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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Review

Laplace Transform

$\mathcal{L}f(t) = F(s) = \int_0^\infty f(t)\, e^{-st} dt$ $\qquad t \geq 0$

s is a complex number, i.e,

$s = \sigma \pm j\omega$

Table 1. Laplace Transform (Ogata, 1997).

$f(t)$	$F(s)$
$\delta(t)$ unit impulse at $t = 0$	1
$u(t)$ unit step at $t = 0$	$\frac{1}{s}$
$u(t-T)$ unit step at $t = T$	$\frac{1}{s}e^{-sT}$
t	$\frac{1}{s^2}$
t^n	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$t^n e^{-at}$	$\frac{n!}{(s+a)^{n+1}}$
$sin\omega t$	$\frac{\omega}{s^2+\omega^2}$

$cos\omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at}\ sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\ cos\omega t$	$\frac{(s+a)}{(s+a)^2+\omega^2}$
$sinh\omega t$	$\frac{\omega}{s^2-\omega^2}$
$cosh\omega t$	$\frac{s}{s^2-\omega^2}$

Introduction to Control Systems

Automatic control is very important in the advanced engineering and science. Also, it is used in space-vehicle systems, missile-guidance systems, robotic systems,…, etc. Some industrial operations like controlling pressure, humidity, viscosity, and flow in the process industries always need automatic control (Ogata, 1997).

The basic purpose to any control systems is the ability to measure the output of the system and to take corrective action if its value deviates from some desired value (Burns, 2001).

Definitions of standard terminology

Initially, what does a system mean? A **system** is a set of components that work together and perform a certain objective (Ogata, 1997). Several words are commonly used in the control systems. Some of these words are shown in the figure1.

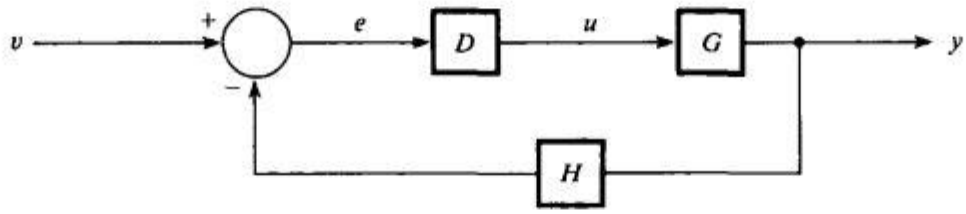

Figure 1 Closed-loop system with feedback element H (Warwick, 1996).

1. Lower case letters refer to signals, e.g. voltage, speed; and are functions of time, u= u (t).
2. Capital letters denote signal magnitudes, as in the case of u(t) =Ucosωt , or otherwise Laplace transformed

quantities, U = U(s). Where s = $j\omega$, this is indicated by U($j\omega$).

Note: s is the Laplace operator and $j\omega = 2\pi f$ where f is frequency.

3. The system under control is also known as the **plant** or **process**, ***G***.
4. The **reference input**, ***v***, also known as the set-point or desired output, is an external signal applied to indicate a desired steady value for the plant output.
5. The **system output**, ***y***, also known as the controlled output, is the signal obtained from the plant which we wish to measure and control.
6. The **error signal**, ***e***, is the difference between the desired system output and the actual system output (when $H = 1$).
   Note: See 8.
7. The **controller**, ***D***, is the element which ensures that the appropriate control signal is applied to the plant. In many cases, it takes the error signal as its input and provides an actuating signal as its output.
8. The **feedback element *H*** provides a multiplying factor on the output y before a comparison is made with the reference input *v*. When $H \neq 1$ the error e is the error between *v* and Hy, i.e. it is no longer the error between *v* and *y*.
9. The **feedback signal** is the signal produced by the operation of *H* on the output *y*.
10. The **control input**, ***u***, also known as the actuating signal, control action or control signal, is applied to the plant *G* and is provided by the controller *D* operating on the error *e*.
11. The **forward path** is the path from the error signal *e* to the output *y*, and includes *D* and *G*.
12. The **feedback path** is the path from the output *y*, through *H*.
13. A **disturbance**, or **noise** (not shown in the figure1), is a signal which enters the system at a point other than the

reference input and has the effect of undermining the normal system operation.

14. A **nonlinear system** is one in which the principles of superposition do not apply, e.g. amplifier saturation at the extremes, or hysteresis effects. Almost all except the simplest systems are nonlinear in practice, to an extent at least. The vast majority of systems can however be dealt with by approximating the system with a linear model, at least over a specific range.
15. A **time-invariant system** is one in which the characteristics of that system do not vary with respect to time. Most systems vary slowly with respect to time, e.g. ageing. However, over a short period, they can be considered time-invariant.
16. A **continuous-time system** is one in which the signals are all functions of time t, in an analog sense.
17. A **discrete-time system** is a system such as a digital system or a sampled data system in which the signals, which consist of pulses, only have values at distinct time instants. The operator z is used to define a discrete-time signal such that $z^3y(t)= y(t+ 3)$ means the value of signal $y(t)$at a point in time three periods in the future, where a period T (sample period) is defined separately for each system.
18. A **transducer** converts one form of energy (signal) into another, e.g. pressure to voltage.
19. **Negative feedback** is obtained when $e = v - Hy$.

20. **Positive feedback** is obtained when $e = v + Hy$.

Note: This is not shown in the figure1.

21. A **regulator** is a control system in which the control objective is to minimize the variations in output signal, such variations being caused by disturbances, about a set-point mean value.

Note: A regulator differs from a servomechanism in which the main purpose is to track a changeable reference input.

22. A **multivariable system** is one which consists of several inputs and several outputs (Warwick, 1996).