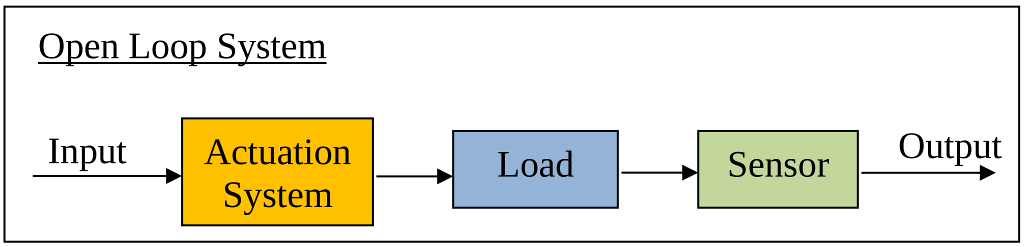
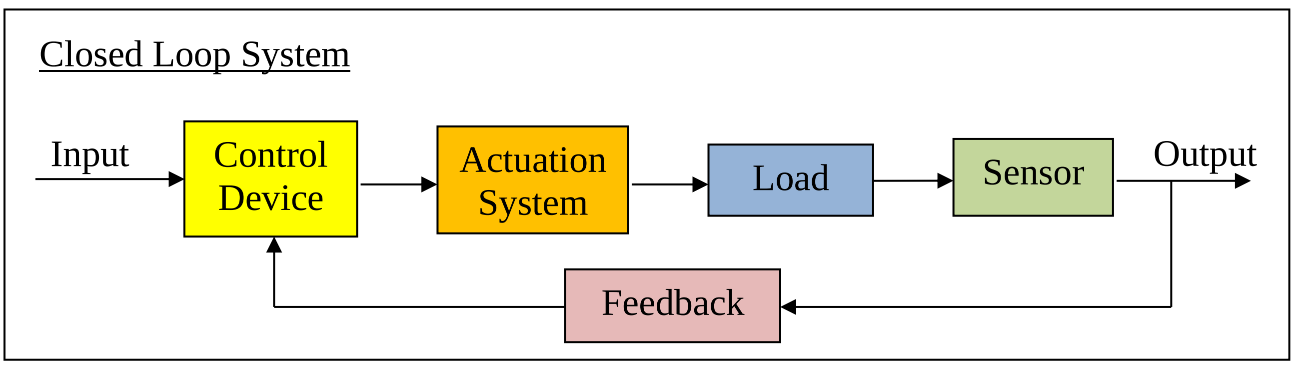
**Introductory Motion and Control**
**Introduction to Motion Control**

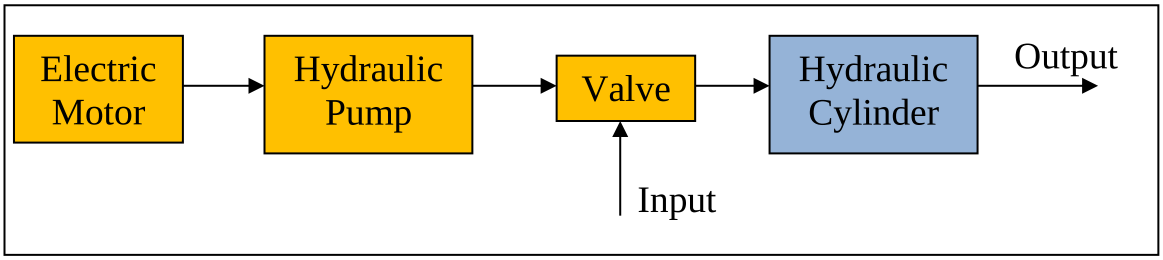
The basic job of a motion control system is to control the ***position, velocity*** and/or ***acceleration*** of some load. A motion control system consists of an ***actuation system***, a ***sensor*** (or sensors), and, if required, a ***control device***. In an ***open loop*** system, a ***command*** is sent directly to the ***actuation system*** to move the load, and a ***sensor*** is used to ***measure*** the response. In a ***closed loop*** system, a ***command*** is made to the ***controlling device*** that, in turn, ***commands*** the ***actuation system*** to move the load. ***Feedback*** is used to automatically correct for response errors. The responses of open and closed loop systems can be ***very different***.

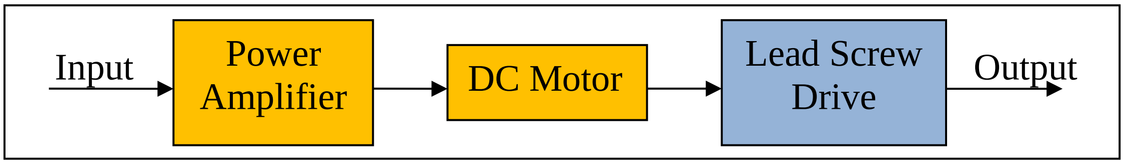



Actuation Systems

An ***actuation system*** contains the necessary components to ***move*** the ***required load***. In general, these systems convert ***chemical*** or ***electrical*** forms of power into ***mechanical power*** to complete the task. Examples include ***engines, electric motors, pumps, hydraulic motors, air compressors, signal*** and ***power amplifiers, electrical solenoids, hydraulic*** and ***pneumatic cylinders,*** and ***valves***. Examples of ***electro-hydraulic*** and ***electro-mechanical*** actuation systems are shown below.




Sensors

Sensors are used to ***monitor*** the ***behavior*** of the system. They should provide ***accurate*** and ***timely measurements*** of important variables within the system. Examples include ***strain gages***, ***pressure gages/transducers***, ***force gages/transducers***, ***flow meters***, ***limit switches***, ***potentiometers***, ***linear variable differential transformers (LVDT)***, ***accelerometers***, ***tachometers***, ***encoder wheels***, ***thermocouples***, ***and resistance temperature detectors (RTD)***.

Sensors can be used to measure the ***position***, ***velocity***, and ***acceleration*** of the load; however, additional sensors may be used to measure other important variables in the system. In an ***electro-hydraulic*** actuation system, for example, there can also be feedback of the ***valve spool position*** and ***fluid pressure*** and ***flow rate***. In an ***electro-mechanical*** system, there can also be feedback of the ***motor speed***. The use of ***additional sensors*** and ***feedback loops*** makes the system more complicated and costly, but it may ***increase system performance*** if properly designed.

Control Device

The ***control device*** may have ***analog circuits***, ***digital circuits***, or both. In either case, the control device must have the ability to form ***differences*** (or sums), ***amplify***, ***integrate***, and ***differentiate*** to behave as our control loop design requires. Analog circuits depend heavily on the use of ***operational amplifiers*** (called Op-Amps). Digital control devices are implemented using microprocessors either in a ***PC-based*** system, a ***microcontroller***, or a ***program logic controller*** (***PLC***). ***PLC's*** are very commonly used in industrial control applications requiring ***continual***

***operation***. PC-based control devices are more commonly used in ***testing***, ***development***, and ***research*** environments.

Analog-to-digital (***A/D***) and digital-to-analog (***D/A***) ***converters*** are required for digital control devices to interface with analog processes and sensors. Two important characteristics of these converters are ***speed*** and ***resolution***. The ***raw speed*** of the converter and the ***number of channels*** it supports determines its ***effective speed***. In some systems, ***each channel*** of data has its own ***dedicated*** converter, while in others a ***single converter*** is ***shared*** by ***multiple channels*** using a multiplexer. ***Resolution*** is determined by the ***number of bits*** used in the conversion process. The ***quantization error*** for a converter using *n* bits in the conversion process is

$$\boxed{e_Q = \frac{V_{\max} - V_{\min}}{2^n - 1}}$$

Here, $V_{\max} - V_{\min}$ represents the ***maximum voltage range*** of the converter. It is important to use the ***full range*** of the converters and use ***enough bits*** to provide the desired resolution.