# (1) Chapter One

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from (1) to (8)

## Introduction to Control Systems

### 1.1 * Definitions

1. Controlled Variable and Manipulated Variable.

* The controlled variable is the quantity or condition that is measured and controlled.

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* The manipulated variable is the quantity or condition that is varied by the controller so as to affect the value of the controlled variable.

2. Plants.

A plant may be a piece of equipment, perhaps just a set of machine parts functioning together, the purpose of which is to perform a particular operation.

3. Processes.

A process is any operation to be controlled.

4. Systems.

A system is a combination of components that act together and perform a certain objective.

5. Disturbances.

A disturbance is a signal that tends to adversely affect the value of the output of a system.

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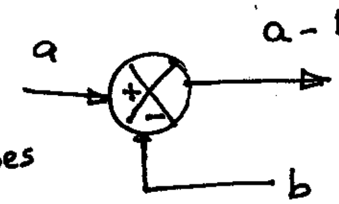
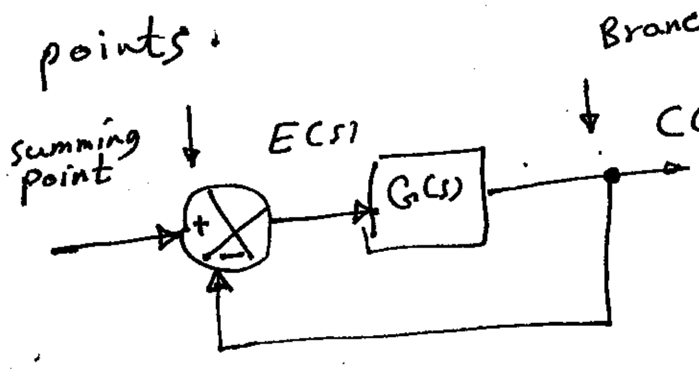
6- Feedback control.
A system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control is called a feedback control system.

7- Summing point.

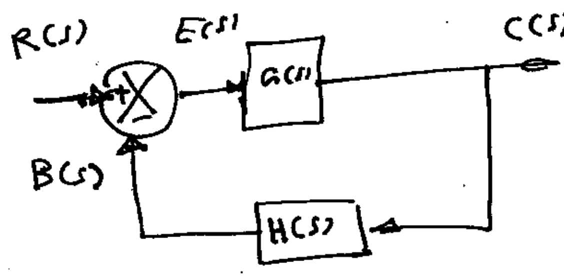



a circle with a cross is the symbol that indicates a summing operation.
The quantities being added or subtracted have the same dimensions and the same units.

8. Branch point.
A branch point is a point from which the signal from a block goes concurrently to other block or summing points.




9. Block diagrams ~~are~~




Block diagram

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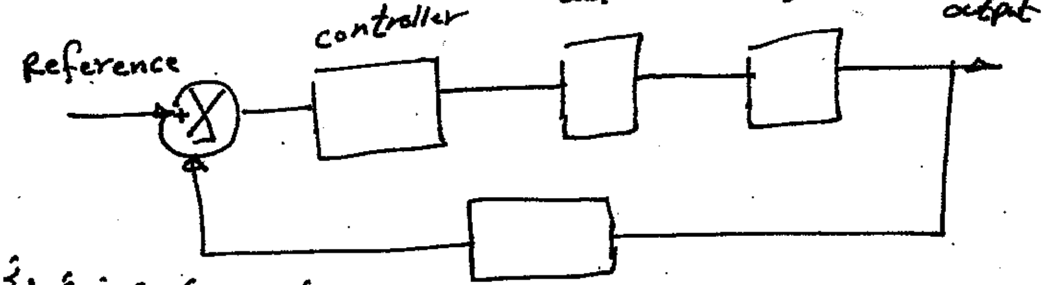
10 Transfer function


Element of a block diagram.

11. closed-Loop control systems.



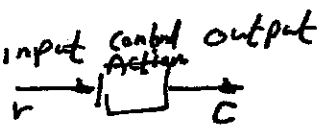

* تغيرات غير متوقعة في الخارج والداخل.

محاسن
* استخدم لعمل تغيرات خارجية والداخلية
* ممكن استعمال معدات رخيصة وغير دقيقة للحصول على نتائج دقيقة

مساوئ
* stability problem
* المعدات المستعملة أكثر لذلك ثمنه أعلى وتصرف power أكثر.

12. open-Loop control systems.

Those systems in which the output has no effect on the control action are called open-Loop control systems.




open-Loop control system

مساوئه
1- Disturbances، calibration، error تتغير
2- للحصول على النتائج المطلوبة calibration يجب إعادة ...

محاسن
1- بسيط البناء
2- أرخص
3- لا توجد مشكلة stability
4- إذا كان صعب قياس الخارج مش دقة على المطلوب

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# chapter Two

## 2.1 The Laplace Transform

$$\mathcal{L}[f(t)] = F(s) = \int_0^{\infty} e^{-st}\, dt\, [f(t)] = \int_0^{\infty} f(t)\, e^{-st}\, dt$$

$$\mathcal{L}^{-1}[F(s)] = f(t) = \frac{1}{2\pi j} \int_{c-j\infty}^{c+j\infty} F(s)\, e^{st}\, ds\,, \quad \text{for } t>0$$

notes:

① $\mathcal{L}[A\,(f(t))] = A\,\mathcal{L}[f(t)]$

② $\mathcal{L}[\alpha f_1(t) + \beta f_2(t)] = \alpha F_1(s) + \beta F_2(s)$

ex: Exponential Function

$$f(t) = 0 \qquad t<0$$
$$= A e^{-\alpha t} \qquad t \geq 0$$

$$\mathcal{L}[A e^{-\alpha t}] = \int_0^{\infty} A e^{-\alpha t} e^{-st}\, dt = A \int_0^{\infty} e^{-(\alpha+s)t}\, dt$$
$$= \frac{A}{s+\alpha}$$

ex: (step function)

$$f(t) = 0 \qquad t<0$$
$$= A \qquad t > 0$$

$$\Rightarrow \mathcal{L}[A] = \int_0^{\infty} A e^{-st}\, dt = \frac{A}{S}$$

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# Laplace Transform pairs

| no. | $f(t)$ | $F(s)$ |
|---|---|---|
| 1 | unit impulse $\delta(t)$ | $1$ |
| 2 | unit step $1(t)$ | $\frac{1}{s}$ |
| 3 | $t$ | $\frac{1}{s^2}$ |
| 4 | $t^n \quad (n = 1, 2, \cdots)$ | $\frac{n!}{s^{n+1}}$ |
| 5 | $e^{-at}$ | $\frac{1}{s+a}$ |
| 6 | $\sin \omega t$ | $\frac{\omega}{s^2+\omega^2}$ |
| 7 | $\cos \omega t$ | $\frac{s}{s^2+\omega^2}$ |
| 8 | $f'(t)$ | $sF(s) - f(0)$ |
| 9 | $f''(t)$ | $s^2F(s) - sf(0) - f'(0)$ |
| 10 | $\int_0^t f(t)\,dt$ | $\frac{F(s)}{s}$ |

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## 2.2 Inverse Laplace Transformation

(1) * Partial – Fraction Expansion Method for Finding inverse Laplace Transforms.

$$F(s) = \frac{B(s)}{A(s)} = \frac{K\,(s+z_1)\cdots(s+z_m)}{(s+p_1)\cdots(s+p_n)} \qquad m<n$$

$$F(s) = \frac{a_1}{s+p_1} + \frac{a_2}{s+p_2} + \cdots \frac{a_n}{s+p_n}$$

$$a_k = \left[(s+p_k)\frac{B(s)}{A(s)}\right]_{s=-p_k}$$

example:

Find the inverse Laplace transform of

$$F(s) = \frac{s+3}{(s+1)(s+2)}$$

solution:

$$F(s) = \frac{a_1}{s+1} + \frac{a_2}{s+2}$$

$$a_1 = \left[(s+1)\frac{s+3}{(s+1)(s+2)}\right]_{s=-1} = \left[\frac{s+3}{s+2}\right]_{s=-1} = 2$$

$$a_2 = \left[(s+2)\frac{s+3}{(s+1)(s+2)}\right]_{s=-2} = \left[\frac{s+3}{s+1}\right]_{s=-2} = -1$$

$$f(t) = \mathcal{L}^{-1}[F(s)] = \mathcal{L}^{-1}\left[\frac{2}{s+1}\right] + \mathcal{L}^{-1}\left[\frac{-1}{s+2}\right]$$

$$= 2e^{-t} - e^{-2t}, \quad \text{for } t \geq 0.$$

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(2) partial-Fraction Expansion when $F(s)$ involves mutiple poles.

$$F(s) = \frac{s^2+2s+3}{(s+1)^3}$$

$$F(s) = \frac{B(s)}{A(s)} = \frac{b_1}{s+1} + \frac{b_2}{(s+1)^2} + \frac{b_3}{(s+1)^3}$$

$$b_3 = \left[(s+1)^3 \frac{B(s)}{A(s)}\right]_{s=-1}$$

$$= (s^2+2s+3)_{s=-1} = 2$$

$$b_2 = \left\{\frac{d}{ds}\left[(s+1)^3 \frac{B(s)}{A(s)}\right]\right\}_{s=-1}$$

$$= \left[\frac{d}{ds}(s^2+2s+3)\right]_{s=-1}$$

$$= (2s+2)_{s=-1}$$

$$= 0$$

$$b_1 = \frac{1}{2!}\left\{\frac{d^2}{ds^2}\left[(s+1)^3 \frac{B(s)}{A(s)}\right]\right\}_{s=-1}$$

$$= \frac{1}{2!}\left[\frac{d^2}{ds^2}(s^2+2s+3)\right]_{s=-1}$$

$$= \frac{1}{2}(2) = 1$$

$$f(t) = \mathcal{L}^{-1} F(s) = \mathcal{L}^{-1}\left[\frac{1}{s+1}\right] + \mathcal{L}^{-1}\left[\frac{0}{(s+1)^2}\right] + \mathcal{L}^{-1}\left[\frac{2}{(s+1)^3}\right]$$

$$= e^{-t} + 0 + t^2 e^{-t} = (1+t^2)e^{-t} \quad \text{for } t \geq 0$$

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## sheet (1)

(1) give examples for open and closed-loop control systems ?

(2) what are the main disadvantages of open-Loop control ?
" closed-Loop " ?

"

(3) "

(4) find the solution $x(t)$ of the differential equation

$$\ddot{x} + 3\dot{x} + 2x = 0 \qquad x(0) = a, \quad \dot{x}(0) = b$$

where (a) and (b) are constants.

## * with Matlab

$$\frac{B(s)}{A(s)} = \frac{r(1)}{s-p(1)} + \frac{r(2)}{s-p(2)} + \cdots \frac{r(n)}{s-p(n)} + K(s)$$

ex :

$$\frac{B(s)}{A(s)} = \frac{2s^3 + 5s^2 + 3s + 6}{s^3 + 6s^2 + 11s + 6}$$

```
num = [2  5  3  6]
den = [1  6  11  6]
[r, p, k] = residue(num, den)

r =
  -6.0000
  -4.0000
   3.0000
p =
  -3.0000
  -2.0000
  -1.0000
k =
```

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