Chapter 1:
Mechatronics System Design

Problem 1:
What is Mechatronics? How is it different from the traditional approach of designing? State the advantage of using the mechatronic design methodology?

Solution:
Mechatronics is essentially a combination of several engineering and technological disciplines. Different than traditional methods of design, mechatronics design usually involves concurrent engineering rather than designing a mechanical system first, then figuring out how to design controls and electronics. The mechatronics design methodology is based on a concurrent, instead of sequential, approach to discipline design, resulting in products with more synergy. Mechatronics combines mechanical, electrical and computer engineering practices into a method that is useful for system optimization. Mechatronics design usually leads to a reliable and effective system. Mechatronics products exhibit performance characteristics that were previously difficult to achieve without the synergistic combination.

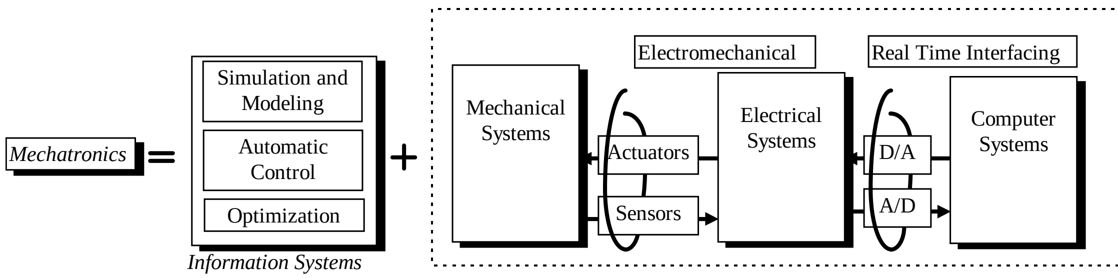


Figure **Error! No text of specified style in document.** Mechatronics key elements

Mechatronics is the result of applying information systems to physical systems. The physical system consists of mechanical, electrical, and computer systems as well as actuators, sensors, and real time interfacing. In some of the literature, this block is called an electromechanical system.

Mechatronics is really nothing but good design practice. The basic idea is to apply new controls to extract new levels of performance from a mechanical device. Sensors and actuators are used to transduce energy from high power, usually the mechanical side, to low power, the electrical and computer side. The block labeled mechanical systems frequently consists of more than just mechanical components and may include fluid, pneumatic, thermal, acoustic, chemical, and other disciplines as well.

Problem 2:
What is the function of a sensor and an actuator in a Mechatronic System? List different types of actuators with at least two examples of each type.

Solution:
Sensors are required to monitor the performance of machines and processes. Sensing systems can be used to evaluate operations, machine health, inspect the work in progress and identify parts and tools. Sensors are needed to provide real-time information that can assist controllers in identifying potential bottlenecks, breakdowns, and other problems with individual machines and with a total manufacturing environment. Using a collection of sensors one can monitor one or more variables in a process. Sensors must be able to ascertain conditions instantaneously and accurately, and provide usable data to system controllers.

Some of the more common measurement variables in mechatronic systems are temperature, speed, position, force, torque and acceleration. Intelligent sensors are available that not only sense information but process it as well. These sensors facilitate operations normally performed by the control algorithm, which include automatic noise filtering, linearization sensitivity, and self-calibration. Microsensors could be used to measure flow, pressure, or concentration of various chemical species in environmental and mechanical applications. Many micro sensors, including biosensors and chemical sensors can be mass-produced. The ability to combine these mechanical structures and electronic circuitry on the same piece of silicon is also important.

Actuators are another important component of a mechatronic system. Actuators are usually electrical, mechanical, fluid power or pneumatic-based. They transform electrical inputs into mechanical outputs such as force, angle and position. Actuators can be classified into three general groups:

- Electromagnetic actuators (e.g.: AC and DC electrical motors, stepper motors, electromagnet)
- Fluid power actuators (e.g.: hydraulics, pneumatics)
- Unconventional actuators (e.g.: piezoelectric, magnetostrictive, etc.)

Problem 3:
Understand the purpose of the following mechatronic system and recommend an appropriate sensor and actuator to carry out the specified task.

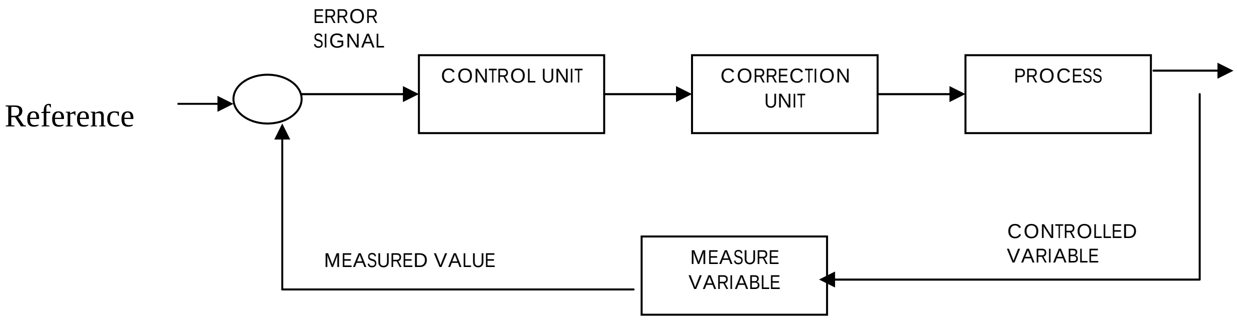
a. Temperature Control System
Purpose: To maintain the temperature of a confined space at the specified temperature. **(**Hint: Decide how to sense the temperature. Decide how to increase or decrease temperature.)

b. Anti-lock Braking System
Purpose: To prevent wheel lock-up by automatically modulating the brake pressure during an emergency stop. **(**Hint: Decide how to sense that the wheels are locked (i.e.: the wheels are not rolling). Decide how to apply or release brakes.)

Solution:

a. Temperature Control System

To control the temperature of a confined space at a specified temperature, an example of a thermostat could be used to control the furnace supplying heat. The thermostat would be programmed with a specific “deadband”, or a range of acceptable temperature for the room. If the temperature of the space drops below the deadband of the thermostat, the thermostat turns the furnace on. Once the thermostat senses that the furnace has heated the space enough, it then shuts the furnace “off”. Having a deadband rather than a single control temperature minimizes the amount of start-ups and shut-downs of the system.



For a thermostatically controlled room heater:
Controlled variable = room temp.
Reference value = required room temp.
Error signal = difference between measured & required temp.
Correction unit = regulator
Process = heating
Measuring device = thermostat

b. Anti-lock Braking System

An anti-lock braking system, or ABS, is a safety system which prevents the wheels on a motor vehicle from locking up (or ceasing to rotate) while braking. In the automobiles fitted with ABS systems, a rotating road wheel allows the driver to maintain steering control under heavy braking by preventing a skid and allowing the wheels to continue interacting with the road surface as directed by driver steering inputs.

In the anti-lock braking system, a sensor at each wheel would need to be used to check the status of the wheels. If the sensor determines that the wheel has stopped spinning during heavy braking, it would then need to rapidly vary the brake pressure to stop the wheels from locking. A simple counting sensor could be used to track the rotation of the wheels. For example, if the sensor stops counting the rotations, this would turn the anti-lock braking system on. A high speed valve or hydraulic actuator would need to be utilized to rapidly change the brake pressure to get the wheels spinning again.

The modern ABS system applies individual brake pressure to all four wheels through a control system of hub mounted sensors and a dedicated micro-controller. A typical ABS is composed of a central electronic control unit (ECU), four wheel speed sensors — one for each wheel — and two or more hydraulic valves within the brake hydraulics. The

ECU constantly monitors the rotational speed of each wheel, and when it detects a wheel rotating significantly slower than the others — a condition indicative of impending wheel lock — it actuates the valves to reduce hydraulic pressure to the brake at the affected wheel, thus reducing the braking force on that wheel. The wheel then turns faster when the ECU detects it is turning significantly faster than the others, brake hydraulic pressure to the wheel is increased so the braking force is reapplied and the wheel slows. This process is repeated continuously, and can be detected by the driver via the brake pedal.