Ministry of Higher Education and Scientific Research

Al-Mustaqbal University College

Department of Technical Computer Engineering

Electrical control fundamentals

Introduction to Control Systems

3rd Stage

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Control System

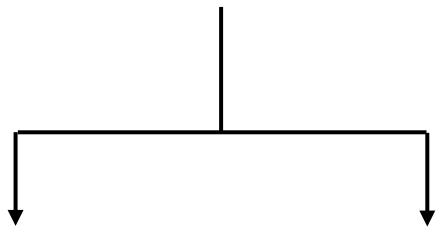
It is an arrangement of physical components connected or related in such manner as to command, direct, or regulate itself or another system.

Kinds of Control Systems

There are two kinds of control systems:

- Open Loop Systems
- Closed Loop Systems

Control Systems



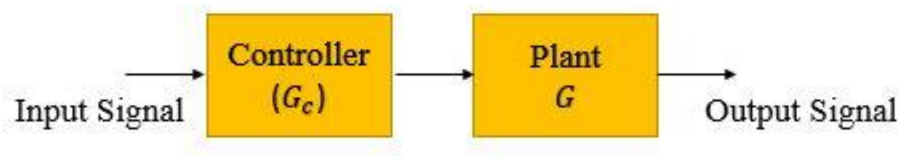
Open Loop Systems   Closed Loop Systems

Open Loop System

It is a system which its input signal has not effects on output signals. In other words, it does not have feedback, so the output signal will not be measured. The examples of the open loop systems are:

a) Traffic Lights.
b) Washing Machines.

It has reference input, controller, plant, and output signal.



TF = $\frac{\text{Output Signal}}{\text{Input Signal}} = GG_c$

<u>Closed Loop System</u>

It is the system which has feedback component. The aim of the feedback is to compare the actual output signal with the reference input to reduce the error. The output signal is measured. The examples of the closed loop systems are:

a) Room temperature control systems.
b) Steering a car on curve road.
c) Turntable speed control.

The **basic components** of the closed loop systems are:

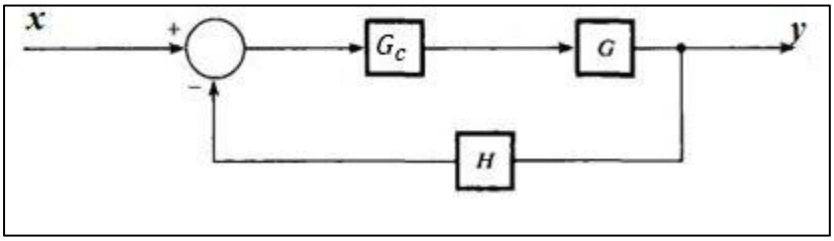
$\boldsymbol{x}$**: Reference input,**

$\boldsymbol{G_c}$: **Controller,**

$\boldsymbol{G}$**: Plant,**

$\boldsymbol{H}$**: Sensor,**

$\boldsymbol{y}$**: Output Signal**.



TF = $\frac{y}{x} = \frac{G_c G}{1+G_c GH}$

$G_c G$: forward path

H : sensor

$1 + G_c GH$: characteristic equation

G_cGH : open loop transfer function

$\frac{G_cG}{1+G_cGH}$: closed loop transfer function

To prove the closed loop transfer function = $\frac{G_cG}{1+G_cGH}$

$Y(s) = G_cGE$

E = Input – output = $X(s) - Y(s)H(s)$

$Y(s) = G_cG[\ X(s) - Y(s)H(s)]$

$Y(s) = G_cGX(s) - G_cG\ H(s)Y(s)$

$Y(s) + G_cG\ H(s)Y(s) = G_cGX(s)$

$Y(s)[1+G_cG\ H(s)] = G_cGX(s)$

$\therefore \frac{Y(s)}{X(s)} = \frac{G_cGX(s)}{1+G_cG\ H(s)}$

Modeling a Control Systems and Components

Electrical Components

1. Resistance (Ω)

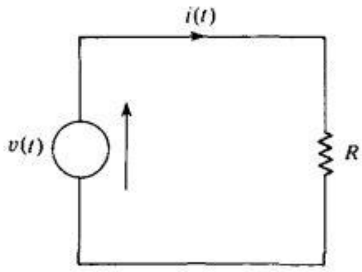


Figure 2. Simple Resistance *(Warwick, 1996)*

$v(t) = Ri(t)$ or

$V(s) = RI(s)$

∴ the transfer function is

$$G(s) = \frac{I(s)}{V(s)} = \frac{1}{R}$$

The block diagram representation of this component is

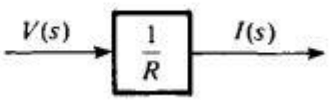


Figure 3. Resistance Block Diagram.

2. Inductor L(H)

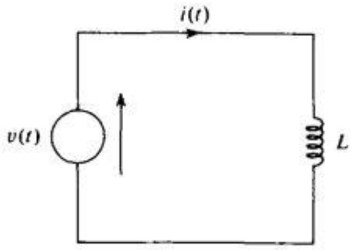


Figure 4. Simple Inductor (Warwick, 1996).

$v(t) = L\frac{d}{dt}i(t)$ or

$V(s) = LsI(s)$

$\frac{I(s)}{V(s)} = \frac{1}{Ls}$

The block diagram representation of this component is

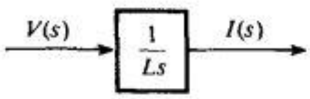


Figure 5. Inductor Block Diagram *(Warwick, 1996)*.

3. Capacitor C (F)

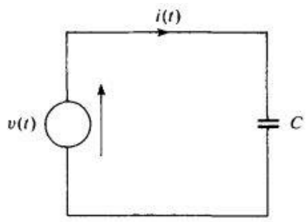


Figure 6. Simple Capacitor *(Warwick, 1996)*.

$v(t) = \frac{1}{c}\int i(t)dt$ or

$V(s) = \frac{1}{C}\frac{1}{s}I(s)$

$$\frac{I(s)}{V(s)} = Cs$$

The block diagram representation of this component is

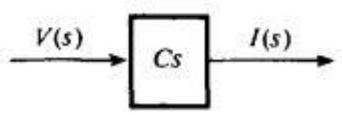


Figure 7. Capacitor Block Diagram (Warwick, 1996).

Series Combination of RLC Components

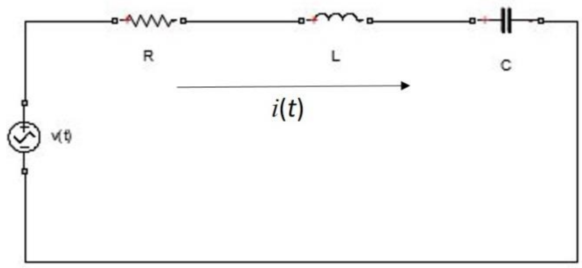


Figure 8. Series RLC.

$v(t) = Ri(t) + L\frac{d}{dt}i(t) + \frac{1}{c}\int i(t)dt$ or

$V(s) = RI(s) + LsI(s) + \frac{1}{C}\frac{1}{s}I(s)$

$= (R + Ls + \frac{1}{Cs})\ I(s)$

$$\frac{I(s)}{V(s)} = \frac{1}{(R + Ls + \frac{1}{Cs})}$$

The block diagram of this combination is

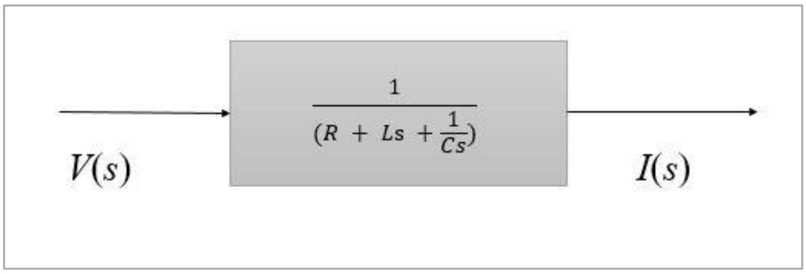


Figure 9. Series RLC Block Diagram.

Parallel Combination of RLC Components

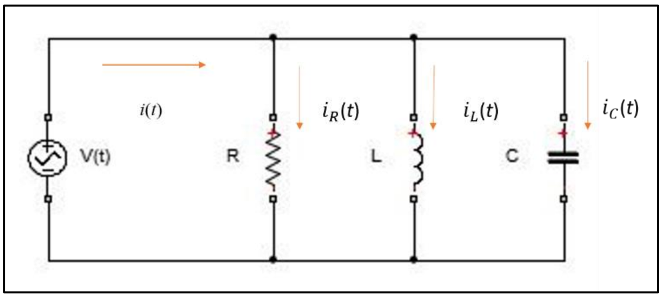


Figure 10. Parallel RLC.

$$i(t) = i_R(t) + i_L(t) + i_R(t) + i_C(t)$$

$$= \frac{v(t)}{R} + \frac{1}{L}\int v(t)dt + C\,\frac{dv(t)}{dt}$$

The Laplace transform of this equation is

$$I(s) = \frac{V(s)}{R} + \frac{V(s)}{LS} + CSV(s)$$

$$= \left(\frac{1}{R} + \frac{1}{LS} + CS\right) V(s)$$

$$V(s) = \frac{1}{\frac{1}{R} + \frac{1}{LS} + CS}\, I(s)$$

$$\frac{I(s)}{V(s)} = \frac{1}{R} + \frac{1}{LS} + CS$$

The block diagram of this combination is

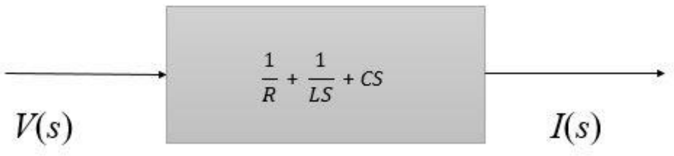


Figure 11. Parallel RLC Block Diagram.

Mechanical Components

Translational Mechanical Components

a. Linear Spring K(N/m)

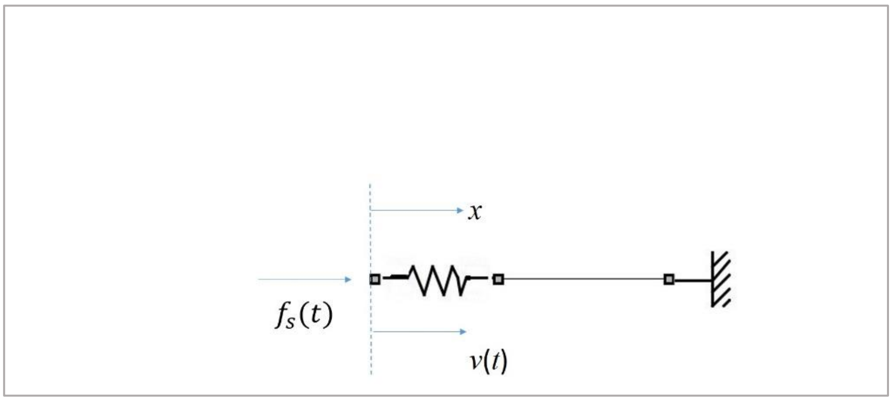


Figure 12. Linear Spring

$$f_s(t) = \int_0^t Kv(t)dt$$

$$\because\ v(t) = \frac{dx}{dt}$$

$$\therefore\ f_s(t) = Kx(t)$$

$$F_s(s) = KX(s)$$