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**AEROSPACE FLUID POWER AND CONTROL/ACTUATION SYSTEM GLOSSARY**

1. PURPOSE:

This aerospace information report contains in a single document terms relevant to high performance flight control actuation systems with fault-tolerant capability. It represents the United States recommendation to the International Organization for Standardization (ISO).

2. SCOPE:

General terms peculiar to aerospace fluid power and control systems are defined in this glossary. Relevant terms have been excerpted from the referenced documents and listed as aerospace terms that are believed to be most useful as a reference for future air vehicle fluid power and control actuation system designs. This is a systems document and the only component-related terms are those significant at the systems level.

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3. REFERENCES:

- ARP243 - Nomenclature, Aircraft Hydraulic and Pneumatic Systems
- ARP1181 - Terminology for Redundant Flight Control Systems
- AIR1799 - Missile Flight Control Actuation Terminology
- DIS 5598 - Hydraulic and Pneumatic Fluid Power - Vocabulary, ISO/TC131
- DP 8625 - Aerospace Fluid Power and Control System Glossary
- ISO 6771 - Pressure and Temperature Classifications - Fluid Systems and Components - Aerospace
- MIL-STD-721 - Definitions of Terms for Reliability and Maintainability

## CHAPTER 1 - GENERAL PRESSURE TERMS AND DEFINITIONS

| TERMS                                       | DEFINITIONS                                                                                                                                                                                          |
|---------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Absolute Pressure                           | Pressure value using absolute vacuum as a reference.                                                                                                                                                 |
| Ambient Pressure                            | The static pressure surrounding a component.                                                                                                                                                         |
| Atmospheric Pressure                        | Absolute pressure of the atmosphere at a given location and time.                                                                                                                                    |
| Breakout Pressure                           | The pressure required to overcome static friction in a component.                                                                                                                                    |
| Burst Pressure, Actual                      | Pressure at which a component bursts, exhibits massive leakage due to permanent or non-permanent structural failure, or due to structural deflection.                                                |
| Burst Pressure, Minimum (Ultimate Pressure) | Pressure during burst pressure testing up to which no externally visible bursting and no significant external leakage occurs. Deformation and permanent set are permitted. Function may be impaired. |
| Certification Pressure                      | The authorized pressure for formal acceptance tests.                                                                                                                                                 |
| Class of Hydraulic System                   | A pressure standard for a military aircraft hydraulic system based on the nominal pump output pressure or other supply pressure, defined in ISO 6771.                                                |
| Control Pressure (Pilot Pressure)           | The pressure required to control or influence any motion or change in motion.                                                                                                                        |
| Cracking Pressure                           | The pressure at which a valve becomes unseated and begins to pass fluid.                                                                                                                             |
| Cut-out Pressure                            | The pressure at which the sequence of reduced flow of a component or system begins.                                                                                                                  |
| Differential Pressure                       | The difference in value between two functionally related pressures occurring simultaneously at different points, such as at opposite sides of an actuator piston.                                    |

## TERMS

## DEFINITIONS

|                                                           |                                                                                                          |
|-----------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Dynamic Pressure                                          | That portion of the local pressure in a fluid, which is recovered when the fluid is brought to rest.     |
| Flushing Pressure                                         | Pressure required to flush a system at defined conditions (for instance: at defined flow).               |
| Gauge Pressure                                            | Absolute pressure minus atmospheric pressure.                                                            |
| Idling Pressure                                           | Pressure required to maintain a system or component at the idling speed, or flow.                        |
| Inlet Pressure<br>(Supply Pressure)                       | Pressure at the inlet of a component.                                                                    |
| Internal Pressure                                         | The pressure inside a system or component.                                                               |
| Maximum Pressure                                          | The highest transient pressure that can occur temporarily.                                               |
| Minimum Operating Pressure                                | The lowest pressure at which a system or component must function.                                        |
| Minimum Pressure                                          | The lowest transient pressure that can occur temporarily.                                                |
| Maximum Permissible Pressure                              | The highest pressure that is permitted for safety reasons.                                               |
| No-Flow Valve Pressure Gain                               | Ratio of change in controlled pressure to the corresponding change of a controlling variable at no flow. |
| No-Load Pressure                                          | Pressure required to maintain a system at a specified speed with no external load.                       |
| Nominal Pressure<br>(System Pressure)<br>(Rated Pressure) | The general pressure setting of the system.                                                              |
| Operating Pressure                                        | The pressure available to a component or system during normal operation.                                 |
| Opposing Load Pressure                                    | Pressure acting to oppose operating pressure.                                                            |
| Outlet Pressure                                           | Pressure at the outlet of a component.                                                                   |
| Peak Pressure                                             | Maximum pressure, usually of short duration.                                                             |

## TERMS

## DEFINITIONS

Precharge Pressure  
(Inflation Pressure)

The pressure at which a component is initially charged or inflated.

Pressure

Pressure is defined as fluid force per unit area. Pressure in a fluid at rest is equal in all directions.

Pressure Curve

Pressure variation, expressed graphically in relation to another variable, for example, time.

Pressure Droop

Change in pressure from a higher level to a lower level with flow of a pressure-compensated pump or regulator.

Pressure Fluctuation

Variation of pressure with time, usually occurring randomly.

Pressure Gradient

The change in pressure value with distance in a steady-state flow.

Pressure Head

Equivalent height of a column of liquid required to produce a given pressure.

Pressure Impulse

A rapid rise and fall of pressure, or vice versa, of extremely short duration.

Pressure Loss  
(Pressure Drop)

Pressure loss is the reduction in pressure caused by resistance to flow or by any extraction of energy that is not converted into useful work.

Pressure Pulsation  
(Pressure Ripple)

Periodical variation of pressure in synchronism with the operating speed of rotating equipment.

Pressure Ratio

Numerical ratio of the value of two pressures.

Pressure Rise

Change in pressure from a lower level to a higher level (due to energy addition or kinetic energy recovery).

Pressure Surge

Pressure rise and fall over a period of time.

Pressure Transient

Pressure rise or drop, or both, of extremely short duration with negligible energy.

Pressure Under Load  
(Load Pressure)

The pressure reacting to a static or dynamic load.

## TERMS

## DEFINITIONS

Pressure Wave

A cyclic variation of pressure with relative low amplitude and long period.

Proof Pressure

Pressure above nominal system pressure of the component or system the application of which, at defined test conditions, must not lead to external leakage, permanent deformation, or any detrimental influence on function.

Rated Pressure

See nominal pressure.

Reference Pressure

The pressure established as a reference value.

Reseat Pressure

The pressure at which the valve is resealed and flow is interrupted.

Response Pressure

The pressure at which a function is initiated.

Return Pressure  
(Back Pressure)

Pressure caused by resistance to flow in the return line or by precharged reservoirs, or both.

Set Pressure

The pressure which a component is designed to provide for a defined operation.

Standard Atmospheric Pressure

Mean atmospheric pressure related to sea level (corresponding to the definition for the physical atmosphere 1013.25 mbar).

Static Pressure

The local pressure in a fluid that has no element due to velocity of the fluid.

Suction Pressure

Atmospheric pressure minus absolute pressure for values below atmospheric pressure.

Switching Pressure

The pressure at which a system or a component is activated, deactivated, or reversed.

Total Pressure

The sum of the static and dynamic pressures at a location.

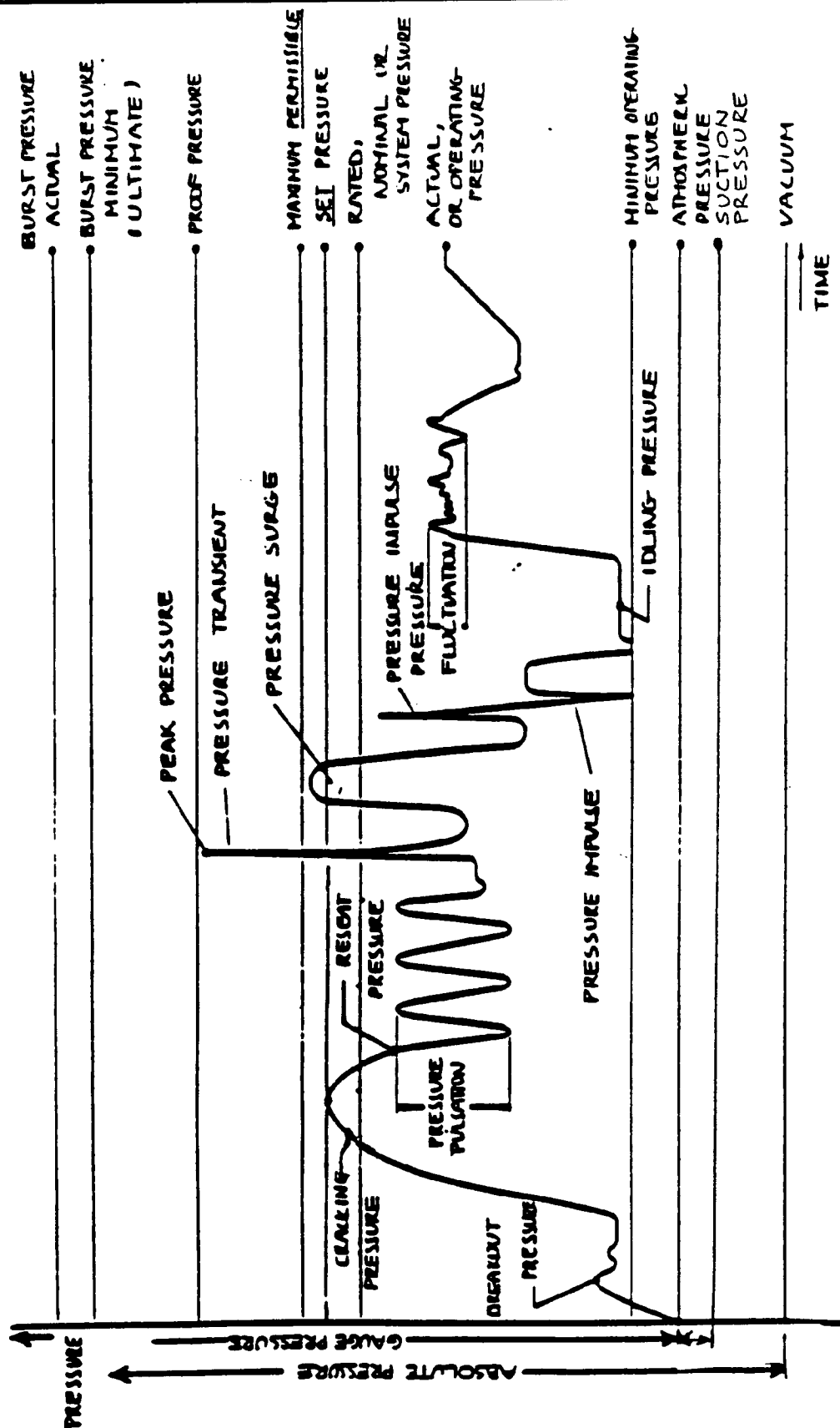


FIGURE 1 - Graphical Presentation of an Arbitrary Pressure Curve

## CHAPTER 2 - GENERAL FLOW TERMS AND DEFINITIONS

| TERMS                   | DEFINITIONS                                                                                                                                                                                                                                                   |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Case Drain Flow         | Cooling flow and internal leakage of a hydraulic pump or motor to the housing and out of the case drain port, not provided in all models.                                                                                                                     |
| Cavitation              | Formation of cavities, either gaseous or vapor, within a liquid stream, which occurs where the pressure is locally reduced to vapor pressure of the liquid. It may include gas coming out of solution in the liquid as pressure is reduced (soft cavitation). |
| Choked Flow             | Flow of a compressible fluid (gas), limited by the speed of sound in the fluid at the throat of a control section.                                                                                                                                            |
| External Leakage        | Leakage from the interior of a device to the exterior, other than out of the fluid ports.                                                                                                                                                                     |
| Flow                    | Quantity of a fluid (volume or mass) crossing the transverse plane of a flow path per unit of time. Gas volume flow may be expressed at standard reference conditions of sea level atmospheric pressure and ambient temperature.                              |
| Flow Surge (Surge)      | Temporary rise and fall of flow.                                                                                                                                                                                                                              |
| Internal Leakage        | Leakage between internal cavities of a device.                                                                                                                                                                                                                |
| Laminar Flow            | Flow of a fluid characterized by the gliding of fluid layers (laminae) past one another in orderly fashion.                                                                                                                                                   |
| Leakage                 | Flow through a passage that is in a nominally closed position or at a location, which normally should permit no flow.                                                                                                                                         |
| No-Load Valve Flow Gain | The increment of valve flow per change in valve input variable at no load across the output.                                                                                                                                                                  |
| Null Leakage            | Internal leakage of a valve when output flow is negligible.                                                                                                                                                                                                   |
| Quiescent Flow          | Total internal leakage of a complete hydraulic system or a branch of a hydraulic system at rest.                                                                                                                                                              |

## TERMS

## DEFINITIONS

Rated Flow

Specified flow at steady-state conditions for a component or system.

Seepage

Occurrence of extremely slight fluid at the surface of a component or part of a hydraulic system, normally due to "breathing" of seals under cyclic pressure load. No drops are allowed over an extended period of observation.

Turbulent Flow

Flow of a fluid characterized by the random motion of fluid particles in directions transverse to the direction of the main flow.

Weepage

Occurrence of slight fluid at the surface of the sliding parts, such as piston rods, pump shafts, and valve spools, due to wiping of fluid from the wetted surface by seals or scrapers. Drops of fluids may be formed after a number of actuation cycles, to be defined. If there is no relative motion, such as at parting lines, weepage must not occur.

## CHAPTER 3 – GENERAL TEMPERATURE TERMS AND DEFINITIONS

| TERMS                          | DEFINITIONS                                                                                                                                                                            |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ambient Temperature            | Temperature of the environment in which the apparatus is working.                                                                                                                      |
| Autoignition Temperature       | Temperature at which the fluid flashes into flame without an external ignition source and continues burning. Actual value is to be determined by one of several approved test methods. |
| Cold Start Temperature         | The temperature at which the hydraulic system will start to operate, but need not necessarily meet full performance.                                                                   |
| Equipment Temperature          | Temperature of the unit at a specified position and measured at a specified point, normally at the surface.                                                                            |
| Flash Point                    | Temperature at which a fluid gives off sufficient vapor to cause it to ignite when a small flame is applied, under controlled conditions.                                              |
| Fluid Temperature              | Temperature of the fluid measured at a specified point in the system.                                                                                                                  |
| Inlet Temperature              | Fluid temperature at the plane of the inlet port.                                                                                                                                      |
| Maximum Fluid Temperature      | Highest fluid temperature in the system at which the fluid is intended to be operated.                                                                                                 |
| Normal Fluid Temperature       | The stabilized fluid temperature normally reached during continuous operation.                                                                                                         |
| Outlet Temperature             | Fluid temperature at the plane of the outlet port.                                                                                                                                     |
| Pour Point                     | Lowest temperature at which a fluid will flow under specified conditions.                                                                                                              |
| Temperature Range of the Fluid | Specified range of fluid temperature that should not be exceeded for satisfactory operation of a system.                                                                               |

## TERMS

Type of Hydraulic System

## DEFINITIONS

A classification standard for a military aircraft hydraulic system based on minimum and maximum allowable fluid temperatures, defined in ISO 6771 as:

Type I -54 to +71°C (-65 to +160°F)

Type II -54 to 135°C (-65 to +275°F)

Type III -54 to 232°C (-65 to +450°F)

## Note:

The upper limit of Type III was reduced from +232°C (+450°F) to +199°C (+390°F) by the U.S. in recognition of hydraulic fluid limitations.

## CHAPTER 4 - CONTROL/ACTUATION SYSTEM TERMINOLOGY

Control/actuation systems are used in aircraft, missiles, and other aerospace vehicles for actuating flight control surfaces, engine air inlets and exhaust nozzles, and other services that require precise positioning.

ABBREVIATIONS:

dB    decibel

PWM   pulse width modulated

LRU   line replaceable unit

CONTROL SYSTEM CLASSIFICATION:

## TERMS

## DEFINITIONS

Adaptive Control

A control system that maintains optimum system performance by automatically changing system parameters.

Bistable and Tristable Control

A control system in which the power to control the load is fully "on" in either polarity (bistable), or fully "on" in one polarity, "off", or fully "on" in the other polarity (tristable). These systems are sometimes called "on-off" systems or "bang-bang" systems. When the time duration of the application of power is modulated by the input, the system is called pulse width modulated (PWM).

Closed-Loop Control System

A control system in which the command is compared with a measurement of system output and the resulting error signal is used to drive the load towards the desired output. Fig. 2 illustrates a closed-loop control system.

Command Input

An input that represents the desired output of the control system.

Control System

A system in which deliberate guidance or manipulation is used to achieve a prescribed value of a variable. A control system has at least one input and one output.

Error Signal

The output of the summing point where algebraic summation of two or more control loop variables is performed.

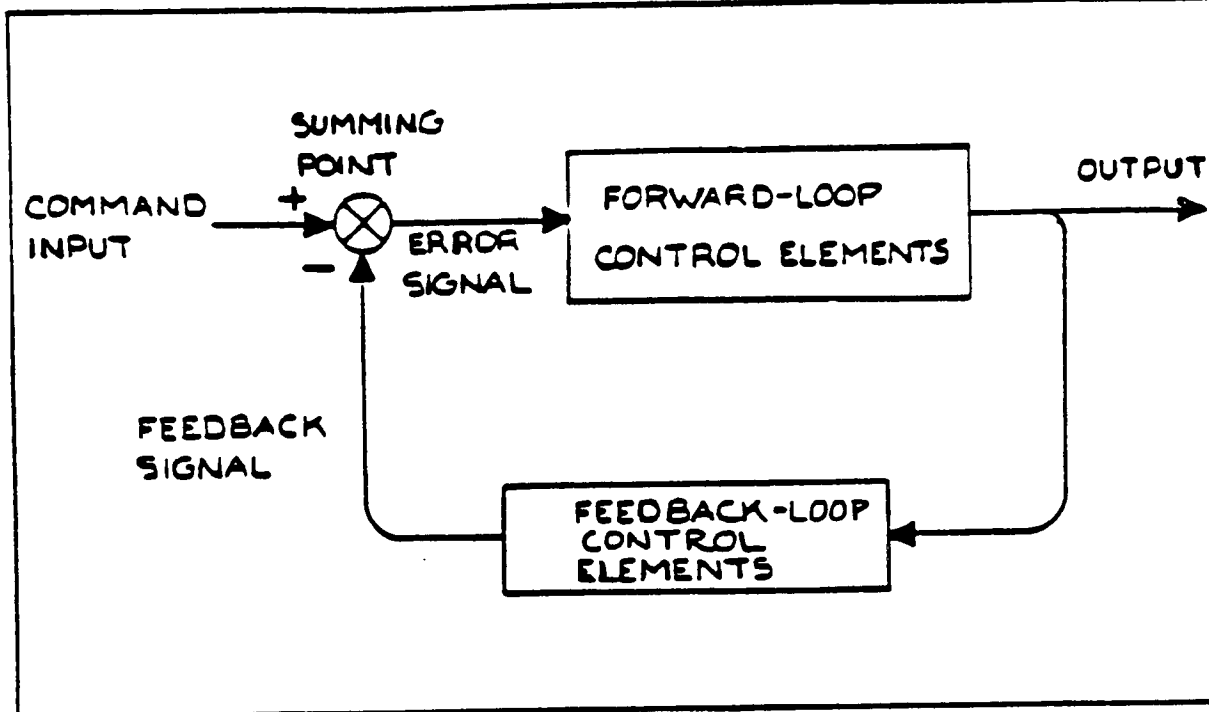


FIGURE 2 - Closed-Loop Control System

## TERMS

## DEFINITIONS

Feedback-Loop Control Elements

Elements in a closed-loop control system that provide the feedback signal of the output, or a function of the output that can be compared with the reference input.

Feedback Signal

The signal used to cancel further action when the command is carried out.

Forward-Loop Control Elements

Elements situated between the error signal and the output of the control system.

Integral Control (Type 1, 2, ...)

A control system that uses integration in the control loop elements to provide an output in response to an error signal. This is referred to as a Type N system, where N is the order of the integration. For more complete explanation refer to text books.

Loop

The signal path in a closed-loop control system beginning with the error signal and ending with the resultant feedback signal that functionally interconnects the forward-loop and feedback-loop elements.

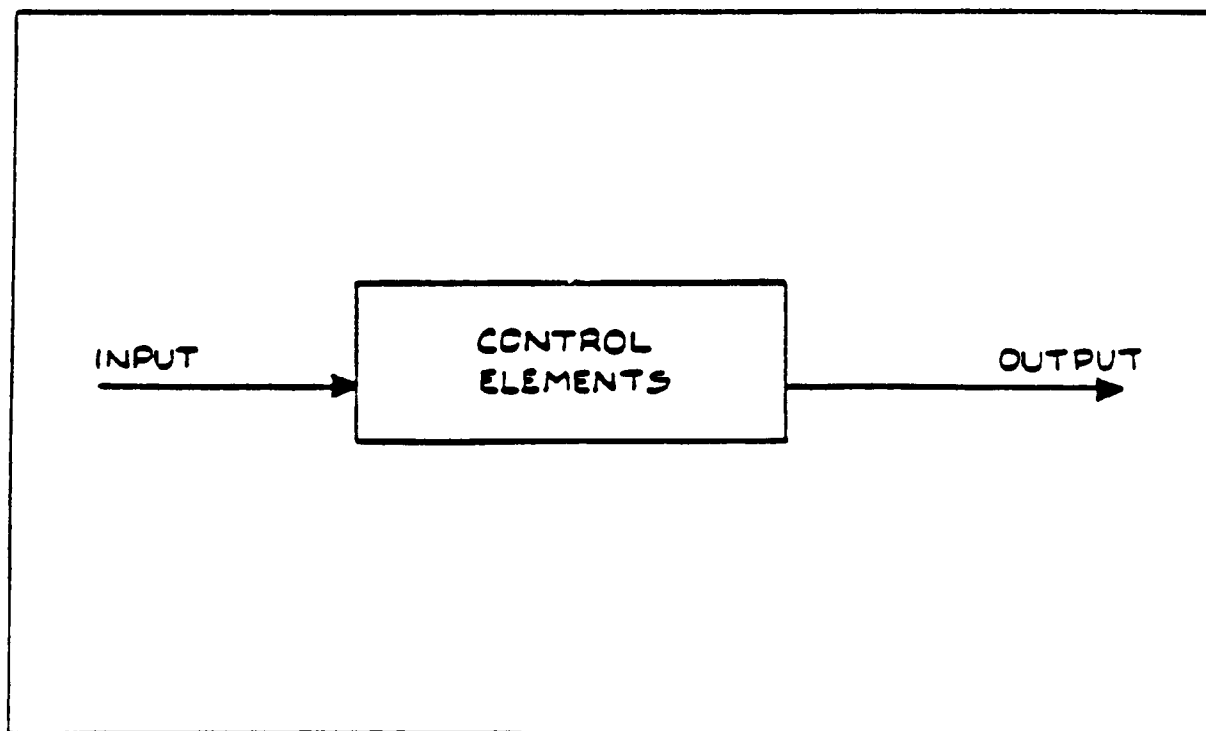


FIGURE 3 - Open-Loop Control System

## TERMS

## DEFINITIONS

Open-Loop Control System

A control system in which gain and power elements are used to provide an output in direct response to a command without feedback comparison. Fig. 3 illustrates an open-loop control system.

Output

The controlled variable resulting from activity of the control system.

Proportional Control (Type 0)

A control system that uses proportional forward and feedback control elements to provide an output in response to the error signal. This is referred to as a Type 0 control system.

Summing Point

Any point in a control system where an algebraic summation of two or more control-loop variables is performed.

CONTROL SYSTEM TECHNOLOGY

An actuation system is a means of power utilization for controlling a specific output variable. Actuation systems include a power source, power converter, controller, power modulator, actuator, and feedback element (if used). Fig. 4 illustrates a complete servo actuation system including controller and power modulator, or both. The controller is basically electronics and is not included in the servoactuator. Fig. 5 shows a simple servo actuation system without a separate controller, such as a simple hydraulic power boost cylinder.

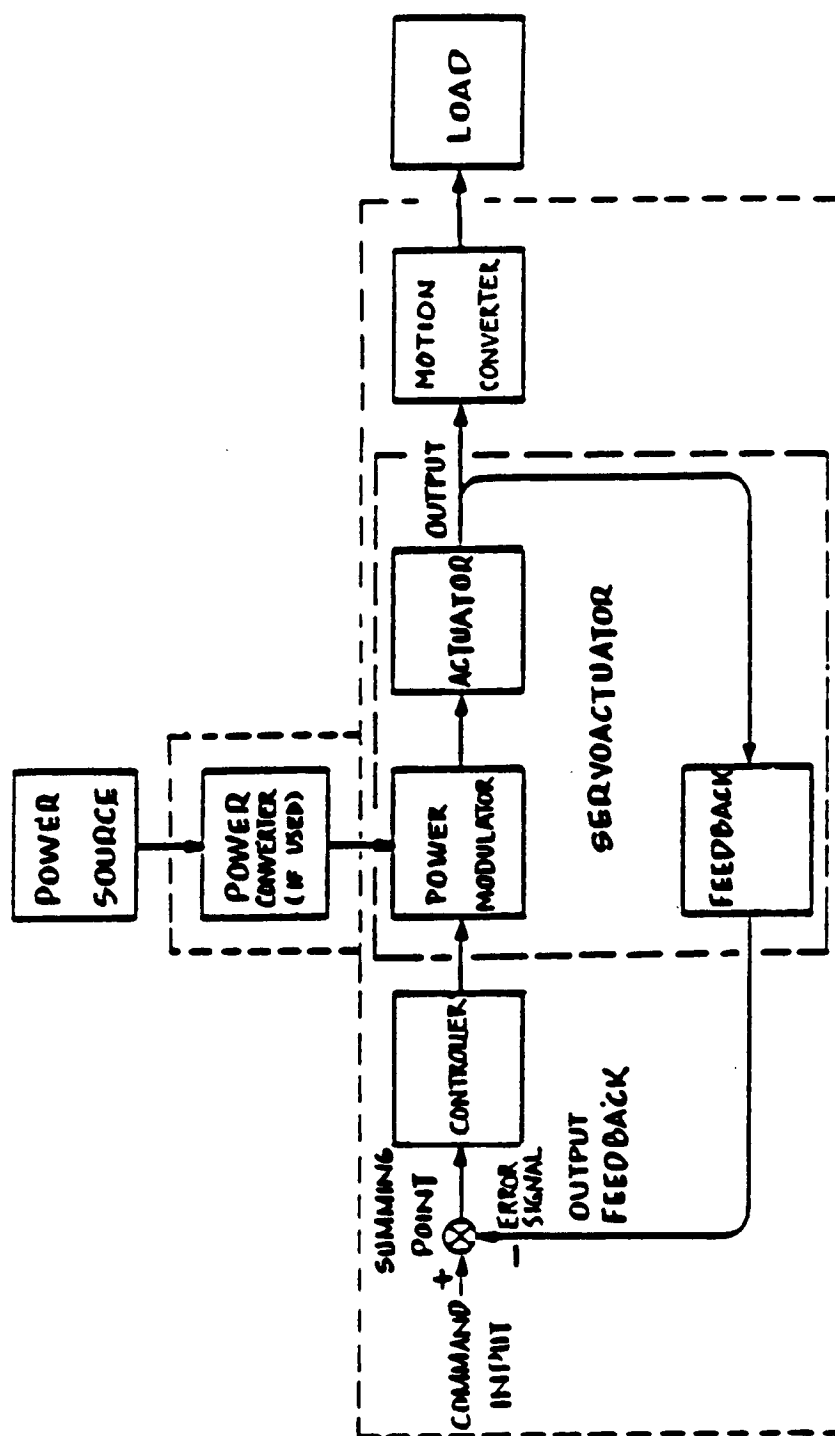


FIGURE 4 - Complete Servoactuation System

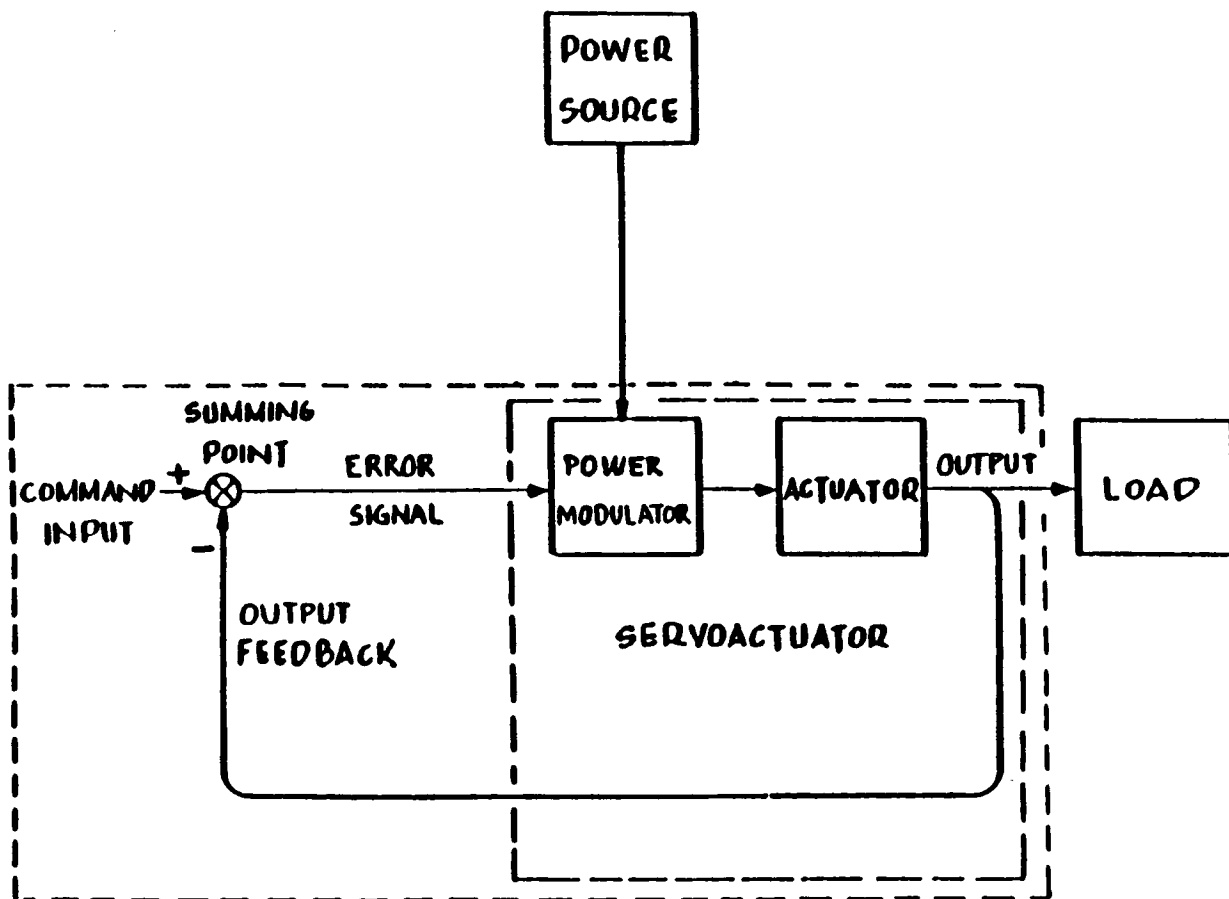


FIGURE 5 – Simple Servoactuation System

## TERMS

## DEFINITIONS

## Actuator

The component of the actuation system that does work or dissipates energy to control a load. Actuator output is achieved by conversion of energy from the power system or load into mechanical work, torque, or force.

## Controller

The component of the actuation system that controls the power modulator as a function of the command or error signal. Many of the electronic controllers have dynamic compensation as well as significant gain, so they must be recognized as separate components in the actuator loop.

## Feedback Element

The component of the actuation system that measures the system output and transforms it in to a form compatible with the command signal.

## Motion Converter

The component of the actuation system that converts the motion of the actuator in to the motion of the load. For example, a ball screw converts rotary motion into linear and a crank arm converts linear motion into rotary.

## Power Converter

The component of the power system that transforms energy from the power source in to a form compatible with the servoactuator requirements.

## Power Modulator

The component of the actuation system that regulates the potential energy of the power source to the actuator as a function of controller output. In a simple hydraulic power boost system, which has no separate controller, the power modulator controls the power to the actuator directly as a function of the command or error signal. See Fig. 5.

## Power Source

The component that supplies energy for load actuation.

## Power System

The power system generates, conditions, and distributes power to the servoactuator. It is not a part of the servo actuation system.

## Servoactuator

An assembly of a controller, an actuator, and feedback element(s), typically packaged together as a single line replaceable unit (LRU).