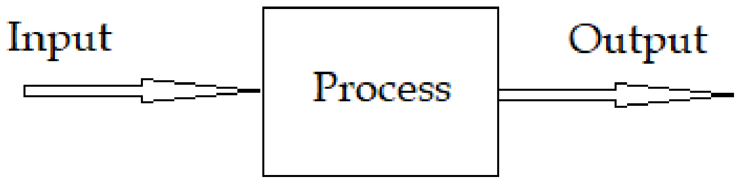
Elements of Control Theory

03 X 2017

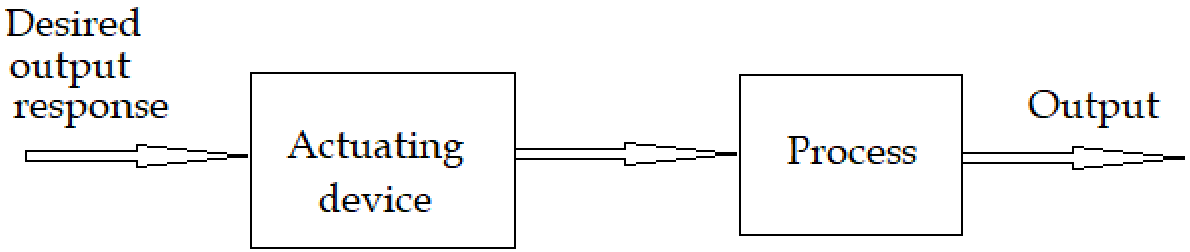
Riga, Latvia

Terminology

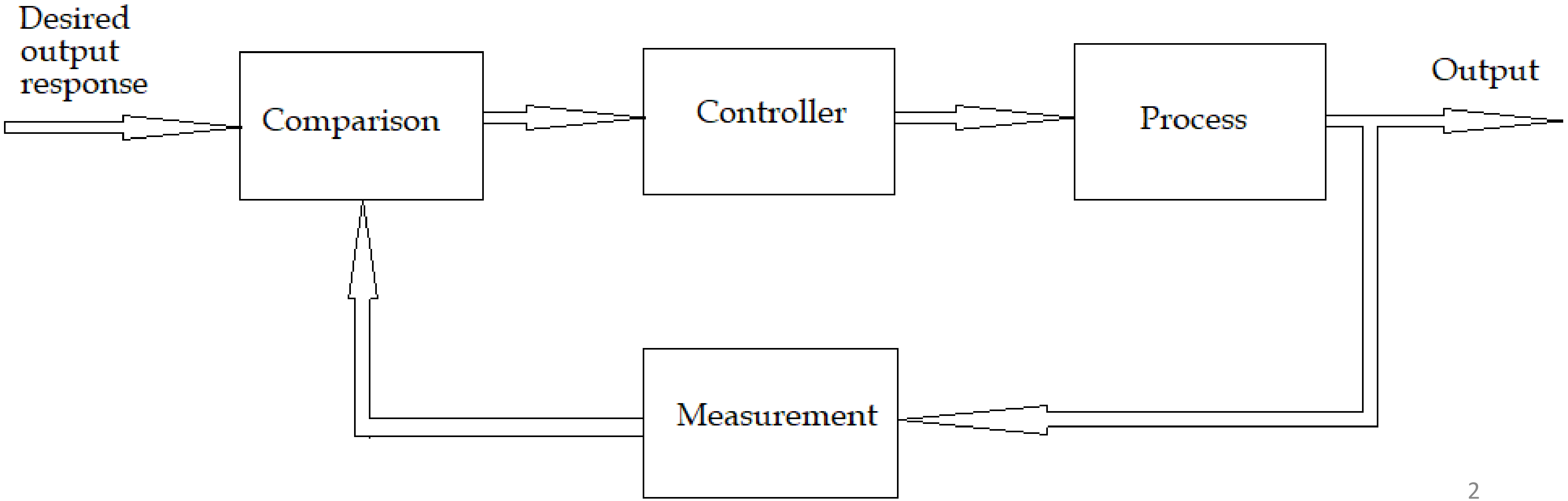
- System
- Control system



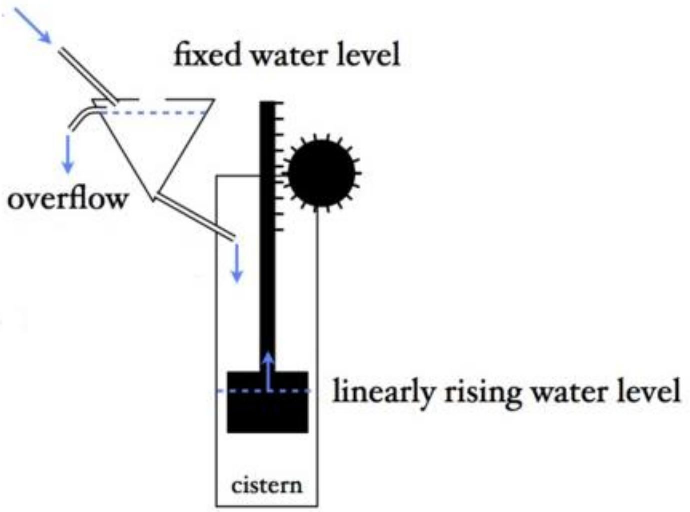
- Open-loop system



- Closed-loop system



Historical overview



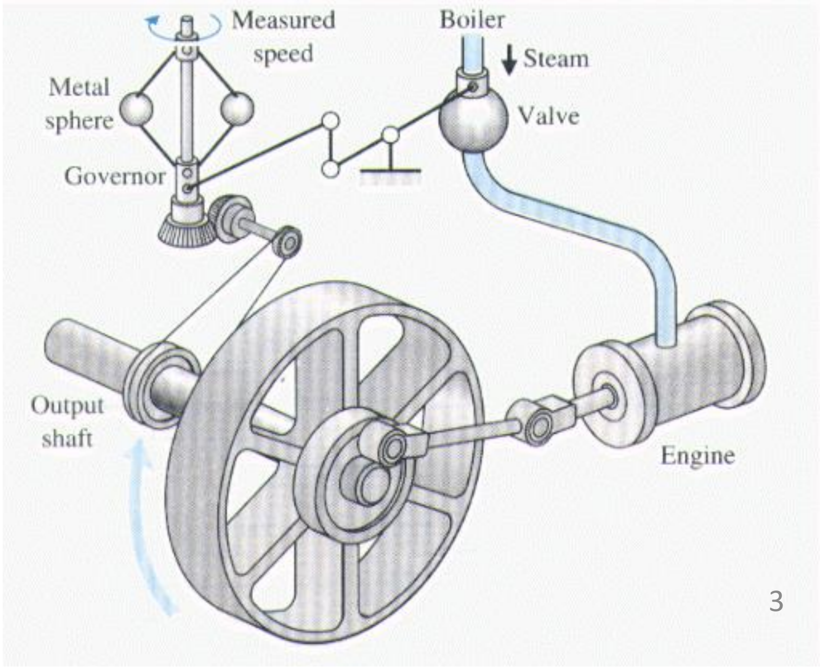
- 300 to 1 b.c. – float regulator mechanism in Greece
- 1st feedback system in modern Europe – temperature regulator (Holland, ~1620), pressure regulator (1681)
- I.Polzunov (1765, steam engine) –

- water-level float regulator
- 1769 – James Watt – flyball governor –

  the first control of steam engine

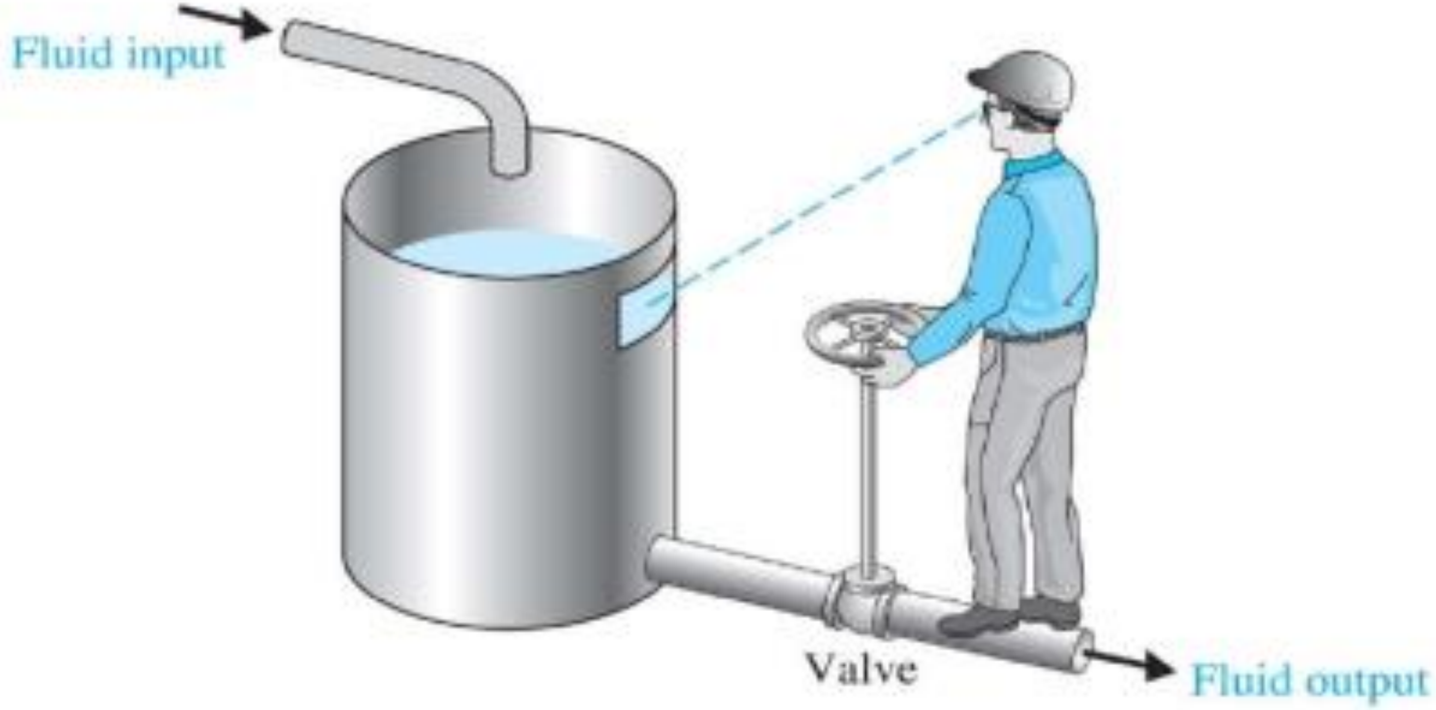
J.C.Maxwell – math.model (1868)

H.Ford (1913); H.W.Bode (1927)



Examples of modern control systems

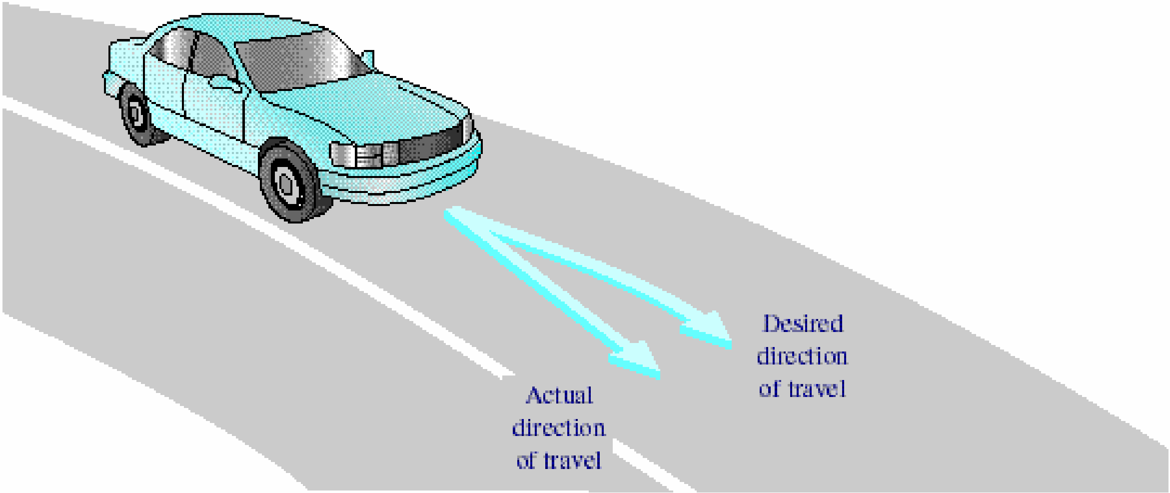
- Manual control of fluid level regulation

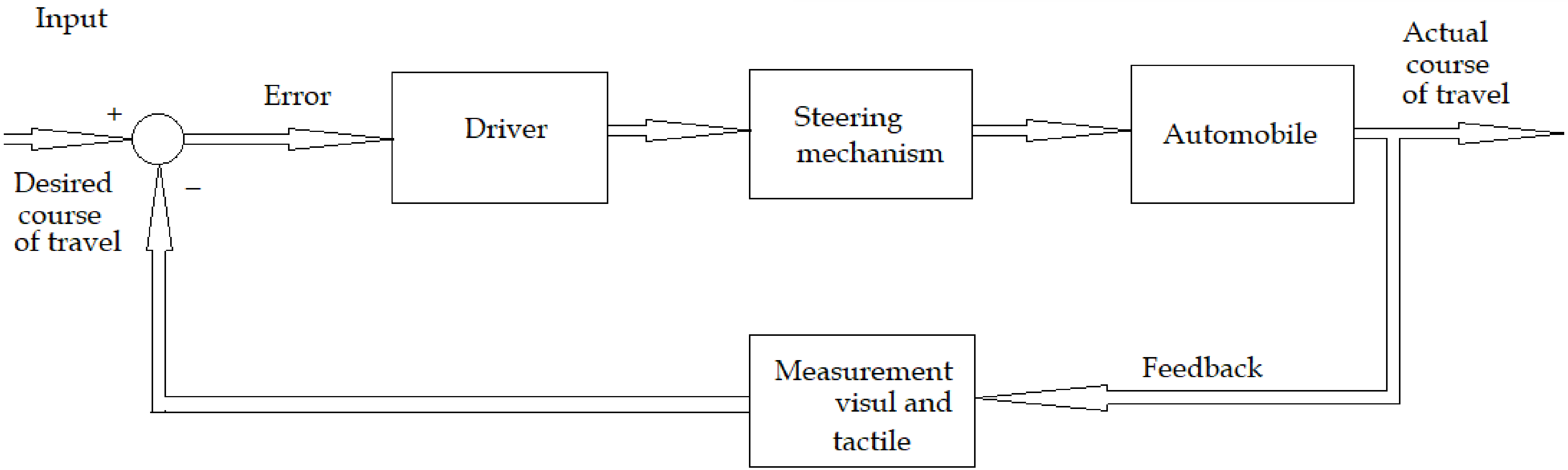


Examples of modern control systems

- Automobile steering control system

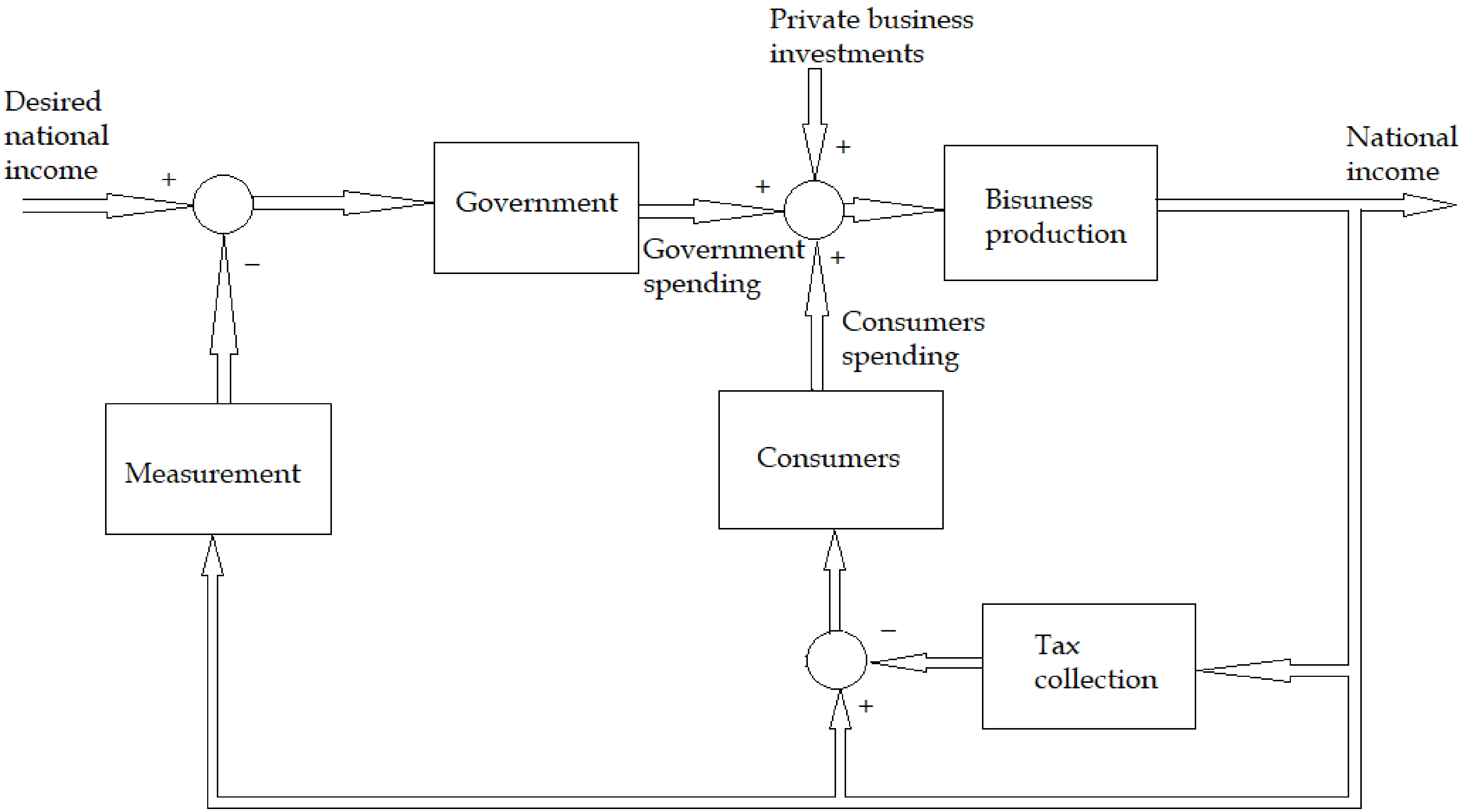
Difference between the desired and actual direction





Examples of modern control systems

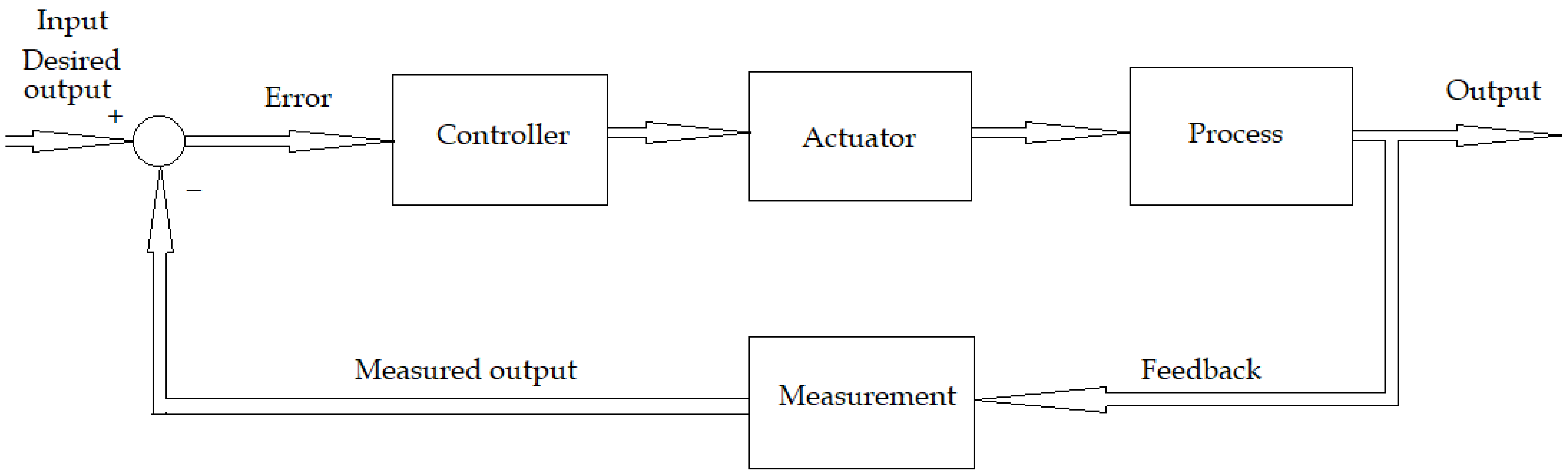
- Control system model of national income



Types of Control System

- Manual Control Systems
  - Room Temperature regulation Via Electric Fan
  - Water Level Control

- Automatic Control System
  - Room Temperature regulation Via A.C
  - Human Body Temperature Control


Input
Desired output
+
Error
Controller
Actuator
Process
Output
−
Measured output
Measurement
Feedback

Transfer function/block-diagram

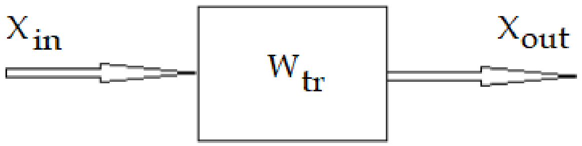
- The time response solution:

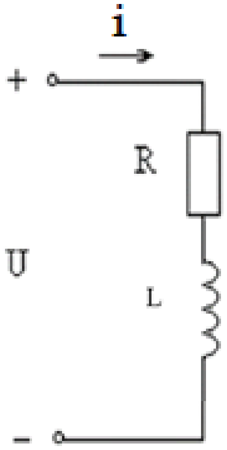
1. Obtain a differential equation
2. Obtain the Laplace transformation of the differential equation
3. Solve the resulting algebraic transform

The Laplace variable $s \equiv \frac{d}{dt}$

Transfer function/block-diagram (example)

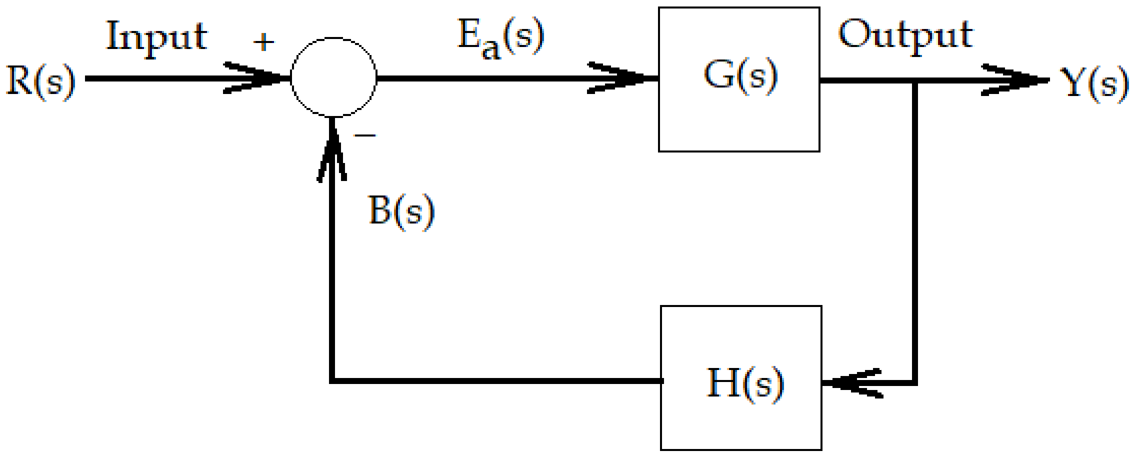
- $W_{tr}(s) = \frac{X_{out}}{X_{in}}$





Transfer function/block-diagram

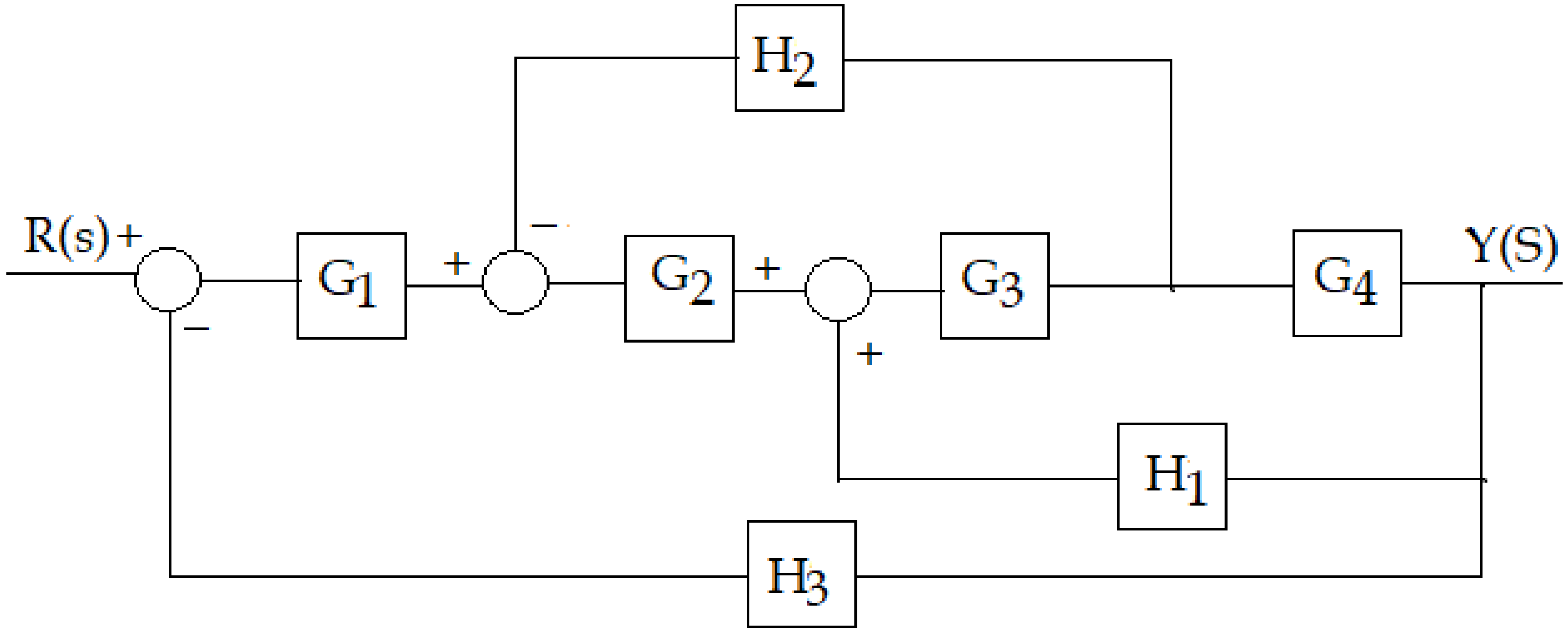
- Negative feedback control system



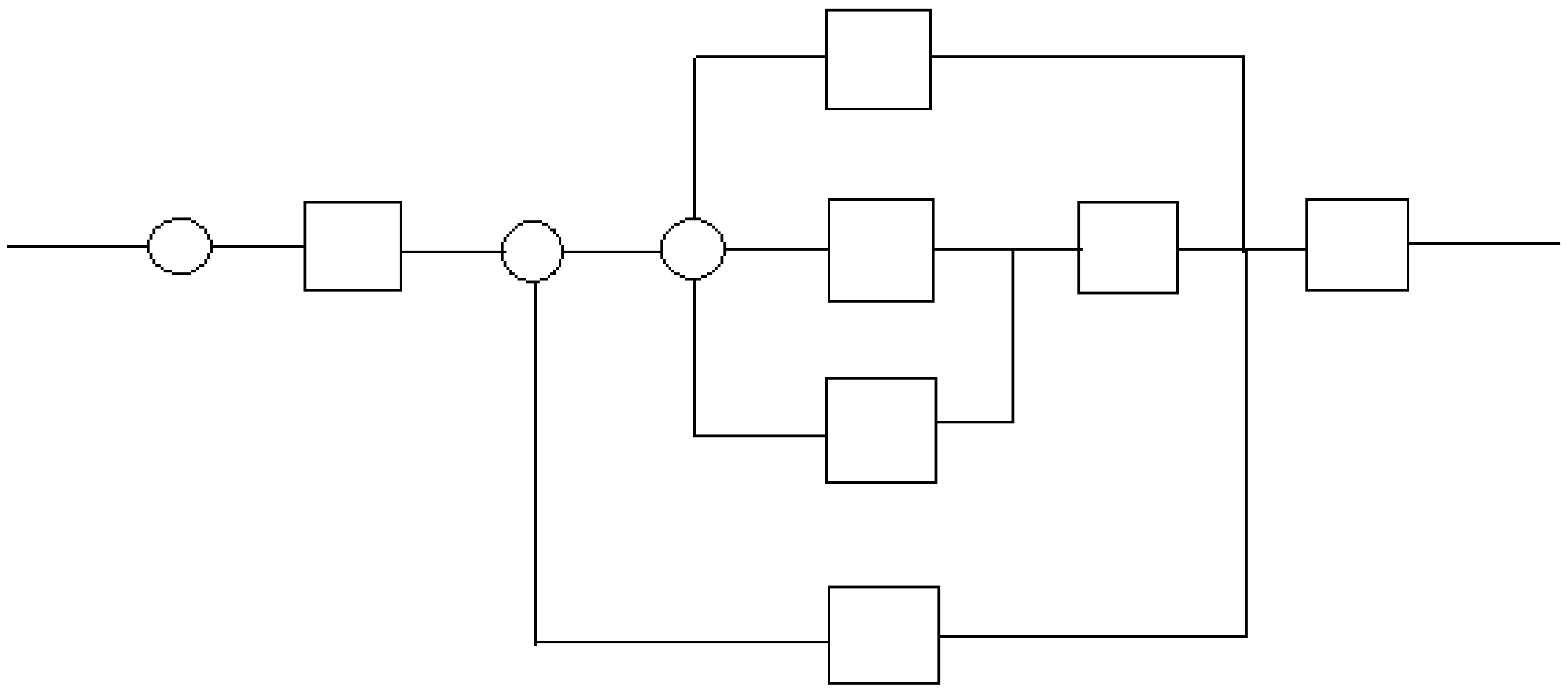
- $\frac{Y(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$

- +

Transfer function/block-diagram (example)

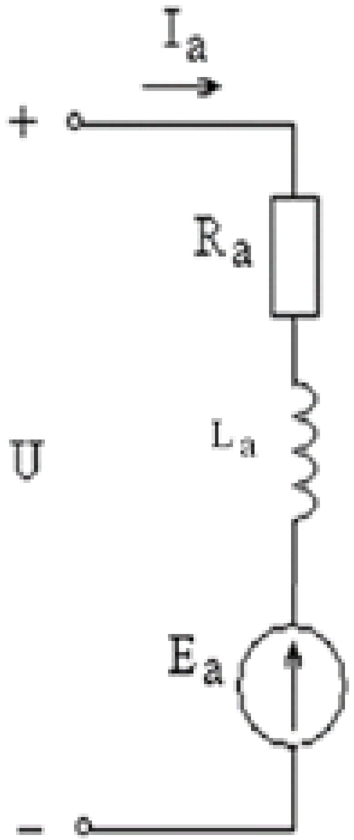


Transfer function/block-diagram (problem solving)



Application/ Systems optimization

DC motor model
description of dynamic regimes



$$u_a = L_a \frac{di_a}{dt} + R_a i_a + e_a$$

$$J \frac{d\omega_m}{dt} = M_m - M_s$$

$$e_a = c\Phi \cdot \omega_m$$

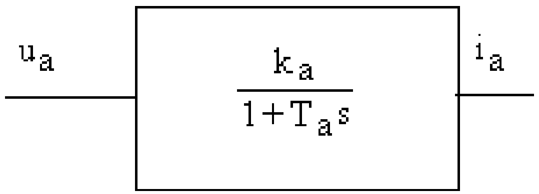
$$M_m = c\Phi \cdot i_a$$

Electrical circuit

$$W(s)=\frac{i_a}{u_a}=\frac{1}{L_a s+R_a}=\frac{1/R_a}{\frac{L_a}{R_a}s+1}$$

$$W(s)=\frac{k_a}{T_a s+1}$$

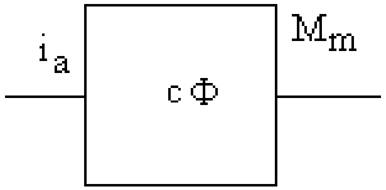
$$\frac{d}{dt}\equiv s$$



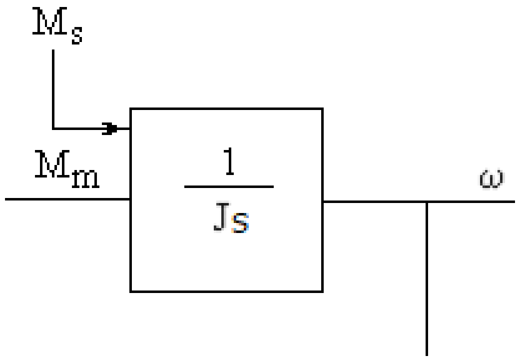
Electromechanical processes

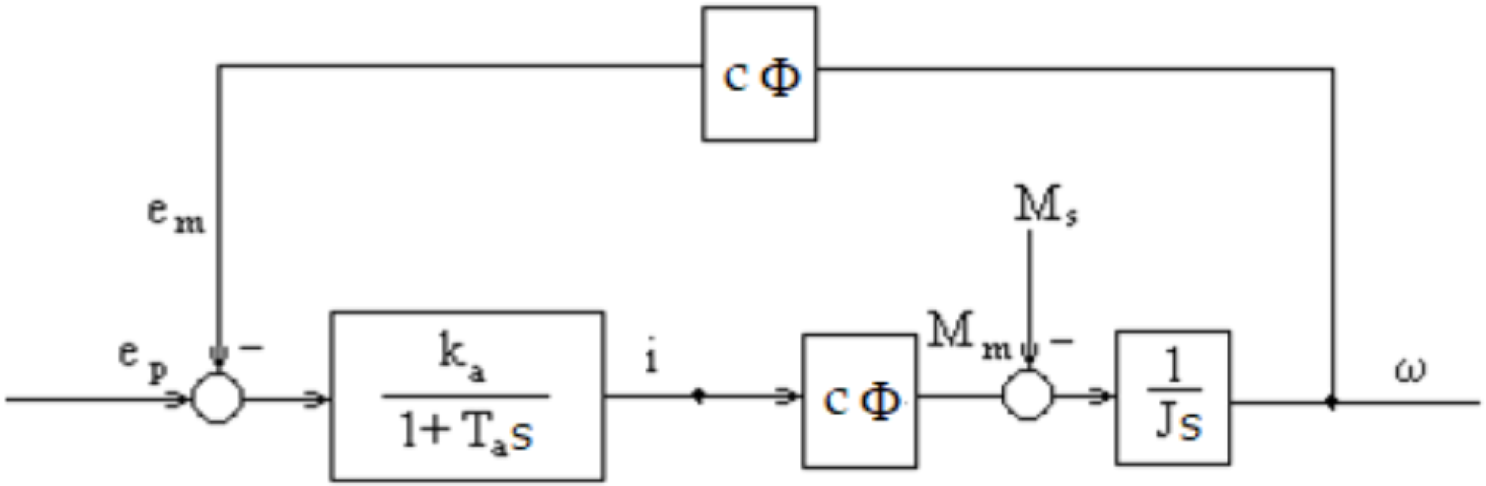
$$J\frac{d\omega_m}{dt} = M_m - M_s$$

$$M_m = c\Phi \cdot i_a$$

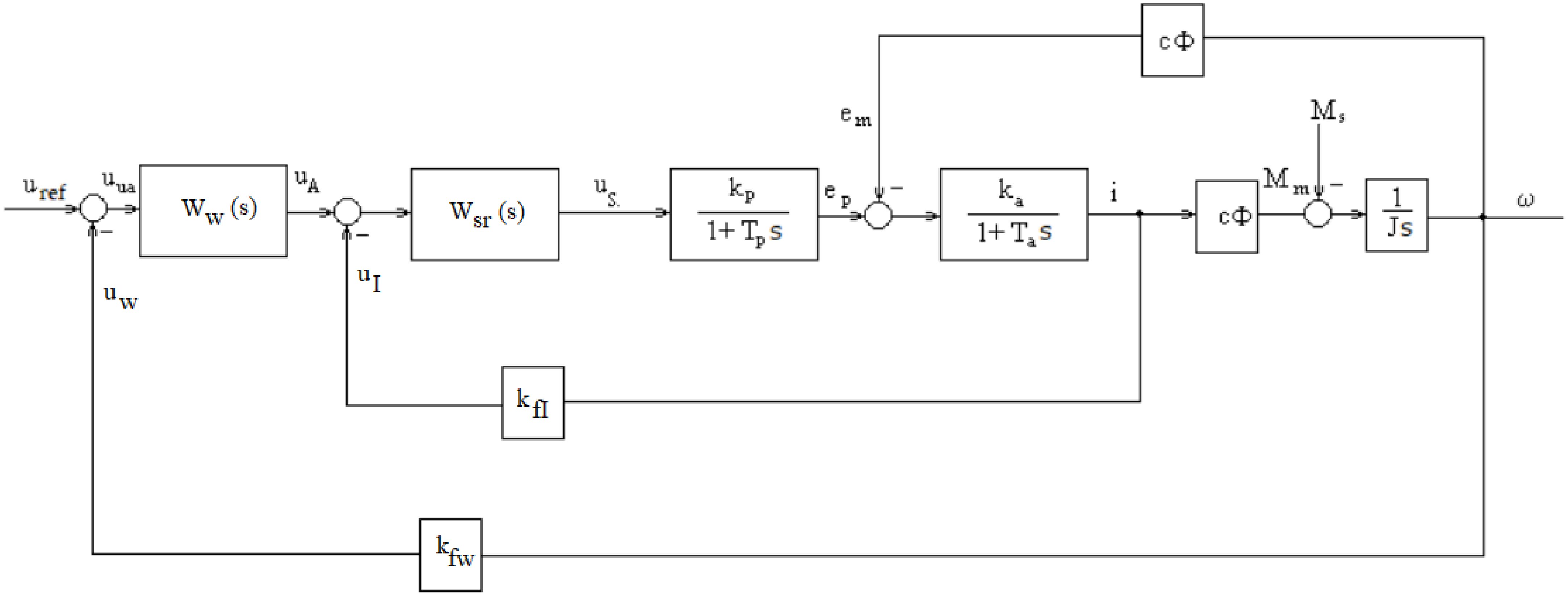


$$M_m = c\Phi \cdot i_a$$

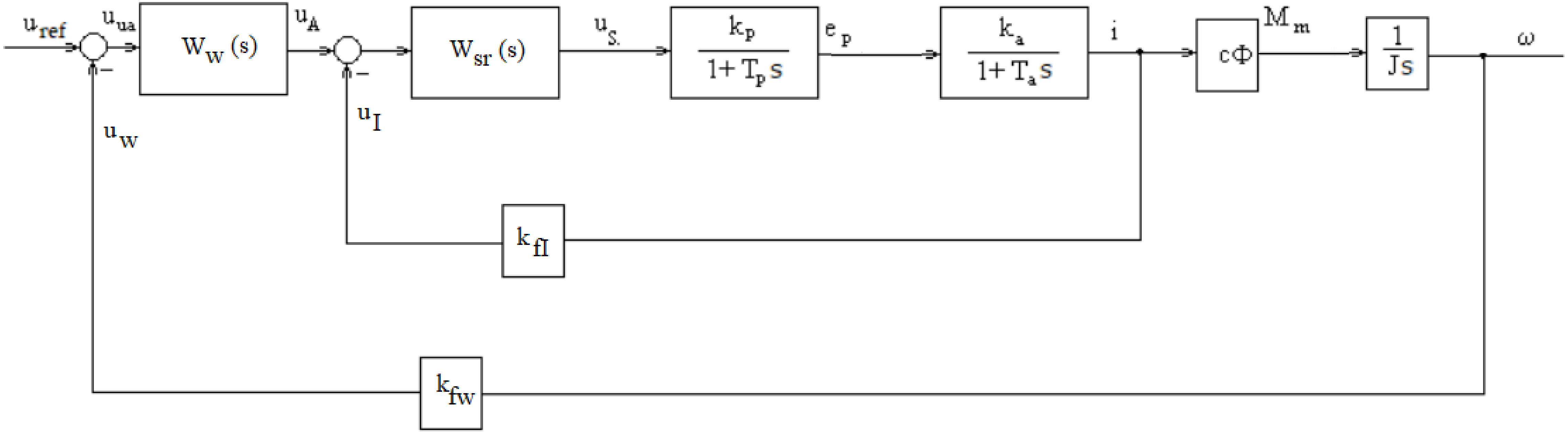




Block-diagram of system with controllers



Application and calculation (tuning) of the controllers



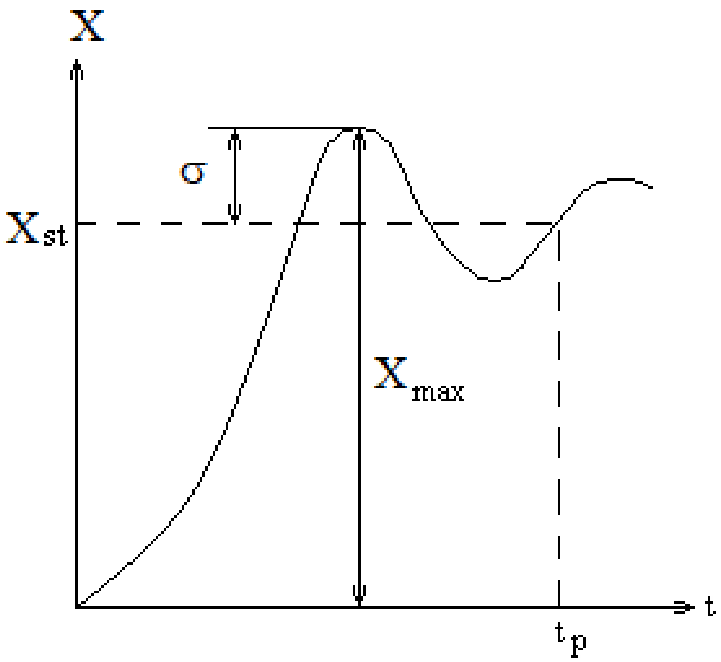
Optimization of the system

- TO / os $W_o(s) = \frac{1}{2T_0 s(T_0 s+1)}$

σ=4.3%; $t_p = 8.4T_o$

- SO / os $W_o(s) = \frac{4T_0 s+1}{8T_0^2 s^2(T_0 s+1)}$

σ=43%;$t_p = 16.5T_o$



Algorithm of the system optimization

1) Equal the transfer function of inner open loop to optimum
2) Solve the TF of the inner loop controller
3) Find the TF of the close inner loop, simplify
4) Equal the transfer function of the next open loop to optimum (each next To is double of the previous To)
5) Solve the TF of the next loop controller, … etc.

$$T_0' = 2T_0$$