Basic Mechatronics Workshop

Module 2: Sensors

LAB-3

Sensor Circuits, Power and Constant voltage, Detector, Amplifier, Display, Output

(Conference of Presentation)

Dr. Mohamed Abdalbar

Lecturer, Mechatronics Department,

Egyptian-Korean Faculty of Technological Industry and Energy,

Beni Suef Technological University

Email: mh_abd2001@yahoo.com

LAB-3

Sensor Circuits, Power and Constant voltage, Detector, Amplifier, Display, Output

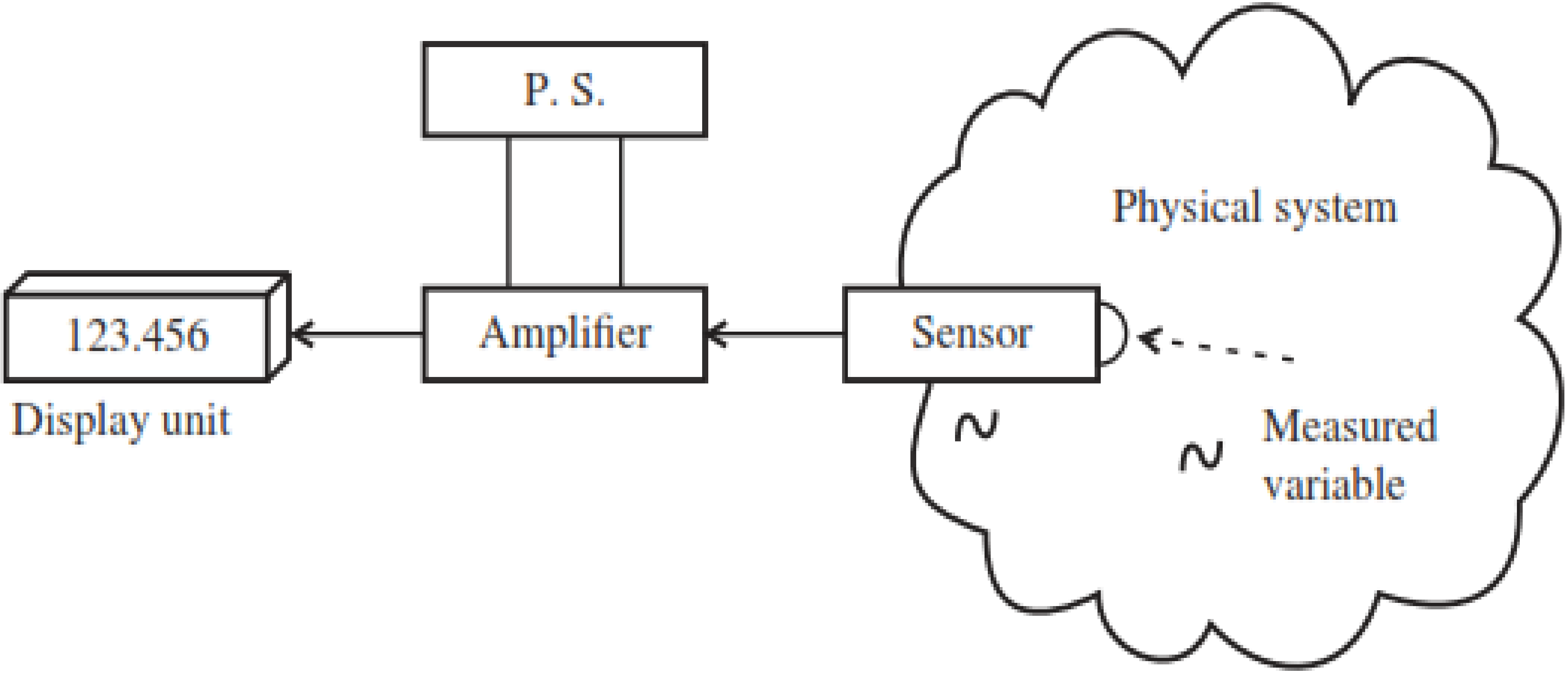
(Conference of Presentation)

Tasks

1. Understand the basic concept of a measurement device
2. Explain the sensor signal conditioning circuit operations.
3. Define the function of the operational amplifier (op-amp)
4. List the different types of the filtering signals
5. Describe sensor protection circuits
6. Explain ADC and DAC data conversion devices

Basic concept of a measurement device

The components of a sensor: sensor head, amplifier, power supply, display or processing unit.



There are three basic phenomena in effect in any sensor operation:

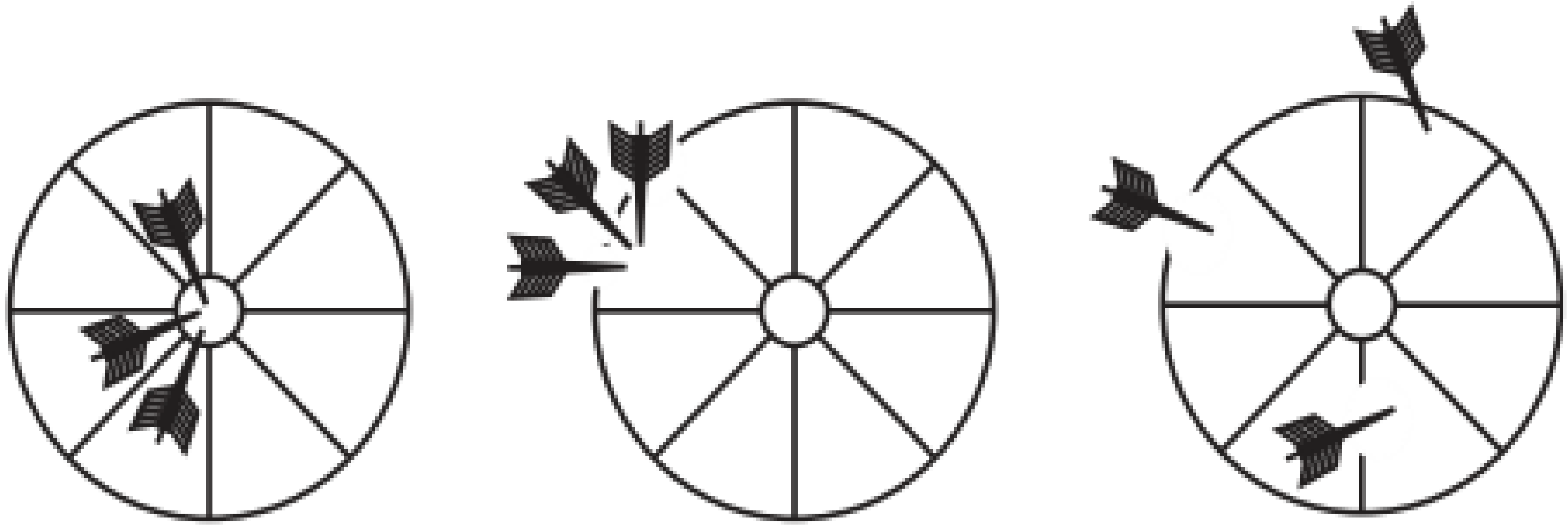
1. The change in the measured physical variable (i.e., pressure, temperature, displacement) is translated into a change in the property (resistance, capacitance, magnetic coupling) of the sensor. This is called the transduction. The change of the measured variable is converted to an equivalent property change in the sensor. The transduction relationship, that is the *relationship between the measured variable and the change in the sensor material property*, is the fundamental physical principle of the sensor operation.

2. The change in the property of the sensor is translated into a low power level electrical signal in the form of voltage or current.

3. This low power sensor signal is amplified, conditioned (filtered), and transmitted to an intelligent device for processing, for example to a display for monitoring purposes or use in a closed loop control algorithm.

Sensor types vary in the transduction stage in measuring a physical variable. In response to the physical variable, a sensor may be designed to change its resistances, capacitance, inductance, induced current, or induced voltage.

The meaning of *accuracy, repeatability, and resolution.*



(a) (b) (c)

The definitions of accuracy and repeatability: (a) accurate, (b) repeatable, but not accurate, (c) not repeatable, not accurate.

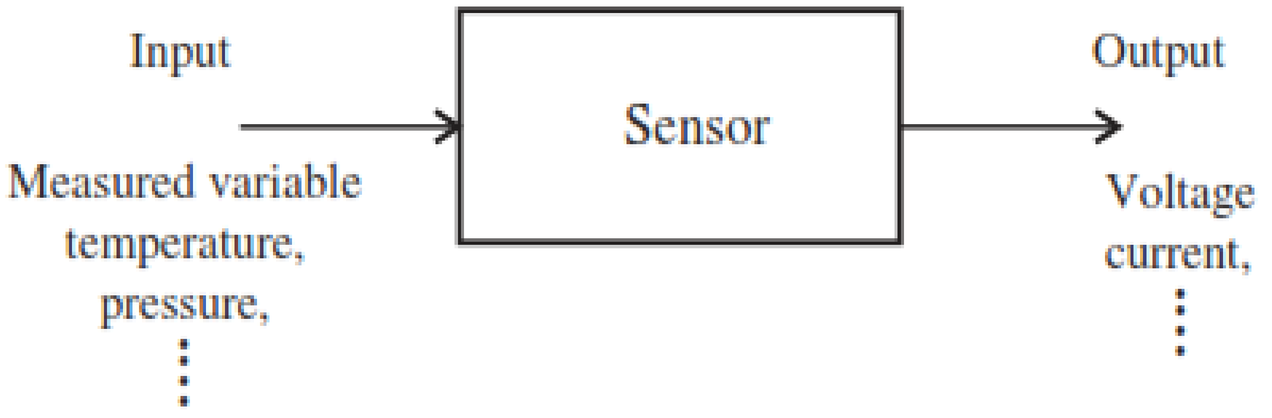
Resolution is the smallest positional change the arrow can be placed on the target (imagine that the target has many small closely spaced holes and the arrow can only go into one of these holes).

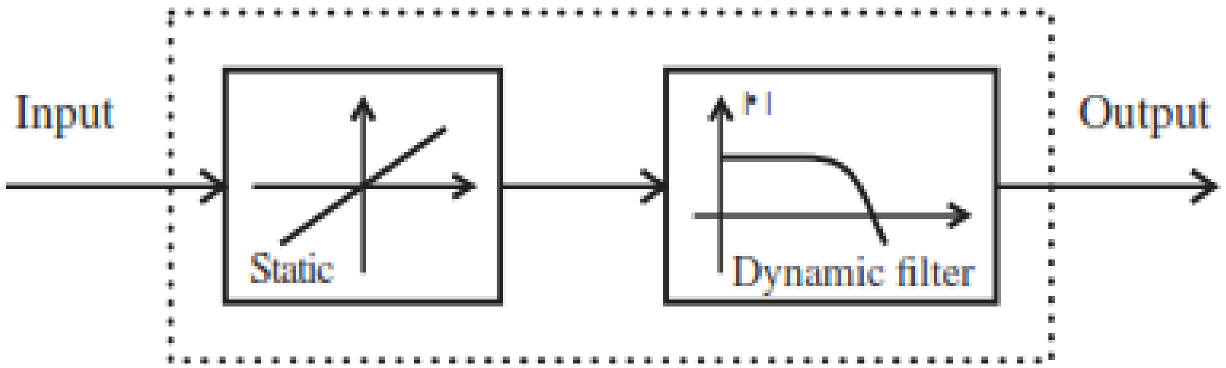
The *accuracy, repeatability, and resolution.*

- ✓ *Resolution* refers to the smallest change in the measured variable that can be detected by the sensor.
- ✓ *Accuracy* refers to the difference between the actual value and the measured value. Accuracy of a measurement can be determined only if there is another way of more accurately measuring the variable so that the sensor measurement can be compared with it. In other words, accuracy of a measurement can be determined only if we know the true value of the variable or a more accurate measurement of the variable.
- ✓ *Repeatability* refers to the average error in between consecutive measurements of the same value. The same definitions apply to the accuracy of a control system as well. In a measurement system, repeatability can be at best as good as the resolution.

Input–Output behavior of a generic sensor

- ✓ The dynamic response of a sensor can be represented by its frequency response or by its bandwidth specification.
- ✓ The bandwidth of the sensor determines the maximum frequency of the physical signal that the sensor can measure.
- ✓ For accurate dynamic signal measurements, the sensor bandwidth must be at least one order of magnitude (X10) larger than the maximum frequency content of the measured variable.





Input–output model of a sensor: steady-state (static) input and output relationship plus the dynamic filtering effect.

Typical non-ideal characteristics of a sensor include

1. gain changes,

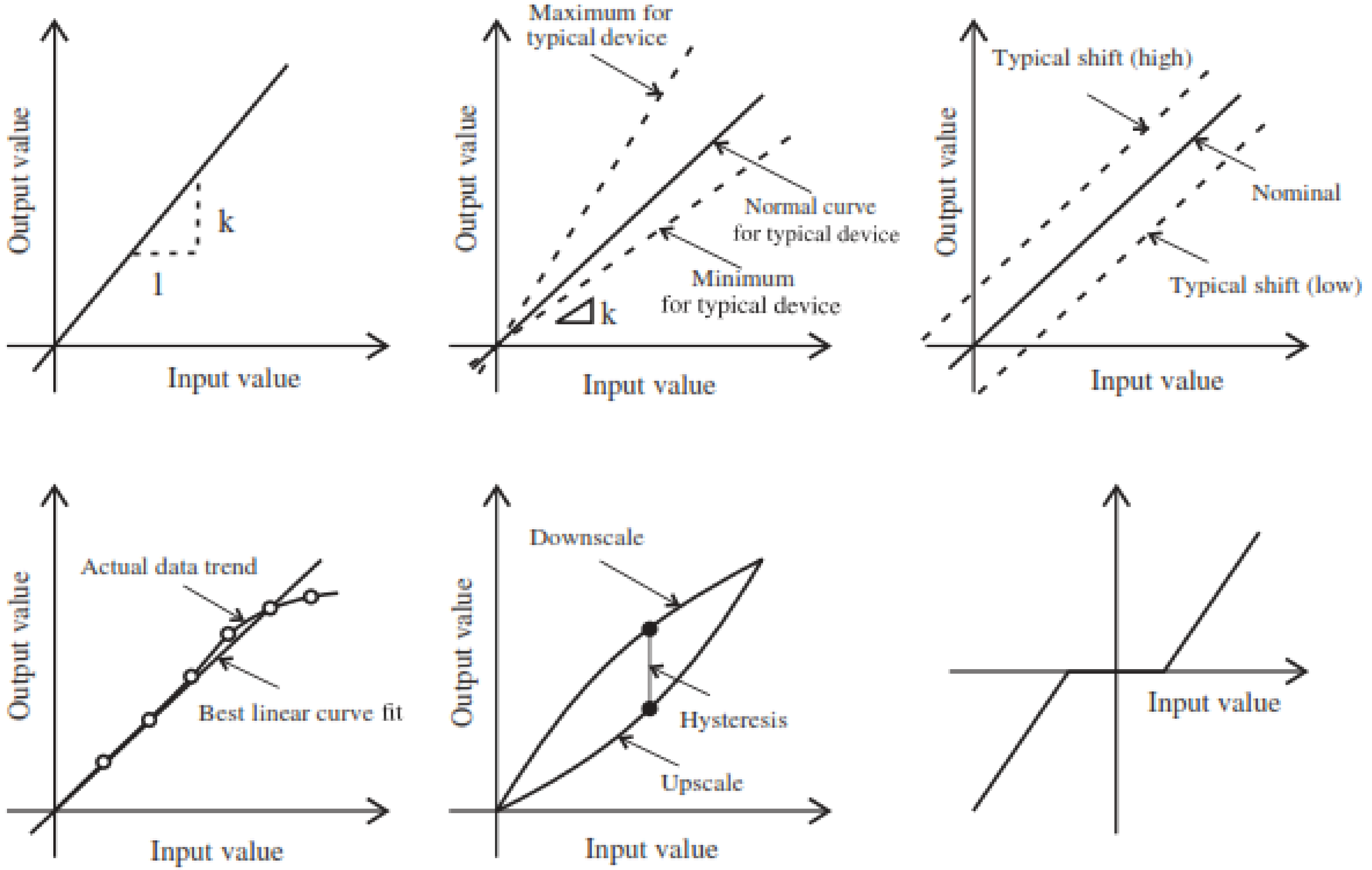
2. offset (bias or zero-shift) changes,

3. saturation,

4. hysteresis,

5. Deadband

6. drift in time

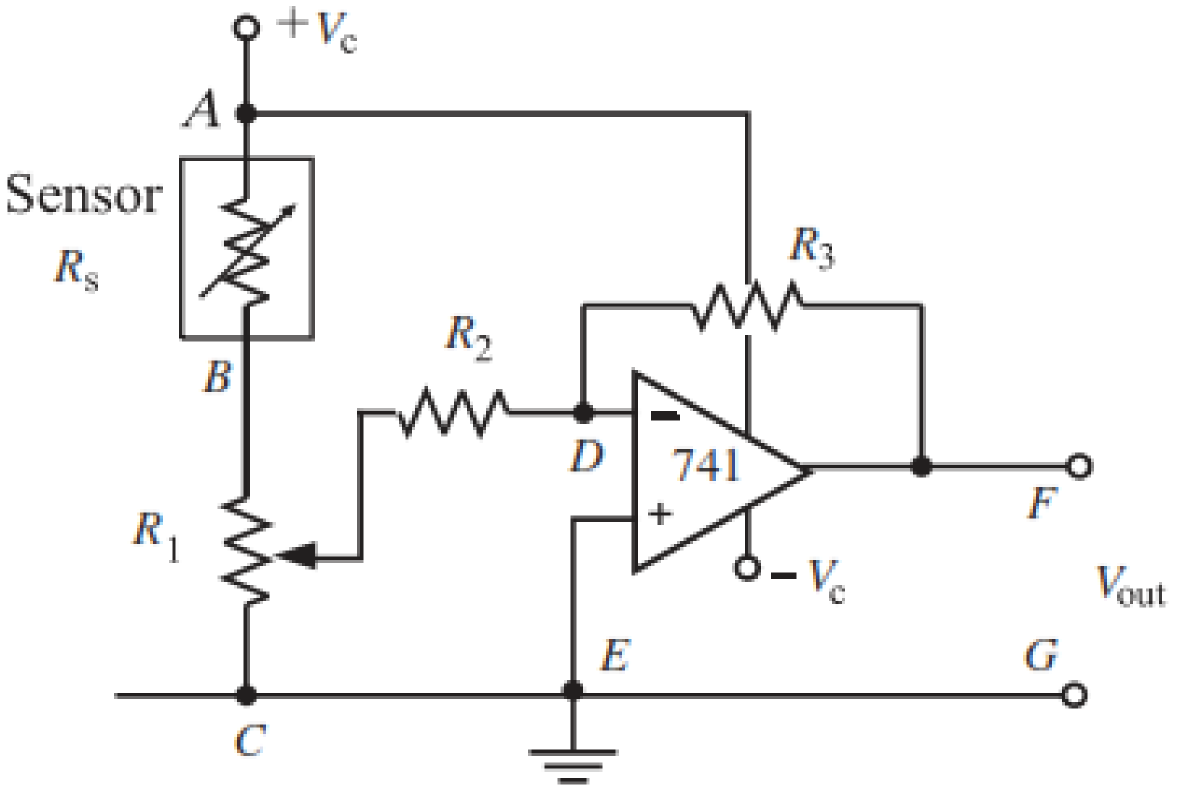


sensor calibration

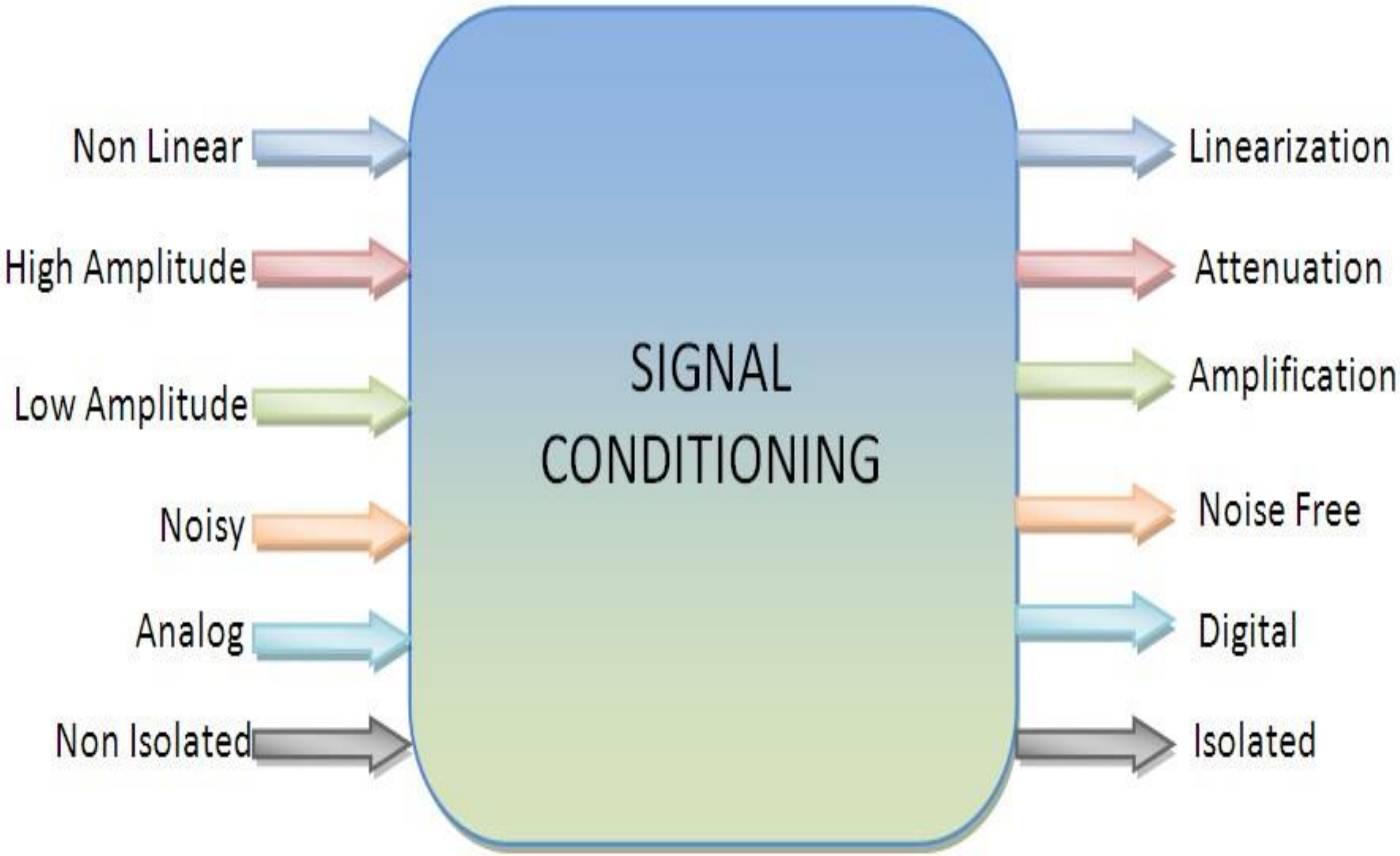
Sensor calibration refers to adjustments in the sensor amplifier to compensate for the variations so that the input (measured physical variable) and output (sensor output signal) relationship stays the same.

The sensor calibration process involves adjustments to compensate for variations in gain, offset, saturation, hysteresis, dea

$$V_{out} = \frac{R_3}{R_2} \times \frac{R_1(y)}{R_s(x) + R_1} \times V_c$$



Signal Conditioning Operations



Signal Conditioning Operations

Signal conditioning system enhances the quality of signal coming from a sensor in terms of:

1. **Protection**

To protect the damage to the next element of mechatronics system such microprocessors from the high current or voltage signals.

2. **Right type of signal**

To convert the output signal from a transducer into the desired form i.e. voltage /current.

3. **Right level of the signal**

To amplify or attenuate the signals to a right /acceptable level for the next element.

4. **Noise**

To eliminate noise from a signal.

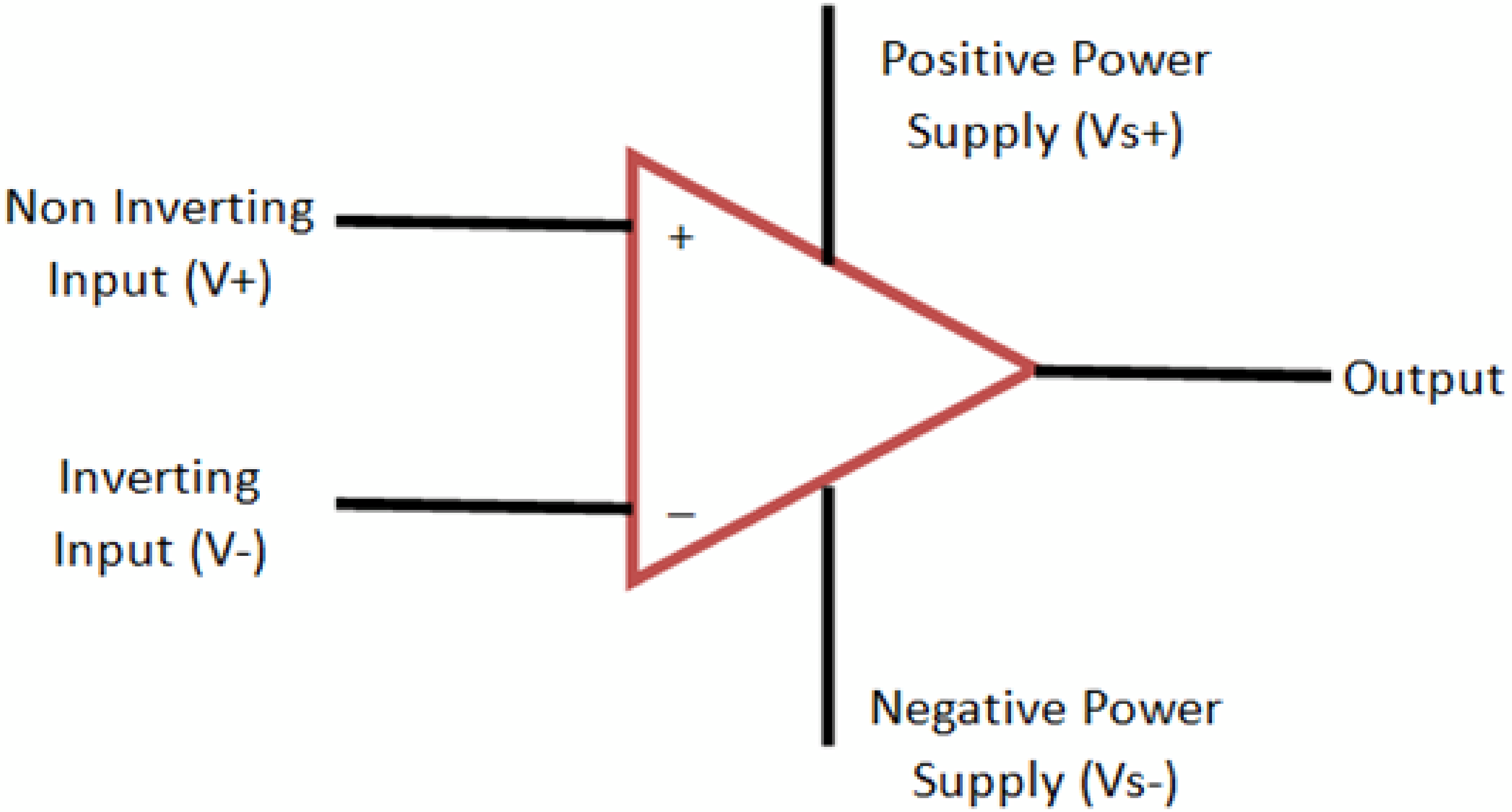
5. **Manipulation**

To manipulate the signal from its nonlinear form to the linear form.

1. Amplification/Attenuation

Various applications of Mechatronics system such as machine tool control unit of a CNC machine tool accept voltage amplitudes in range of 0 to 10 Volts. However, many sensors produce signals of the order of milli volts. This low-level input signals from sensors must be amplified to use them for further control action. Operational amplifiers (op-amp) are widely used for amplification of input signals. The details are as follows.

Operational amplifier (op-amp)



Circuit diagram of an Op-amp

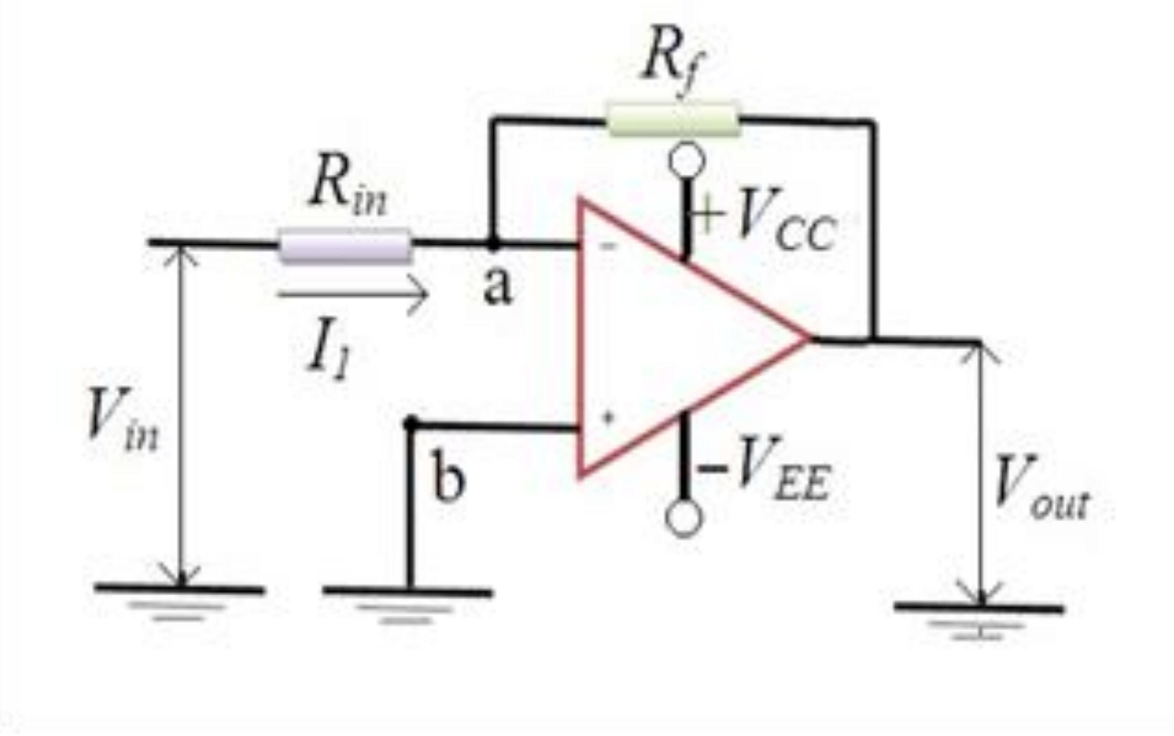
Operational amplifier (op-amp)

$$V_{out} = G * (V+ - V-)$$

where G is Op-amp Gain.

At node a, current can write,

$$I_1 = V_{in}/R_1$$



Inverting op-amp

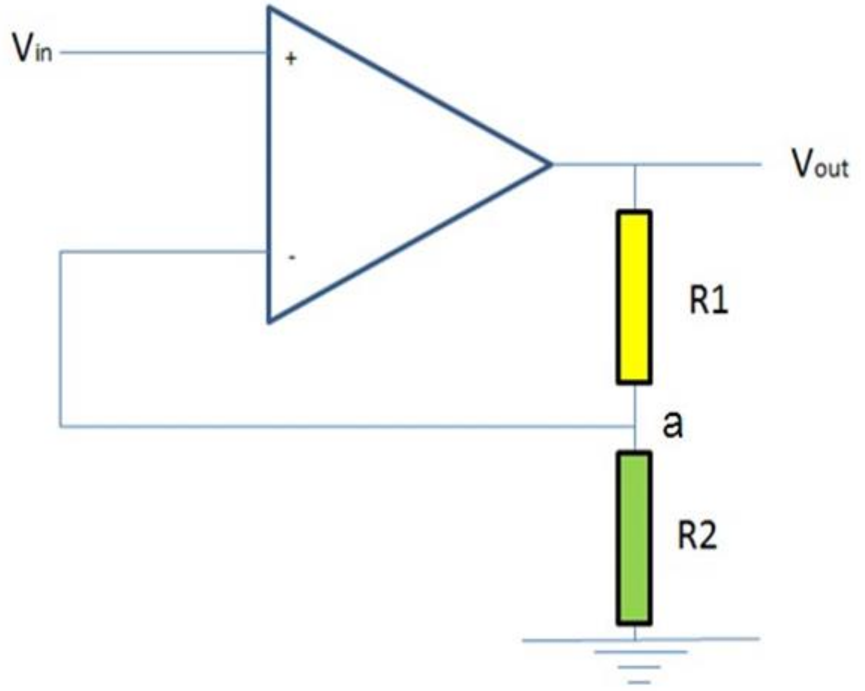
The output voltage is given by,

$$Vout = -I_1 R_f = -V_{in} R_f / R_1$$

Thus, the closed loop gain of op-amp can be given as,

$$G = V_{out}/V_{in} = -R_f/R_1$$

Amplification of input signal by using Op-amp



Amplification using an Op-amp

Figure shows a configuration to amplify an input voltage signal. It has two registers connected at node a. If we consider that the voltage at positive terminal is equal to voltage at negative terminal, then the circuit can be treated as two resistances in series. In series connection of resistances, the current flowing through circuit is

same. Therefore, we can write,

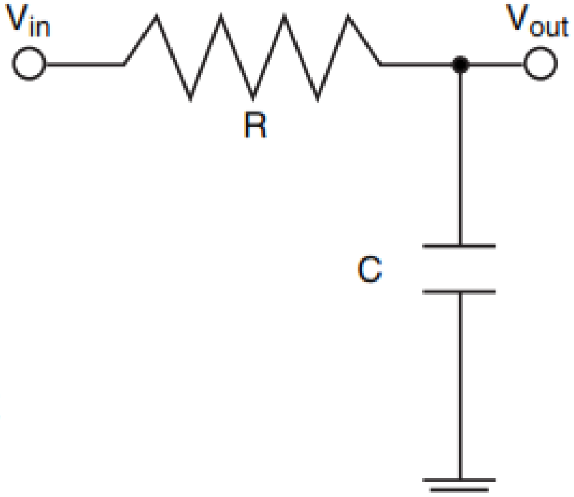
$$\frac{V_{out} - V_{in}}{R_1} = \frac{V_{in} - 0}{R_2}$$

$$\frac{V_{out} - V_{in}}{R_1} = \frac{V_{in}}{R_2}$$

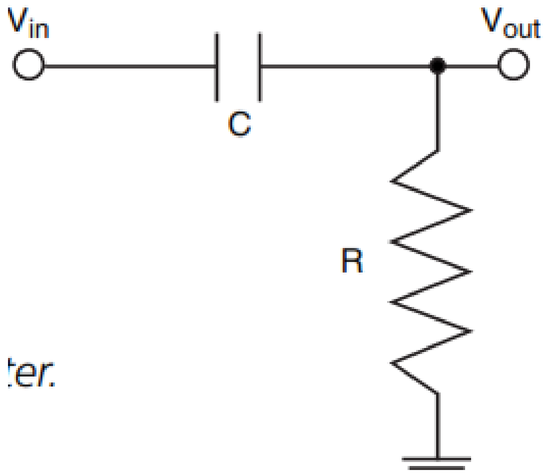
Filtering

Output signals from sensors contain noise due to various external factors like improper hardware connections, environment etc. Noise gives an error in the final output of system. Therefore, it must be removed. In practice, change in desired frequency level of output signal is a commonly noted noise. This can be rectified by suing filters. Following types of filters are used in practice:

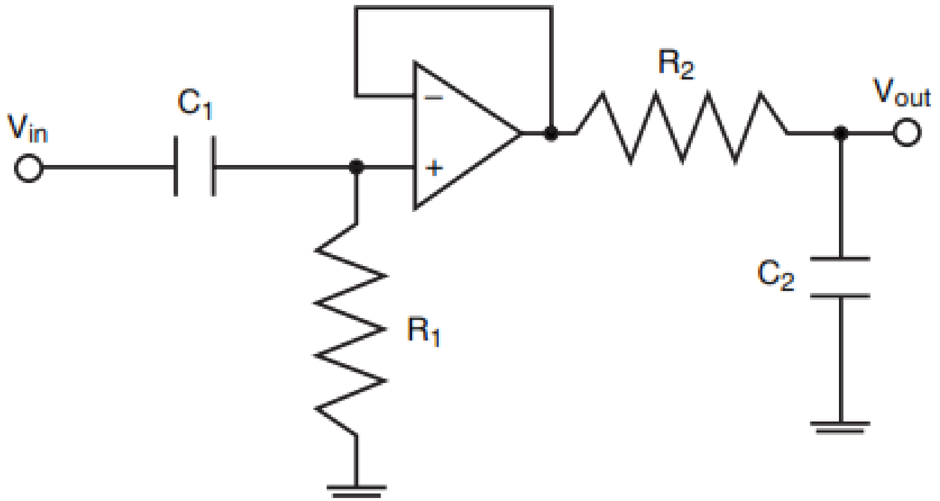
1. Low Pass Filter



2.High Pass Filter



1. Band Pass Filter



1. Protection

In many situations sensors or transducers provide very high output signals such as high current or high voltage which may damage the next element of the control system such as microprocessor.

1.1 Protection from high current

The high current to flow in a sensitive control system can be limited by:

1. Using a series of resistors

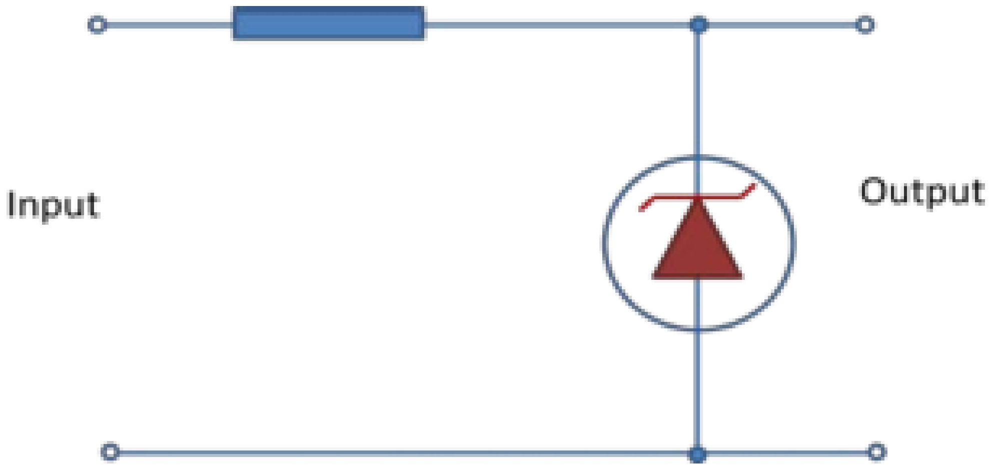
2. Using fuse to break the circuit if current value exceeds a preset or safe value

1. Protection

1.2 Protection from high voltage

Zener diode circuits are widely used to protect a mechatronics control system from high values of voltages and wrong polarity. Figure 2.7.1 shows a typical Zener diode circuit.

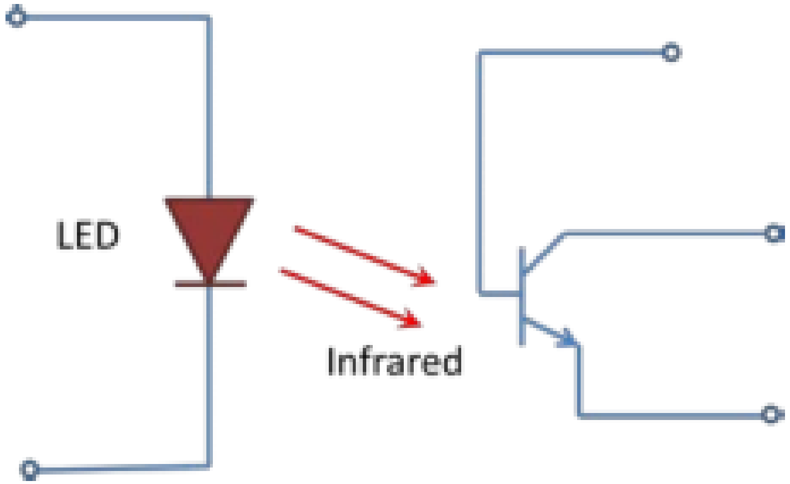
Zener diode acts as ordinary or regular diodes up to certain breakdown voltage level when they are conducting. When the voltage rises to the breakdown voltage level, Zener diode breaks down and stops the voltage to pass to the next circuit.



1. Protection

Zener diode as being a diode has low resistance for current to flow in one direction through it and high resistance for the opposite direction. When connected in correct polarity, a high resistance produces high voltage drop. If the polarity reverses, the diode will have less resistance and therefore results in less voltage drop.

In many high voltage scenarios, it is required to isolate the control circuit completely from the input high voltages to avoid the possible damage. This can be achieved by Optoisolators. Figure shows the typical circuit of an Optoisolator. It comprises of a Light emitting diode (LED) and a photo transistor. LED irradiates infra-red due to the voltage supplied to it from a microprocessor circuit. The transistor detects irradiation and produces a current in proportion to the voltage applied. In case of high voltages, output current from Optoisolator is utilized for disconnecting the power supply to the circuit and thus the circuit gets protected.



Schematic of an Optoisolator.

Data conversion devices

A control system with ADC and DAC devices