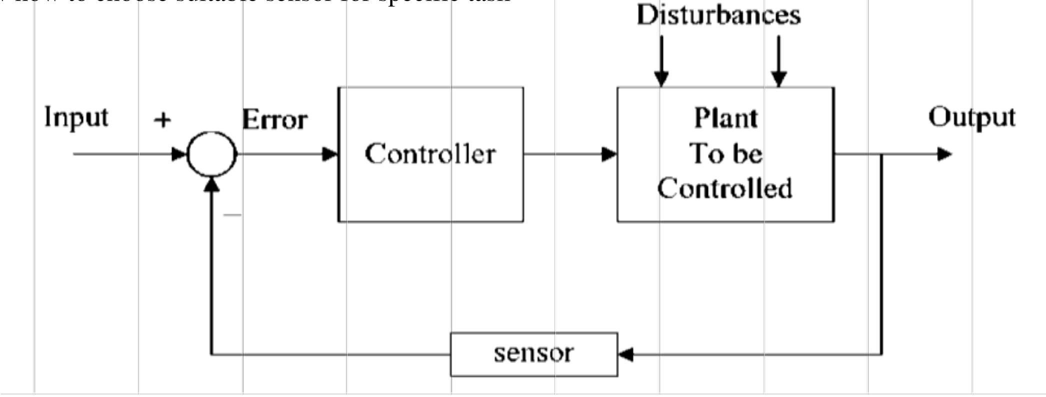
Umm Al-Qura University
College of Engineering & Islamic Architecture
Mechanical Engineering Department

Course #: 804465–Automatic Control Lab #2

Sensors in Control Systems

Objective

- To study sensors, their types and working in control systems.
- To know how to read sensor data sheets
- To know how to choose suitable sensor for specific task



A sensor is a device that outputs a signal which is related to the measurement of (i.e. is a function of) a physical quantity such as temperature, speed, force, pressure, displacement, acceleration, torque, flow, light or sound. Sensors are used in closed-loop systems in the feedback loops, and they provide information about the actual output of a plant.

The choice of a sensor for a particular application depends on many factors such as the cost, reliability, required accuracy, resolution, range and linearity of the sensor. Some important factors are described below.

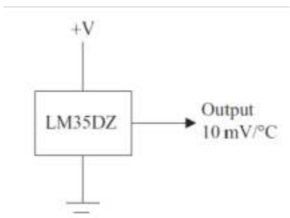
Range.
The range of a sensor specifies the upper and lower limits of the measured variable for which a measurement can be made.
Resolution.
The resolution of a sensor is specified as the largest change in measured value that will not result in a change in the sensor's output, i.e. the measured value can change by the amount quoted by the resolution before this change can be detected by the sensor.
Repeatability.
The repeatability of a sensor is the variation of output values that can be expected when the sensor measures the same physical quantity several times.
Linearity.
An ideal sensor is expected to have a linear transfer function, i.e. the sensor output is expected to be exactly proportional to the measured value.
Dynamic response.
The dynamic response of a sensor specifies the limits of the sensor characteristics when the sensor is subject to a sinusoidal frequency change.

Temperature Sensors

Temperature is one of the fundamental physical variables in most chemical and process control applications. Accurate and reliable measurement of the temperature is important in nearly all process control applications. Temperature sensors can be analog or digital. Some of the most commonly used **analog temperature sensors** are:

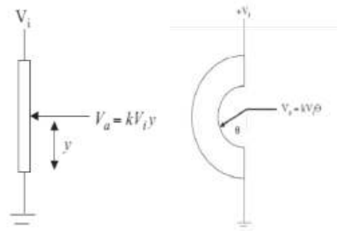
thermocouples, resistance temperature detectors (RTDs) and thermistors. **Digital sensors** are in the form of integrated circuits. The choice of a sensor depends on the accuracy, the temperature range, speed of response, thermal coupling, the environment (chemical, electrical, or physical) and the cost.

A popular voltage output analog integrated circuit temperature sensor is the **LM35DZ**, manufactured by National Semiconductors Inc. This is a 3-pin analog output sensor which provides a linear output voltage of 10mV/^{0}C. The temperature range is 0 ^{0}C to +100 ^{0}C, with an accuracy of +-1.5 ^{0}C.



Position sensors

Position sensors are used to measure the position of moving objects. These sensors are basically of two types: sensors to measure linear movement, and sensors to measure angular movement. Potentiometers are available in linear and rotary forms. In a typical application, a fixed voltage is applied across the potentiometer and the voltage across the potentiometer arm is measured. This voltage is proportional to the position of the arm, and hence by measuring the voltage we know the position of the arm.



Linear Potentiometer Rotary potentiometer

Among other types of position sensors are capacitive sensors, inductive sensors, linear variable differential transformers (LVDTs) and optical encoders.

Velocity and acceleration sensors

One of the most widely used rotary velocity sensors is the tachometer (tacho-generator).A tachometer (see Figure) is connected to the shaft of a rotating device (e.g. a motor)and produces an analog D.C. voltage which is proportional to the speed of the shaft. If ω is the angular velocity of the shaft, the output voltage of the tachometer is given by $V_0 = k\omega$,

where k is the gain constant of the tachometer.

Another popular velocity sensor is the optical encoder. This basically consists of a light source and a disk with opaque and transparent sections where the disk is attached to the rotating shaft. A light sensor at the other side of the wheel detects light and a pulse is produced when the transparent section of the disk comes round. The encoder's controller counts the pulses in a given time, and this is proportional to the speed of the shaft.

Tachometer

Optical encoder

Acceleration is the differentiation of velocity, or the double differentiation of position. Thus, in general, position sensors can be used to measure acceleration. The differentiation can be done either by using operational amplifiers or by a computer program. For accurate measurement of the acceleration, semiconductor accelerometers can be used. For example, the ADXL202 is an accelerometer chip manufactured by Analog Devices Inc. This is a low-cost 8-pin chip with two outputs to measure the acceleration in two dimensions. The measurement range of the ADXL202 is

+-2 *g*, where *g* is acceleration due to gravity, and the device can measure both dynamic acceleration

(e.g. vibration), and static acceleration (e.g. gravity).

Pressure sensors

Early pressure measurement was based on using a flexible device (e.g. a diaphragm) as a sensor; the pressure changed as the device moved and caused a dial connected to the device to move and indicate the pressure. Nowadays, the movement is converted into an electrical signal which is proportional to the applied pressure. Strain gauges, capacitance change, inductance change, piezoelectric effect, optical pressure sensors and similar techniques are used to measure the pressure.

Liquid sensors

There are many different types of liquid sensors. These sensors are used to:

- detect the presence of liquid;
- measure the level of liquid;
- measure the flow rate of liquid, for example through a pipe.

The presence of a liquid can be detected by using optical, ultrasonic, change of resistance, change of capacitance or similar techniques.