K.T.S.P.Mandal's

Hutatma Rajguru Mahavidyalaya, Rajgurunagar

Tal-Khed, Dist.-Pune 410505.

F.Y.BSc (Computer Science)

Semester-II

Electronics Paper-I

Subject- ELC-121 – Instrumentation Systems

According to new CBCS syllabus w.e.f.2019-2020

Prof.Aparna P.Kulkarni

Department of Computer Science

Hutatma Rajguru Mahavidyalaya, Rajgurunagar.

Unit-III- Smart Instrumentation System and Smart Sensors

- Block diagram of Smart Instrumentation System.
- Concept of Smart Sensor.
- Film Sensor, Nano Sensor.

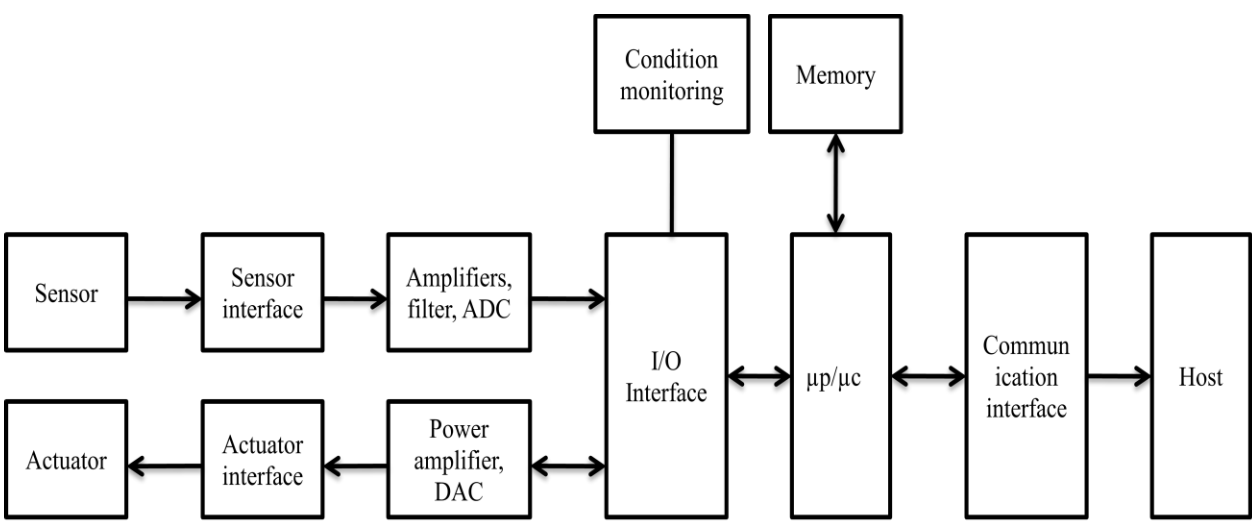
Introduction:

Instrumentation system design for measurement and control of variables makes our lives easy and comfortable. The comfortness level can be increased further by incorporating some intelligence to the system.

Block Diagram of Smart Instrumentation System:

Typical functions that are possible with intelligent instrumentation system are

1. Automatic ranging and calibration.
2. Real time data sensing and storage in local memory.
3. Auto-correction of offsets, timing and drifts.
4. For non-linear sensors, auto-linearization with the help of algorithms or using look up tables.
5. Auto-controlling with the help of fuzzy logic.
6. Easy upgradation of system.
7. Corrective action in case of failure of devices.
8. Communicating data to host for further analysis.



Basic blocks of the system are:

1. Sensor
2. Microprocessor/microcontroller based controller
3. Memory
4. Communication interface
5. Actuator

The blocks have integrated digital technologies. The process variable values are captured by sensors. Now a days smart sensors are also available which has built in signal conditioning circuits. It reduces burden on smart controller.

In case of traditional sensors signal conditioners are required which are digitally controlled. The gain of amplifiers, filtering frequency, resolution or related parameters are set by microprocessor. This is very important advantage as in case of multi-sensing applications, output produced by each sensor may have different voltage / current / frequency / power range. The facility of auto adjustment of signal conditioning parameters can lead to universal signal conditioner, which can be used for any application / sensor / actuator.

The heart of the system is microprocessor / microcontroller.
It does following functions:

1. To receive real time data from sensor through I/O interface.
2. To set the parameters for signal conditioners.
3. Store the acquired data.
4. To make error free data available for communication.
5. To monitor continuously the functions of all blocks.
6. To take corrective measures in case of fault detection.
7. To alert the user in case of problems / non-functioning of the devices.

Main advantage of smart instrumentation system is that since overall system is based on advanced digital technologies, easy upgradation of the system is possible. In case of use of newly developed (sensors / actuators) in replacement of old ones, the same system can be used with little variation in software program.

Concept of Smart Sensor:

A sensor is called as smart sensor if its output is interfaced with electronic circuits which can perform functions like linearization, calibration, ranging, decision making communication and utilization of data etc. Thus smart sensor has digital technologies incorporated inside it will makes it intelligent.

The smart sensor has

1. New sensing methods
2. Improved computing capability and
3. Digital communication.

New sensing methods are implemented from individual sensor synthesis with combined technologies and integration techniques. Digital correction improves performance of smart sensor to meet required specifications.

Features of Smart Sensors

1. Minimization of processing load:

Different variable type needs different kind of processing. If at all centralized computer is used for processing it gets overloaded with processing load.

The smart sensors senses as well as do the sensing related processing within itself. Because of availability of communication interface, the response is communicated to the host system so that the efficiency and accuracy of information distribution increases with reduction in cost.

2. Advanced in-built Processing technologies

Older processing technologies have been replaced by new advanced technologies which increase efficiency and speed of system. Amplification is a common frequently required process. The signals to be amplified are analog. In traditional system, amplifiers using transistor, opamp etc. are used as signal conditioning. In smart sensor programmable gain amplifiers are available in which gain is controlled digitally. This minimizes circuitry and also provides flexibility. Second frequently required signal conditioning is filter. Analog filters are replaced by their digital counterpart.

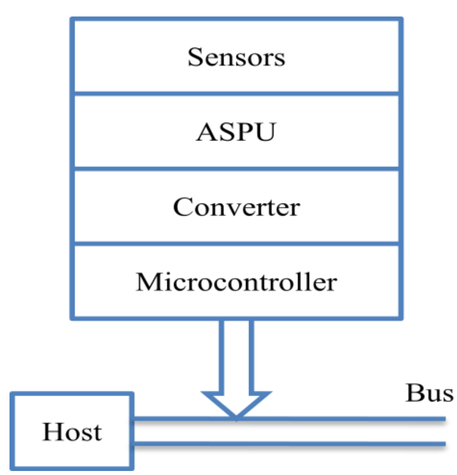
These two need supply. Currently Analog Signal Processing Unit (ASPU) is available which comprise of supply amplification and filter.

Smart sensor also has data conversion module of

a. Analog to digital conversion or
b. Frequency to digital conversion.

These interfaces with the microprocessors for information processing and bus interfacing communication.

Thus typical smart sensor has block diagram as:



3. In built excitation

Excitation is a generalized term used for supply to the primary sensors. When necessary this also means the supply for the entire chip including the processing units. Smart sensors are made available with self excitation.

4. Improved response time

The storage devices imposes quite inferior time response and dynamic correction of sensors becomes necessary. Use of microprocessor make it possible with suitable algorithm.

5. Improved Drift characteristics

Drift in physical parameter is one of the important characteristic of primary sensor occurs either due to ageing or deterioration in ways of oxidation, sulphation and so on. Drift is a kind of noise and should be counteracted. As drift tends to change the sensor characteristics, the reference points also tend to drift. These can be easily updated through an algorithm in smart sensors.

6. Reduction in Noise and interference

There are many unwanted signals called as noise signals affect the performance of sensor. Noise signals may be interference because of external magnetic field, may be introduced at different stages of signal processing such as data conversion, filtering etc.

In smart sensors, noise is minimized using the techniques such as digital filtering, signal averaging correlation.

7. Compensation of non-linearity

Analog processing shows severe nonlinearity. This can be easily compensated using digital processing methods. Such as look up table reference, interpolation techniques etc.

Recent Trends in Sensors:

Conventional sensors are replaced by solid state sensors, semiconductor micro-and nano-sensors, ceramic and chemical sensors etc. these offer better performance. Besides, reliability, sensitivity, uniformity and stability are also better.

Film Sensor:

Film sensors are produced by depositing a film of different thickness on the substrate. Working principles of these sensors show changes in electrical and mechanical properties with process variable. There are two types of film sensors:

1. Thick film sensors
2. Thin film sensors

Thick film sensors

The sensors are produced by thick film deposition of 20 um. They are used for sensing temperature, pressure, gas concentration and humidity.

The thick film process has been use for producing capacitor, resistor and conductors -and has subsequently been used in thick film sensor development.

The substrate used for smart sensors are alumina and beryllia. Overall sensitivity of sensor is decided by porosity of the films. It is controlled by adding organic materials such as H2, inorganic materials in a selective manner.

The other thick film sensors are cemet which has gold / silver / palladium based oxides in an insulating medium. While fabricating these sensors, precise heat treatment is needed. The resistivity is controlled by the size, concentration and distribution of the metallic component.

Thick film sensors are widely used in automotive industry to check mixture of fuel/air, engine and gearbox control, pressure sensors, sensors for releasing air bags. In all the applications high reliability is required.

Thin film sensors:

A thin film sensor has a coating or layered material that has a thickness ranging from less than a nanometer to several micrometer.

Thin film sensors differ from thick film sensors in film deposition techniques. The techniques used for thin film sensor fabrication are

- Thermal evaporation - may be using resistive heating or electron beam heating.
- Chemical Vapour Deposition (CVD).
- Sputter deposition
- Metallo-organic deposition.

Thin film sensors are precise stable, dependable and cheap. Main advantage is small size, and their distinctive housing being an especially useful feature for particular applications.

The more specified application domains are:

i. Medical field: ‘Tube sensors' are used to keep track of pressure in blocked tube. Useful here because of necessary reliability, durability and precesion needed in this application.

ii. Thin film pressure sensors are commonly used in industrial applications, particularly in hydraulic equipment and vehicles, like cranes, steamrollers, and agricultural machinery.

iii. Depending upon the deposited material, sensors are used for measurement of flow, humidity, oxygen, pressure, magnetic field, strain, temperature, radiation.

Advantages:

Thin film sensors have many advantages over conventional sensors such as

i. Sensor is extremely small and compact.

ii. More précised.

iii. Response time is better

iv. Production methods are efficient and low cost.

v. Are capable of operating at high temperatures.

vi. Not affected by moisture.

Nanosensors:

Nanosensors are nanoscale devices that measure physical quantities and covert those into signal that can be detected and analyzed. Though nano sensors have wide application domain, mainly they are used in medical field. Detection of contaminants and pathogens, monitoring manufacturing processes, transportation systems defense and military forensic etc. In mentioned applications the variable to be measured is different in every case. But basic working principle is same a selective binding of an analyte, a signal is generated from the interaction of the nanosensor with the bioelement, and then it is processed into useful metrics.

Types of Nanosensors:

Depending upon transduction principle, the nanosensors are classified as

1. Electrochemical nanosensors

Here resistance of the nanomaterial changes according to process variable. The change is due to changes in scattering or accumulation of charge carriers. Carbon nanotubes, conductive polymers or metal oxides nanowires can be used.

2. Chemical nanosensors

It consists of chemical receptor and physiochemical transducer. Here impedance change occurs when the receptor interacts with analyte. This impedance change is converted into electrical signal

3. Optical nanosensors

Here photonic devices are used to measure concentrations of samples. Working principle is based on chemical modulation of a hydrogel film. Film has Bragg grating. Here upon chemical stimulation, hydrogel swells or shrinks. The bragg grating changes color and diffracts light at different wavelengths. Thus concentration of analyte is converted to variable wavelength diffraction.

In some optical nanosensor, the change is converted into visible color change. Many harmful gases in environment are detected by this principle. The gold nanoparticles can be used for the detection of heavy metals is another application.

Manufacturing Methods

The nanosensors are manufactured either using Top-down or bottom-up lithography, In **top-down approach** a large block of required material is prepared first and then carved it for different micro sizes and shapes.

In **bottom-up technology**, individual atoms or molecules are assemble together to manufacture nanosensor.

Features of Nanosensors:

1. Better sensitivity as compared to traditional sensors.
2. Better response time makes them suitable for high – throughput applications.
3. Provide real-time monitoring compared to traditional detection methods.

Limitation of Nanosensors:

1. Because of drift, calibration is required frequently.
2. In biological applications, toxicology is main concern. Some nanosensors affect cell metabolism and changes cellular molecular profiles.