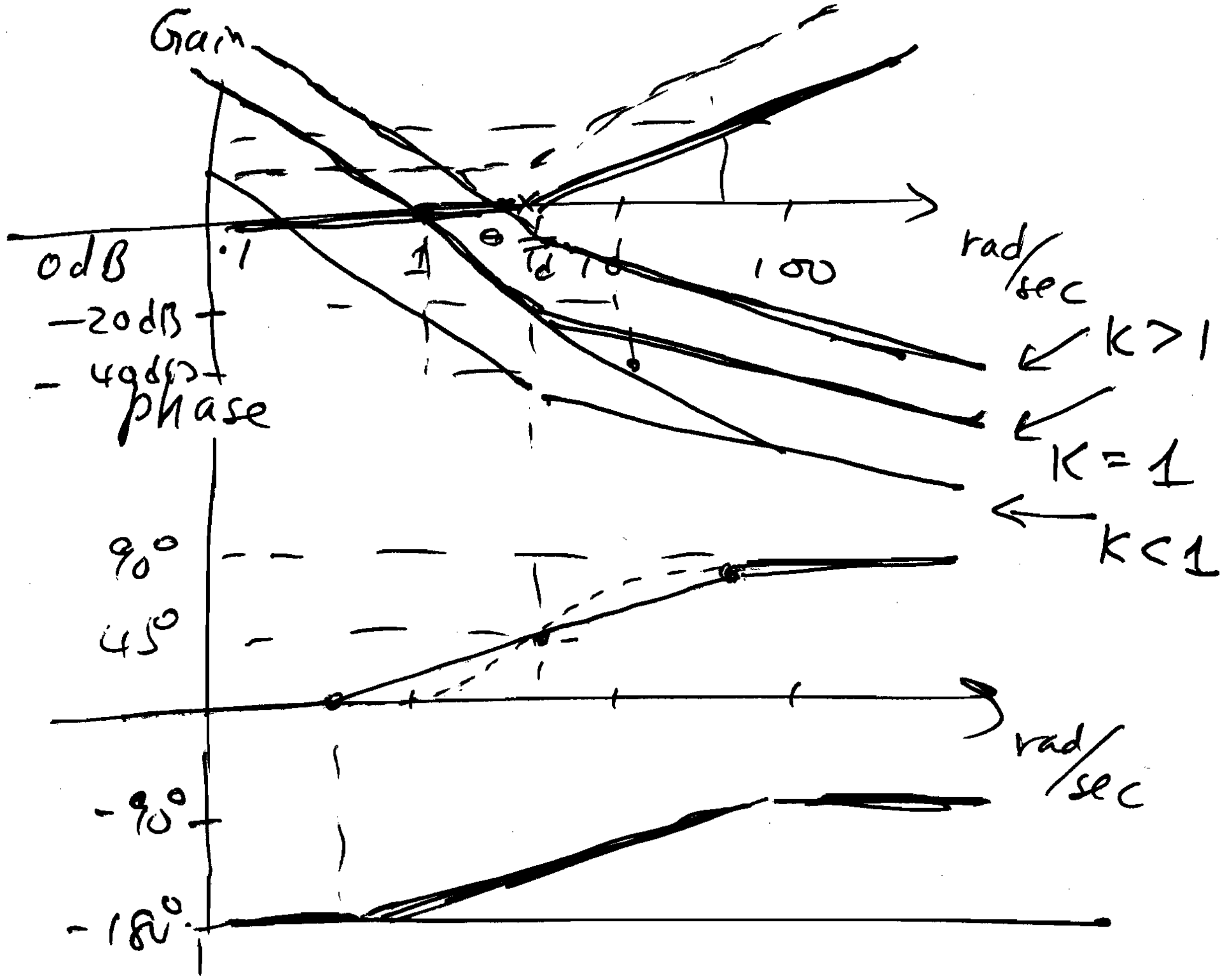
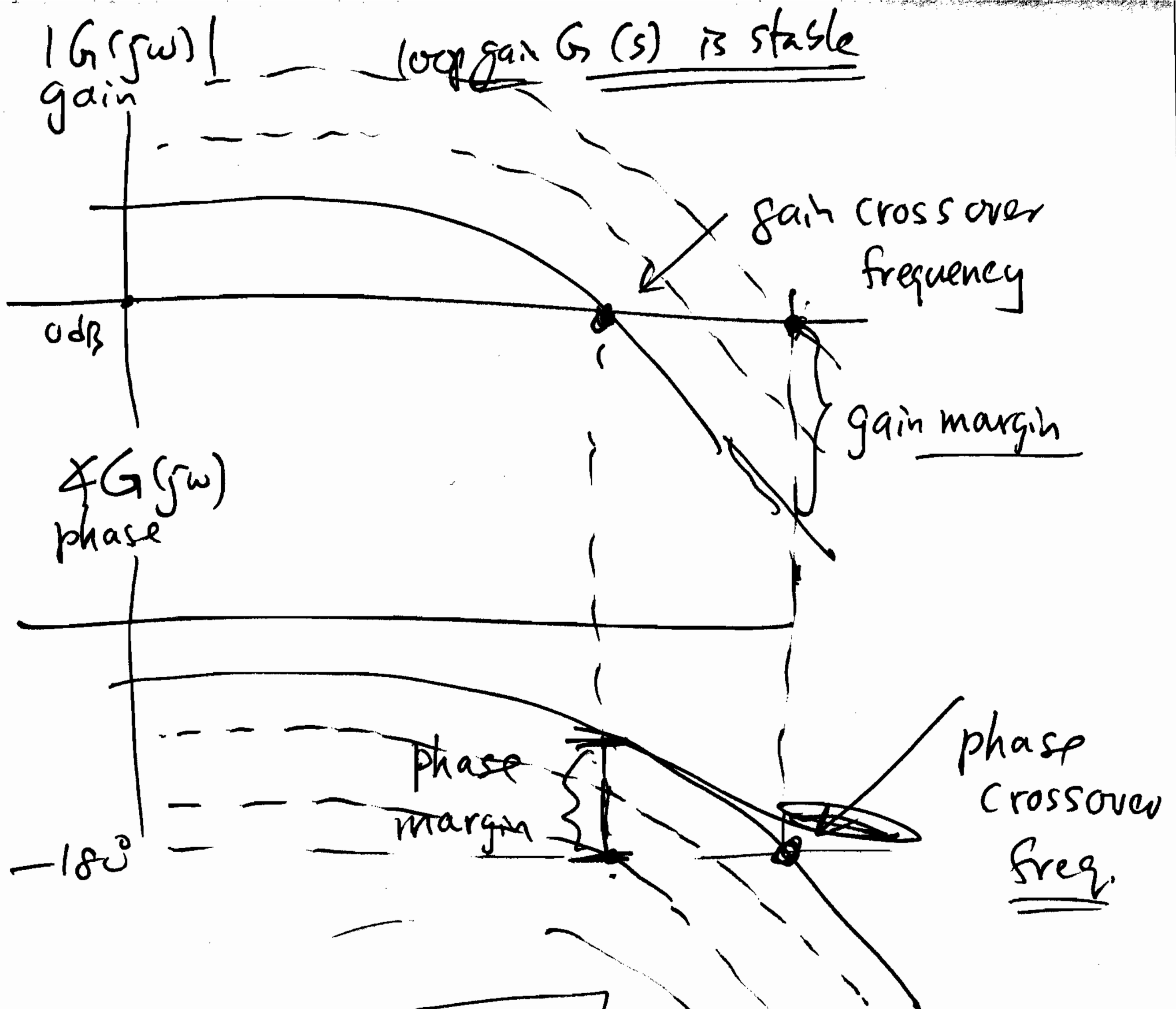
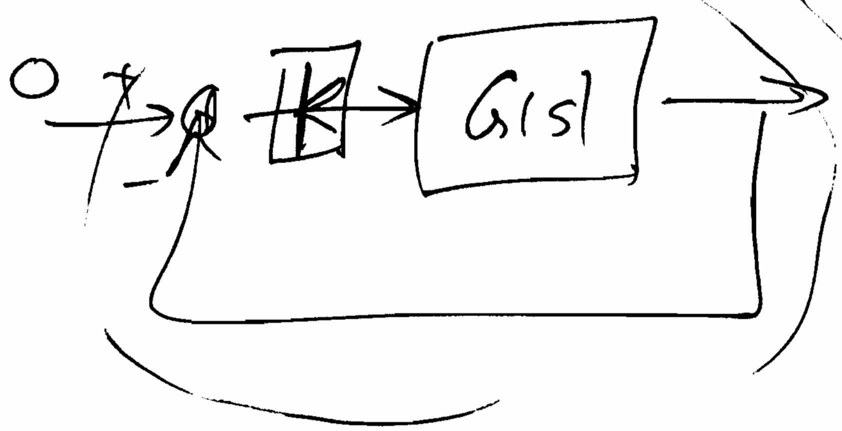
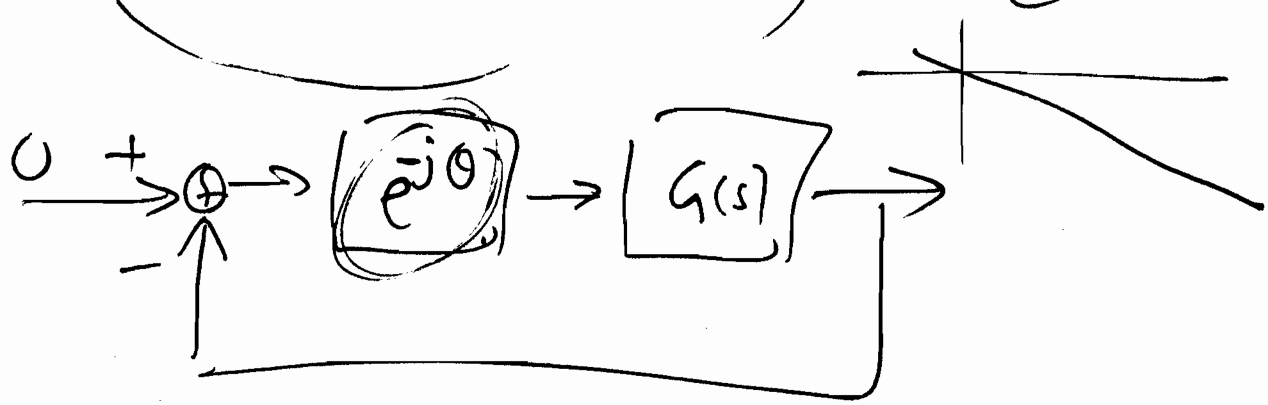

+
−
K(1+Td s)
1/s²

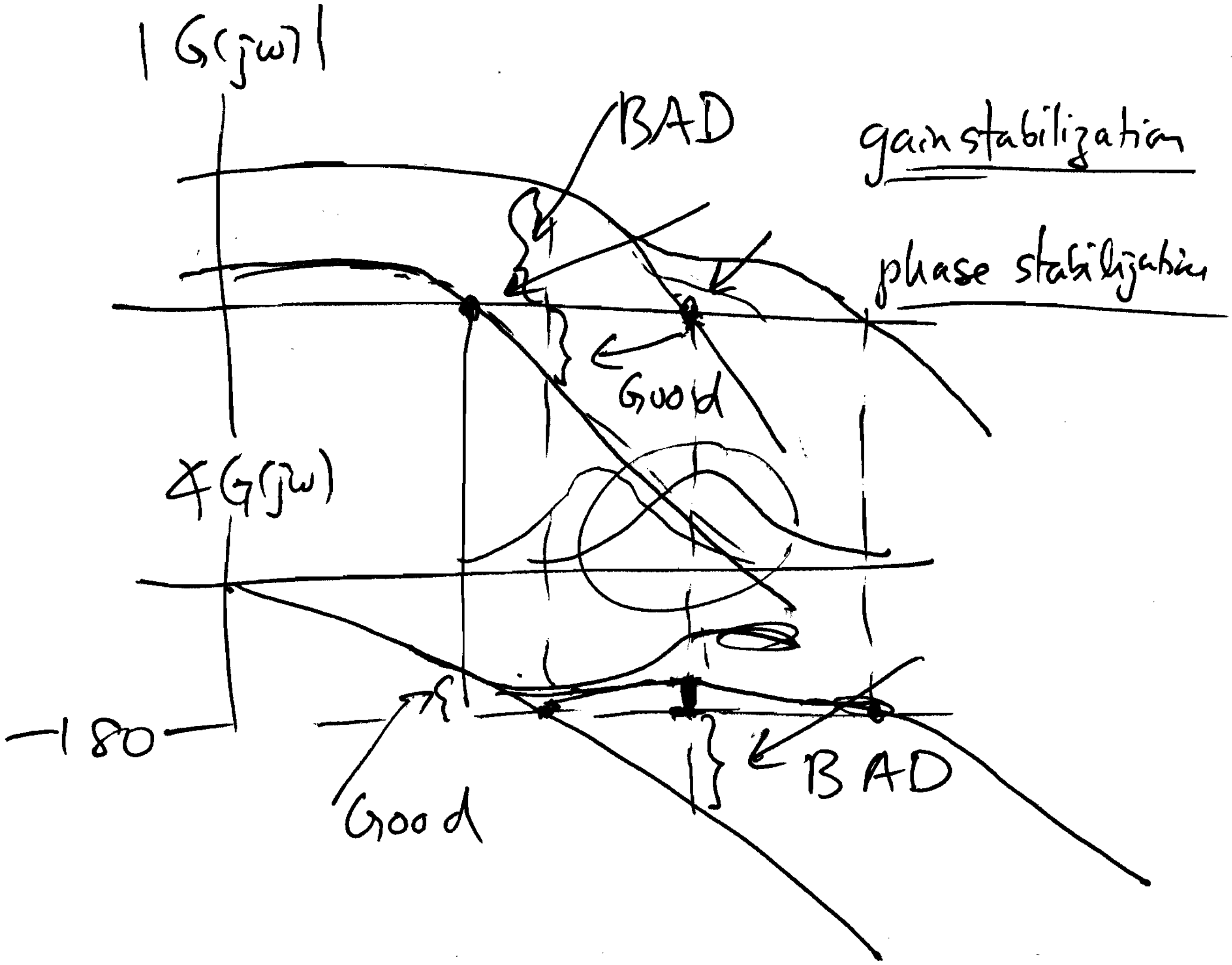

Gain
0dB
.1
1
1/Td
10
100
rad/sec
−20dB
−40dB
K>1
K=1
K<1
phase
90°
45°
rad/sec
−90°
−180°

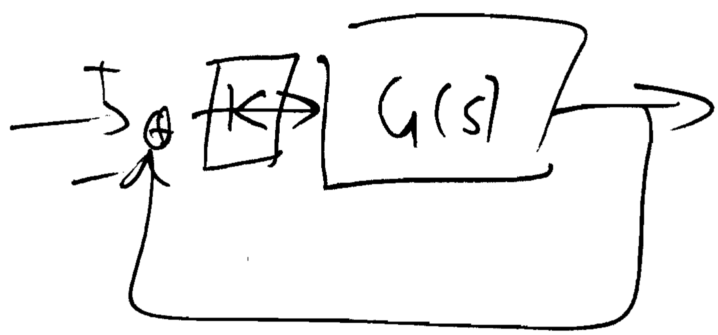

$|G(j\omega)|$
gain
loop gain G(s) is stable
gain crossover frequency
0dB
gain margin
$\angle G(j\omega)$
phase
phase margin
phase crossover freq.
$-180°$


0
+
−
K
G(s)

$e^{-j\omega T_d}$


0
+
−
$e^{-j\theta}$
G(s)


|G(jω)|
BAD
gain stabilization
phase stabilization
Good
∡G(jω)
-180
Good
BAD


K
G(s)

$$G(s) = \frac{b_1 s + b_0}{s^2 + a_1 s + a_0}$$

$$y = G(s)u \longleftrightarrow \underline{\ddot{y} + a_1 \dot{y} + a_0 y = b_1 \dot{u} + b_0 u}$$

$$y(s) = \frac{n(s)}{d(s)} \overbrace{u}^{\xi}$$

$$\underbrace{\xi(s) = \frac{u(s)}{d(s)}} \qquad y(s) = n(s)\,\xi(s)$$

$$\xi = \frac{u}{s^2 + a_1 s + a_0} \qquad y = (b_1 s + b_0)\,\xi$$

$$\updownarrow$$

$$\boxed{\ddot{\xi} + a_1 \dot{\xi} + a_0 \xi = u}$$

$$\begin{cases} x_1 = \xi \\ x_2 = \dot{\xi} \end{cases} \qquad \begin{aligned} \dot{x}_1 &= \dot{\xi} = x_2 \\ \dot{x}_2 &= \ddot{\xi} = -a_0 \xi - a_1 \dot{\xi} + u \\ &= -a_0 x_1 - a_1 x_2 + u \end{aligned}$$

$$\underbrace{\frac{d}{dt}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}}_{\substack{\text{state} \\ x}} = \underbrace{\begin{bmatrix} 0 & 1 \\ -a_0 & -a_1 \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}}_{x} + \underbrace{\begin{bmatrix} 0 \\ 1 \end{bmatrix}}_{B} u$$

state equation

$$\dot{x} = Ax + Bu$$

$$y = b_1 \dot{\xi} + b_0 \xi$$

$$= b_0 x_1 + b_1 x_2$$

$$= \underbrace{\begin{bmatrix} b_0 & b_1 \end{bmatrix}}_{C} \underbrace{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}}_{x}$$

What if $y = b_2 \ddot{\xi} + \underbrace{b_1 \dot{\xi} + b_0 \xi}_{b_1 x_2 + b_0 x_1}$?

$$= b_2 \dot{x}_2 = b_2 \left(-a_0 x_1 - a_1 x_2 + u\right)$$

$$y = (b_0 - a_0 b_2)\, x_1 + (b_1 - a_1 b_2)\, x_2 + b_2 u$$

$$y = \underbrace{\begin{bmatrix} b_0 - a_0 b_2 & b_1 - a_1 b_2 \end{bmatrix}}_{C} \underbrace{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}}_{x} + \underbrace{b_2}_{D} u$$

$$\dot{x} = A x + B u \qquad x(0) = x_0 = \underline{\underline{\begin{bmatrix} \xi(0) \\ \dot{\xi}(0) \end{bmatrix}}}$$

$$y = C x + D u$$