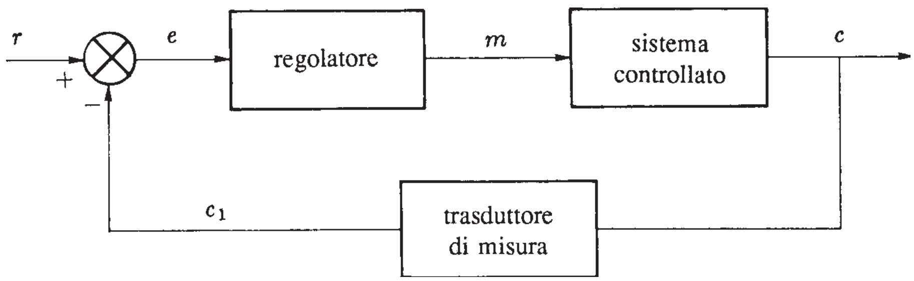
Standard PID regulators

• Block diagram of a feedback control:



• In the control of many industrial processes the dynamic characteristics of the controlled systems can vary within wide limits: it is economically convenient to unify the control devices.

• Typically, standard control apparatuses are used, but provided with correction devices with adjustable parameters within wide limits, so that they can be adapted to the particular regulation system in which they are inserted.

• Place $G_c(s) = M(s)/E(s)$, we distinguish the following standard types:

1. *Proportional regulator* (P):

$$G_c(s) = K_p \; ;$$

2. *Integral regulator* (I):

$$G_c(s) = \frac{K_p}{T_i\, s} \; ;$$

3. *Proportional-integral regulator* (PI):

$$G_c(s) = K_p\left(1 + \frac{1}{T_i\, s}\right) \; ;$$

4. *Proportional-derivative regulator* (PD):

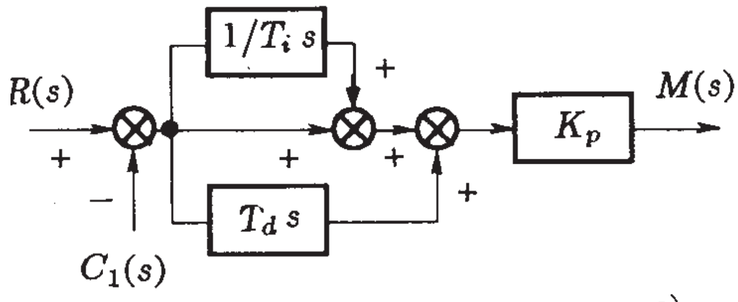
$$G_c(s) = K_p\,(1 + T_d\, s) \; ;$$

5. *Proportional-integral-derivative regulator* (PID):

$$G_c(s) = K_p\left(1 + T_d\, s + \frac{1}{T_i\, s}\right) .$$

The constant K_p is called *sensitivity to proportional* /, T_d*derivative time constant* /, T_i*time constant of the integral action* /.

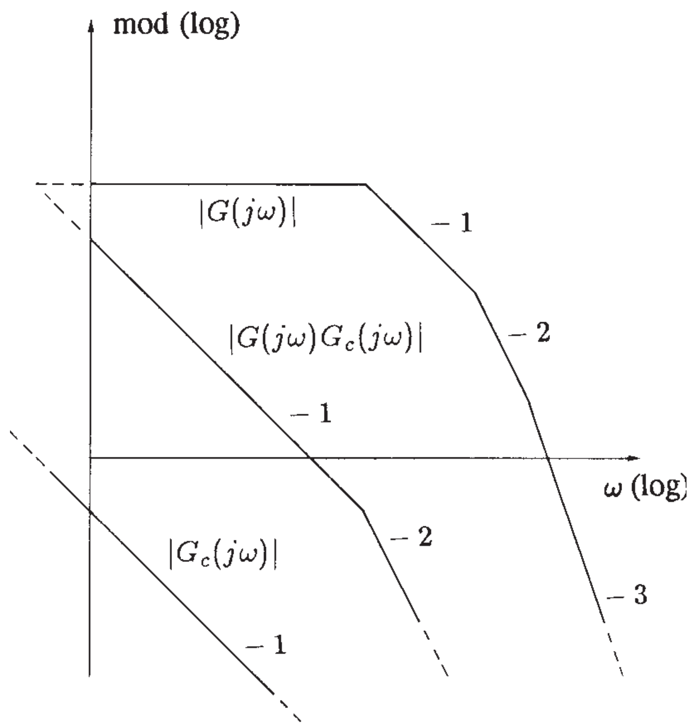
• General structure of the PID regulator:



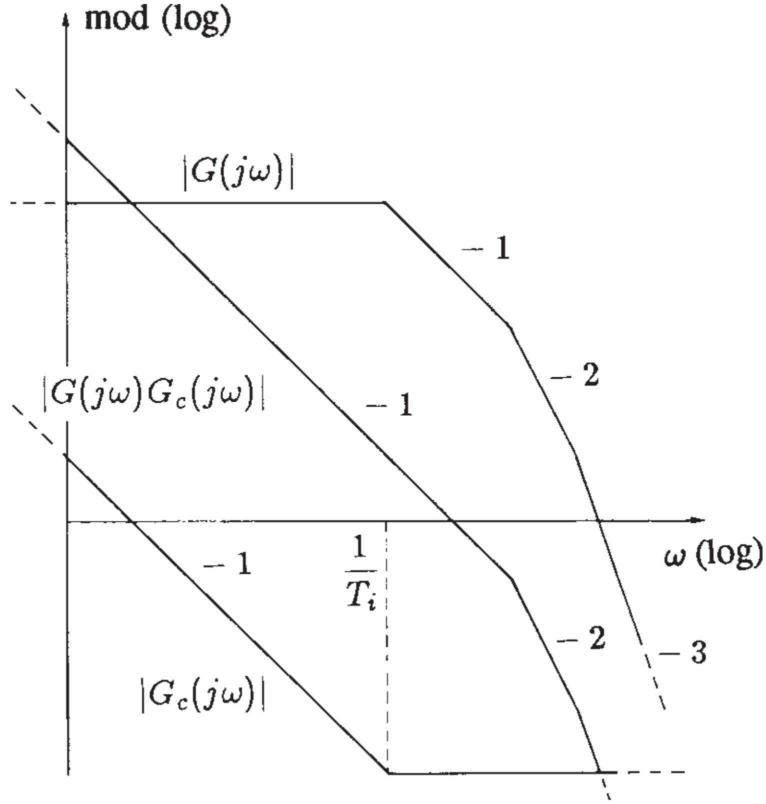
For what concerns the relative advantages and the particularity of use of the various types of regulators previously mentioned, similar considerations apply to those developed for the corrector networks.

• The P regulator is used when the process allows a high ring gain constant without compromising stability, such as systems having the dynamic behavior of a integrator (for example controlling a level by varying a flow) or characterized by the presence of a single predominant time constant.

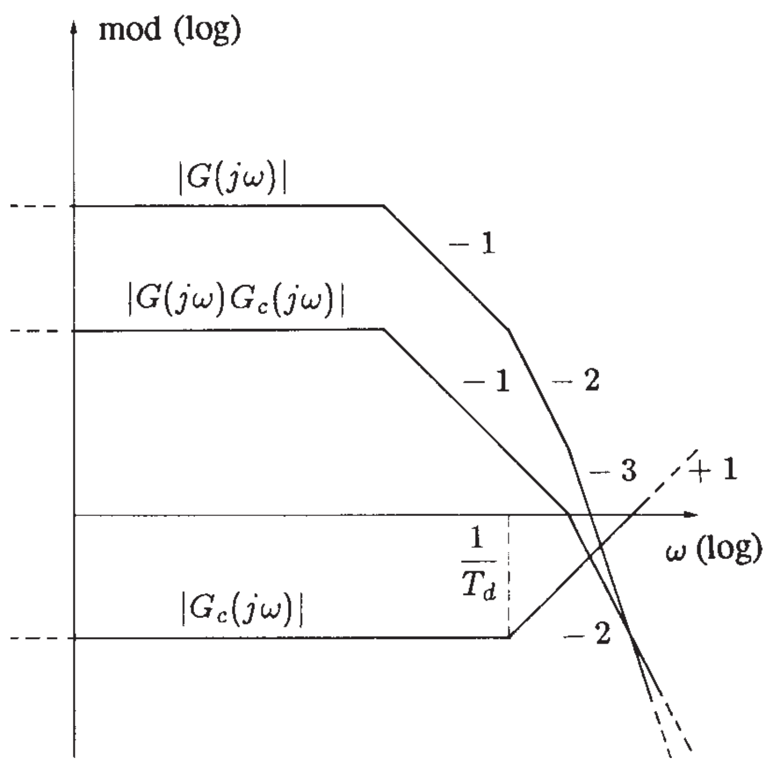
• The I regulator is used for systems of type 0 difficult to stabilize and for systems with dominant ending delays: in this last case a P regulator can not be used because it corresponds to an error at unacceptable regime, while an integral control guarantees a stable behavior with null static error.



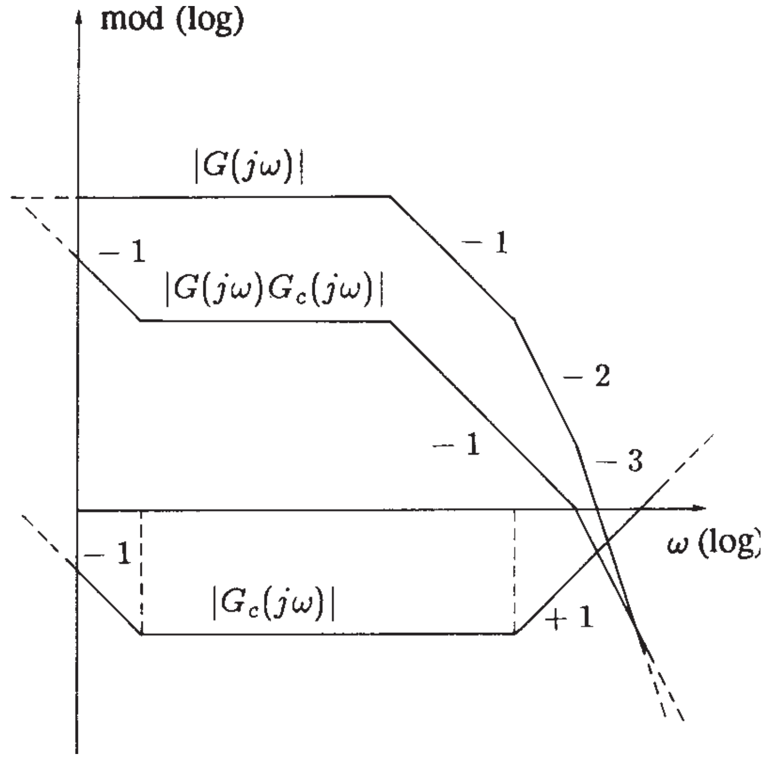
• The PI regulator compared to the I regulator allows to keep a greater bandwidth and therefore a greater promptness of response.



• The PD regulator is used instead for intrinsically type 1 systems or for type 0 systems to improve the response speed: its intervention is completely analogous to that of an anticipating network.



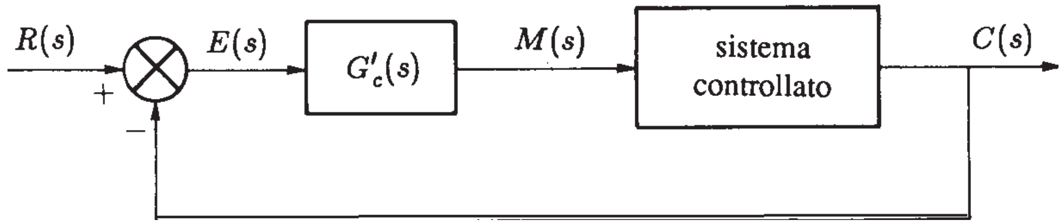
• The PID regulator can be used, as an alternative to the PD, for type 0 systems and has the advantage of allowing, in addition to a good response speed, also a null static error.



The triple action regulator is therefore the most general: by appropriately choosing the values of the three parameters that characterize its dynamic behavior, it is possible to obtain, as special cases, the actions of all the types of regulators previously taken into consideration.

Calibration of standard regulators

Many industrial systems (eg chemical and petrochemical) are characterized by strongly nonlinear models. In these cases the choice of the parameters of the regulators is carried out in many cases with semiempirical methods.

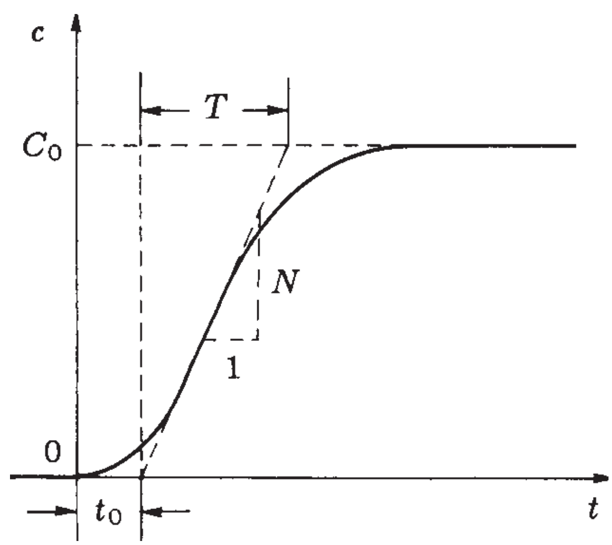


Ziegler-Nichols method

It provides the values of the first attempt of the parameters of the regulator according to some parameters of the step response (often aperiodic) of the controlled system.

The physical system can be approximated with a system of the first order:

$$G(s) \simeq \frac{K\, e^{-t_0 s}}{1 + T\, s}$$



The values of the characteristic parameters are obtained from the curve of response to the step at the inflection point:

-t_0 : time lag;

-T : constant of time;

-$R := t_0/T = N\, t_0/C_0$: delay report;

-$N := C_0/T$: response speed;

-$K := C_0/M_0$: static gain (M_0 is the width of the step applied).

Place $G'_c(s) = M(s)/E(s)$, the parameter values recommended by Ziegler and Nichols, modified by Cohen and Coon, are:

1. P control :
$$G'_c(s) = K'_p \,, \quad \text{con} \quad K'_p = \frac{M_0}{N\,t_0}\left(1 + \frac{R}{3}\right) \;;$$
2. Check I :
$$G'_c(s) = \frac{K'_p}{T_i\,s} \,, \quad \text{con} \quad \frac{K'_p}{T_i} = \frac{4\,M_0}{N\,t_0^2}\,\frac{R^2}{1 + 5\,R} \;;$$
3. Control PI :
$$G'_c(s) = K'_p\left(1 + \frac{1}{T_i\,s}\right) \,, \quad \text{con}$$
$$K'_p = \frac{M_0}{N\,t_0}\left(\frac{9}{10} + \frac{R}{12}\right) \,, \quad T_i = t_0\,\frac{30 + 3\,R}{9 + 20\,R} \;;$$
4. Check PD :
$$G'_c(s) = K'_p\,(1 + T_d\,s) \,, \quad \text{con}$$
$$K'_p = \frac{M_0}{N\,t_0}\left(\frac{5}{4} + \frac{R}{6}\right) \,, \quad T_d = t_0\,\frac{6 - 2\,R}{22 + 3\,R} \;;$$
5. Controllo PID :
$$G'_c(s) = K'_p\left(1 + \frac{1}{T_i\,s} + T_d\,s\right) \,, \quad \text{con}$$
$$K'_p = \frac{M_0}{N\,t_0}\left(\frac{4}{3} + \frac{R}{4}\right) \,, \quad T_i = t_0\,\frac{32 + 6\,R}{13 + 8\,R} \,, \quad T_d = t_0\,\frac{4}{11 + 2\,R} \,.$$

Proportional pendulum band method

The proportional pendulum band is defined as the value of the proportional band $1/K_0$ which, in the absence of integral and derivative actions, brings the regulating system into a condition of limit stability, that is in permanent oscillation. In this condition the oscillation period T_0 is determined and the following formulas are applied, also due to Ziegler and Nichols:

1. Check P : $K'_p = 0,5\,K_0$;
2. Control PI : $K'_p = 0,45\,K_0$, $T_i = 0,85\,T_0$;
3. Check PD : $K'_p = 0,5\,K_0$, $T_d = 0,2\,T_0$;
4. PID check: $K'_p = 0,6\,K_0$, $T_i = 0,5\,T_0$, $T_d = 0,12\,T_0$.