**Feedback System**

Feedback systems play an important role in modern engineering practice because they have the possibility for being adopted to perform their assigned tasks automatically. A feedback (closed-loop) system represented by the block diagram and signal glow graph in fig(a) is driven by two signals (more signals could be employed), one the input signal and the other, a signal called the feedback signal derived from the output of the system. The feedback signal gives this system the capability to act as self-correcting mechanism as explained below.

Input r

R(s)

Actuating

Signal e

Process

G(s)

Sensor

H(s)

Comparator

E(s)

B(s)

Feedback

b

Output c

C(s)

Fig (a) A Feedback (closed-loop) system

R(s)

E(s)

C(s)

C(s)

G(s)

-H(s)

The output signal c is measured by a sensor H(s), which produces a feedback signal b. The comparator compares the feedback signal b with the input (command) signal r generating the actuating signal e, which is as measure of discrepancy between r and b. The actuating signal is applied to the process G(s) so as to influence the output c in a manner which tends to reduce the error e.

Feedback as a means of automatic regulation and control is, in fact, inherent in nature and can be noticed in many physical, biological and soft systems. For example, the body temperature of any living being is automatically regulated through a process which is essentially a feedback process.

**Importance of Feedback System**

1. The controlled variable accurately follows the desired value.
2. Effects on the controlled variable of external disturbances other than those associated with the feedback sensor are greatly reduced.
3. Effect of variation in controller and process parameters on system performance is reduced to acceptable levels. These variations occur due to wear, aging, environmental changes etc.
4. Feedback in the control loop allows accurate control of the output (by means of the input signal) even when process or controlled plant parameters are not known accurately.
5. Feedback in a simulation greatly improves the speed of its response.

**Types of Feedback System**

1. **Positive Feedback System**

Positivefeedback (or regenerative feedback) occurs in a feedback loop when the mathematical sign of the net gain around the feedback loop (sometimes called the *loop gain*) is positive. That is, positive feedback is *in phase with* the input, in the sense that it adds to make the input larger.

"Positive feed-back increases the gain of the amplifier.”

Positive feedback is a process in which the effects of a small disturbance on a system can include an increase in the magnitude of the perturbation. Positive feedback tends to cause system instability. When the loop gain is positive and above 1, there will typically be exponential growth of any oscillations or divergences from equilibrium.

1. **Negative Feedback System**

Negativefeedback (also known as degenerativefeedback**)** occurs when information about a gap between the actual value and a reference value of a system parameter is used to *reduce* the gap. If a system has overall a high degree of negative feedback, then the system will tend to be stable.

"Negative feed-back reduces the gain of the amplifier."

**Application of Feedback System**

1. **Biology**

In biological systems such as organisms, ecosystems, or the biosphere, most parameters must stay under control within a narrow range around a certain optimal level under certain environmental conditions. The deviation of the optimal value of the controlled parameter can result from the changes in internal and external environments. A change of some of the environmental conditions may also require change of that range to change for the system to function.

1. **Climate Science**

The climate system is characterized by strong positive and negative feedback loops between processes that affect the state of the atmosphere, ocean, and land. A simple example is the ice-albedo positive feedback loop whereby melting snow exposes more dark ground, which in turn absorbs heat and causes more snow to melt.

1. **Control Theory**

Feedback is extensively used in control theory, using a variety of methods including state space (controls), full state feedback (also known as pole placement), and so forth. Note that in the context of control theory, "feedback" is traditionally assumed to specify "negative feedback".

1. **Mechanical Engineering**

Internal combustion engines of the late 20th century employed mechanical feedback mechanisms such as the vacuum timing advance but mechanical feedback was replaced by electronic engine management systems once small, robust and powerful single-chip microcontrollers became affordable. Now-a-days each and every modern engines uses feedback system.

1. **Electronic Engineering**

The use of feedback is widespread in the design of electronic amplifiers, oscillators, and logic circuit elements. Electronic feedback systems are also very commonly used to control mechanical, thermal and other physical processes. If the signal is inverted on its way round the control loop, the system is said to have *negative feedback*; otherwise, the feedback is said to be *positive*. Negative feedback is often deliberately introduced to increase the stability and accuracy of a system by correcting unwanted changes.

Electronic feedback loops are used to control the output of electronic devices, such as amplifiers. A feedback loop is created when all or some portion of the output is fed back to the input. A device is said to be operating *open loop* if no output feedback is being employed and *closed loop* if feedback is being used.

1. **Software Engineering and Computing System**

Feedback loops provide generic mechanisms for controlling the running, maintenance, and evolution of software and computing systems. Feedback-loops are important models in the engineering of adaptive software, as they define the behavior of the interactions among the control elements over the adaptation process, to guarantee system properties at run-time. Feedback loops and foundations of control theory have been successfully applied to computing systems.

1. **Social Science**

A feedback loop to control human behavior involves four distinct stages.1) - Evidence. A behavior must be measured, captured, and data stored. 2) - Relevance. The information must be relayed to the individual, not in the raw-data form in which it was captured but in a context that makes it emotionally resonant. 3) - Consequence. The information must illuminate one or more paths ahead. 4) - Action. There must be a clear moment when the individual can recalibrate a behavior, make a choice, and act. Then that action is measured, and the feedback loop can run once more, every action stimulating new behaviors that inch the individual closer to their goals.

1. **Reflexive Feedback**

A sociological concept that states a feedback association is created within a certain relationship whereby the subject/object that delivers a stimulus to a second subject/object, will in response receive the stimulus back. This first impulse is reflected back and forth over and over again.

**Rocket Autopilot System**

An autopilot system which steers a rocket vehicle in response to radioed command. Figure shows a simplified block diagram representation of the system.

Radio

Receiver

Digital

Computer

Digital

To analog

Converter

Hydraulic

Actuator

Rocket

Engine

Vehicle

Dynamics

Gyros

Analog

To

Digital

Converter

Position pick-off

Accelerometer

Radio command signal

(from ground station)

Fig: A typical autopilot system

Digital

Coded input

Control signal

Engine angle

Displacement

Vehicle

Motions

The state of motion of the vehicle (velocity, acceleration) is fed to the control computer by means of motion sensors (gyros, acceleration). A position pick-off feeds the computer with the information about engine angle displacement and hence the direction in which the vehicle is heading. In response to heading-commands from the ground, the computer generates a signal which controls the hydraulic actuator and in turn moves the engine.

**Time Response Specifications**

C(t)

t

td

tr

tp

ts

1.0

0.5

Mp

Allowable tolerance

Figure: Time response specifications

The time response of second and higher order control systems to a step input is generally of damped oscillatory nature as shown in the above figure. It is observed from this figure that the step response has a number of overshoots and undershoots with respect to the final steady value. Since the overshoot and undershoots decay exponentially, the peak overshoot is the first overshoot and is the same as the peak of the complete time response. This type of step response is characterized by the following performance indices.

It may be noted that various indices are not independent of each other.

1. Delay time td: It is the time required for the response to reach 50% of the final value in first attempt.
2. Rise time tr: It is the time required for the response to rise from 10% to 90% of the final value for overdamped systems and 0 to 100% of the final value for underdamped systems. Above figure shows an underdamped case.
3. Peak time tp: It is the time required for the response to reach the peak of time response or the peak overshoot.
4. Peak overshoot Mp: It indicates the normalized difference between the time response peak and the steady output and is defined as

Peak percent overshoot

1. Setting time ts: It is the time required for the response to reach and stay within a specified tolerance band (usually 2% or 5%) of its final value.
2. Steady-state error ess: It indicates the error between the actual output and desired output as t tends to infinity.