Microsystems Development

A. <u>Sensors & System</u>

Sensors are integral part of almost every electronic system. Sensors can be classified according to the energy domain of its primary input/output. Today's micro sensors with at least one physical dimension at the sub-millimeter are developed. This has happened due to CMOS process technology which is applicable for fabrication of Micro-Electro-Mechanical-Systems (MEMS). MEMS have revolutionized the market for sensors by providing small, fast-responding measurement devices at low cost MEMS device performs a function such as sensing or actuation. MEMS technology has demonstrated unique solutions and delivered innovative products in chemical, biological and medical domains as well. Typically, electronics are used to interface MEMS devices from its functional domain (i.e., Physical, Chemical, or Biological) to the electrical domain for signal transduction and/or recording.

Recent advances in micro-electro-mechanical systems and in low-power wireless network technology have created the technical conditions to build multi-functional tiny sensor devices, which can be used to observe and to react according to physical phenomena of their surrounding environment. Wireless sensor nodes are low-power devices equipped with a processor, storage, a power supply, a transceiver, and one or more sensors and, in some cases, with an actuator.
There are some challenges that need to be addressed. The most relevant are sensor integration, power management etc. The proposed system architecture is shown in fig.4.

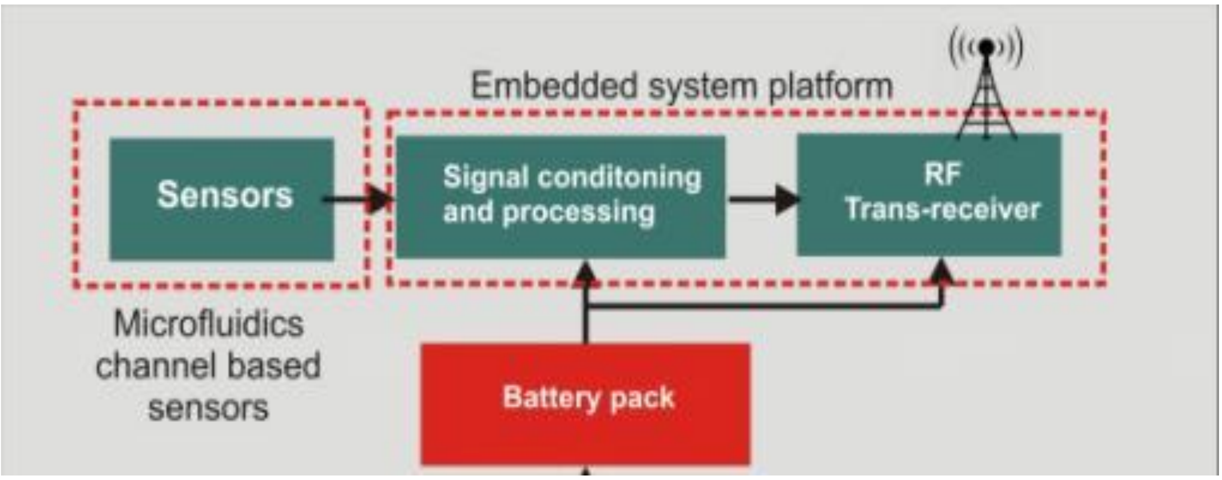

Fig 1. Microsystem Architecture

This is essential for long-term operation, especially when it is needed for monitoring remote and hostile environments. Battery size and radio power requirements play an important role in size reduction. Available sensor platforms on the market are expensive which precludes its use widely. Produce cheaper and disposable sensor platforms it is also a challenge.

The integrated micro system will be developed for online/offline monitoring. This system encompasses mainly microfluidics chip, micropumps, reagent storage, readout, an embedded system with RF module. A microfluidics chip is a set of micro-channels etched or molded into a material like glass, paper, silicon, or polymer such as Polydimethylsiloxane (PDMS). The micro-channels forming the microfluidics chip are connected together in order to achieve the desired action which also includes mixing of different fluids. These micro-channels can be connected to the outside by inputs and outputs pierced through the chip. It is through these holes that the liquid will be injected and removed from the microfluidics chip.

The flow chart below depicts the complete process flow for development of low-cost microfluidics-based sensors and systems. Microfluidics chips fabrication using polymers (e.g. PDMS), ceramics (e.g. glass), and semiconductors (e.g. silicon), and metal is currently possible because of the development of specific processes: deposition and electro-deposition, etching, bonding, injection molding, embossing and soft lithography (especially with PDMS).

Accessing these materials makes it possible to design microfluidics chips with new features like specific optical characteristics, biological or chemical compatibility, faster prototyping or lower production costs, the possibility of electro sensing, etc.
Following sensors and system will be developed

- Water quality monitoring system
- Remote health monitoring system
- Microfluidics based biological sensing system with terahertz spectroscopy
- Bio Fuel Cell
- Development of Microfluidics Platform for Fluid Analysis (Milk, fuel)

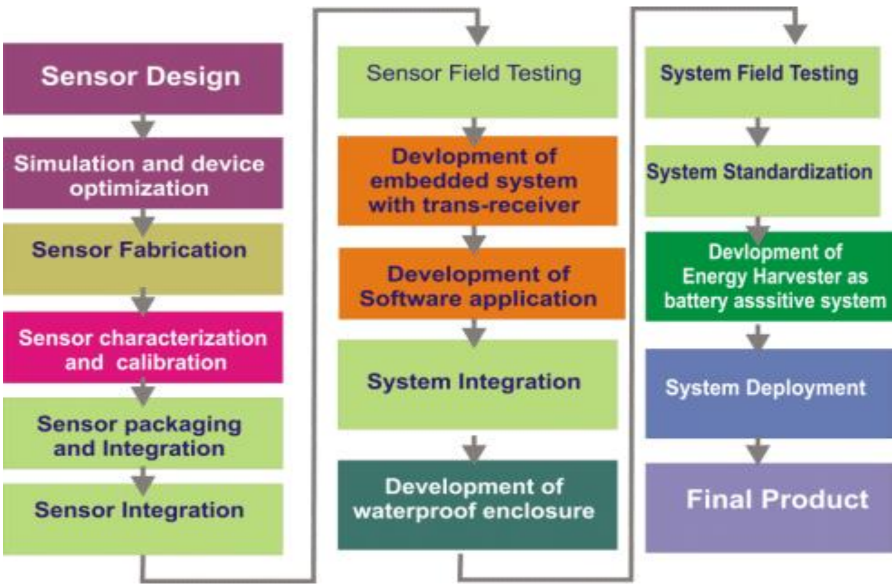

Fig 2. System Development process flow

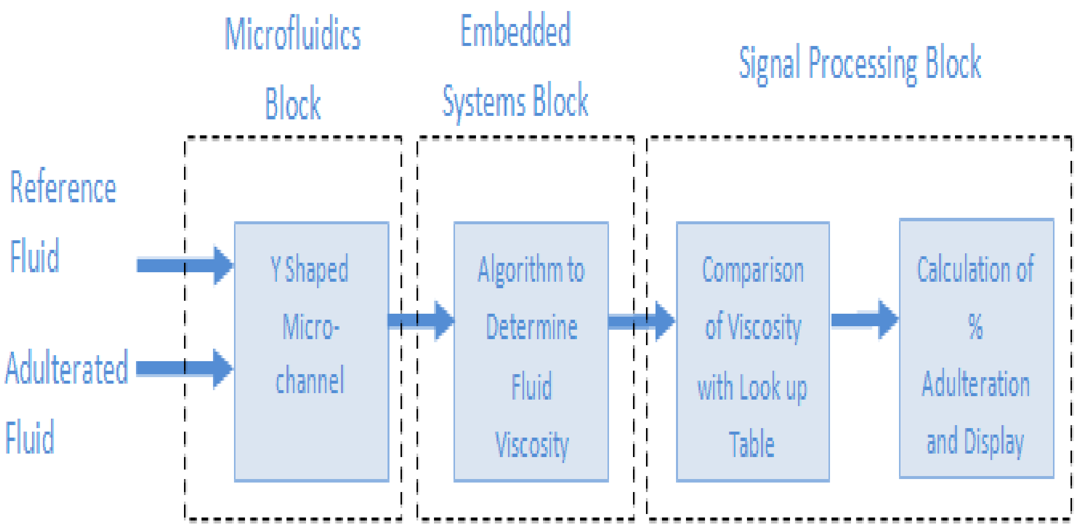

Fig. 6. Development of Microfluidics Platform for Fluid Analysis

- **Signal conditioning &Processing (Readout methods for sensors):**

Different readout methods can be used to monitor the output of sensor. Some of the methods proposed to be implemented are described as follows:

Colorimetry:

A colorimetric method is commonly used to determine the concentration of a chemical element or compound in solution by using a color-generating reagent. The color change occurs when the target analyte reacts with a specific reagent. The absorbance may increase in proportion to the concentration of colored species formed, or due to increased light scattering through the aggregation of smaller particles. The main advantages of this technique are that it is specific to one chemical species and is inexpensive for analysis. In recent years, colorimetric determinations of chemicals have attracted a great deal of attention because they offer an easy detection procedure. Simple and cost-effective colorimetric detection setup that can read the final results directly from the detection chamber has to be designed and developed. The developed detection setup can facilitate the main goal of the development of a simple, portable, on-site, and cost-effective method for the detection of chemical compounds. For signal readout and display, a different embedded platform like Arduino, Raspberry Pi can be used. It will be programmed to read sensor data and transmitted remotely. Likewise, Microfluidics along with terahertz source and detector can also be explored for detection of different contaminants like nitrogen components, Phosphate, and other contaminants.

Other technique like fluorescence technique based on spectroscopic analysis method will be explored. In this method, the analyte is excited electronically by irradiation with a specific wavelength, and then emits radiation of a different wavelength. The emission spectrum provides information for the quantitative and qualitative characterization of the target analyte.

Electrochemical methods using Interdigitated Electrodes (IDE):

Electrochemical methods rely on the chemical response of an analyte generated on electrical stimulation. It deals with the loss of electrons (oxidation), or the gain of Electrons (reduction), that a material experiences during the electrical process. These redox reactions can provide information about the analyte concentration, kinetics and reaction mechanisms, chemical status, and other aspects of the behavior of a species in solution. Electrochemical sensors operate by reacting with the samples of interest to generate an electrical signal proportional to the analyte concentration in the sample. A typical electrochemical sensor consists of a sensing/working electrode, a reference electrode, and a counter electrode. A variety of electrodes and electrochemical methods has been used to detect various parameters like phosphorus in water.

Many microfluidics devices incorporate other features that require the integration of electrodes, nanostructures, or surface functionalization. This type of additional steps uses generally standard techniques of micro and nanotechnology (thin film deposition, plasma etching, and self-assembled monolayers). The data acquisition can be performed with an impedance analyzer. A minimum set of two different IDEs can be used to evaluate the impact of impurities.

B. Energy Harvester as a battery assistive system

Energy harvesting is the process by which energy is derived from external sources, captured, and stored for Microsystems. Converting mechanical vibration energy to electrical energy using piezoelectric materials has been the choice for many energy harvesting applications. The Energy harvesting (EH) technologies are receiving significant interest due to the realization of ‘zero-power’ wireless sensors and Internet-of-Things (IoT). The power consumption of current milli-scale commercial node has an average consumption of 0.1–1000μW which has made self-powered sensor nodes a reality.

During this decade, there has been a rapid growth in research within the field of energy harvesting devices. The trend is the continual increase in applications for wireless sensors used in, for example, Machine health, structural health monitoring, asset condition monitoring etc. Devices which utilize ambient energy sources such as light, thermal, wind and vibration are widely reported and are seen as possible replacements or assistive system to batteries.

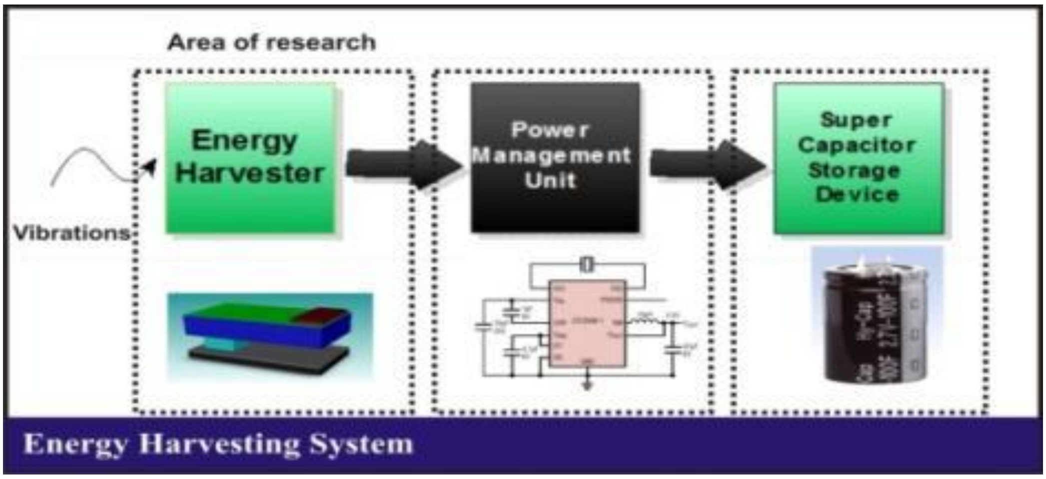

Fig.6 Block schematic of energy harvesting system

The energy harvesting system is divided into three major parts as shown in Fig.5.The purpose of the first block is to harvest the energy from ambient vibrations and feeding to power management unit for further processing. Finally, it is transferred to storage devices such as a rechargeable battery or super capacitor.

Battery assistive System

Multimodal of Energy harvesting is proposed in which multi transduction schemes will be explored to harvest maximum energy. The energy harvesting can charge the battery when sufficient power is accumulated. The hence higher capacity of the battery pack is not required which in turn reduces battery size and cost also. The piezoelectric energy harvester-based system as a battery assistive system is depicted in fig. 7 and other transduction mechanism will also be incorporated similarly.

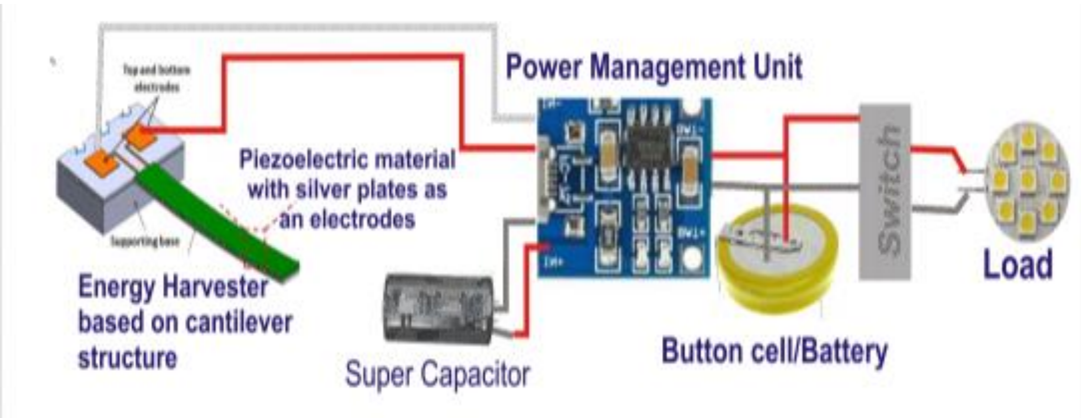

Fig 3. Battery assistive system

C. ***RF MEMS Devices***

Over the past few years, significant growth has been observed using MEMS based passive components in the RF microelectronics domain, especially in transceiver system. RF MEMS devices Micro resonator, Filter & Reconfigurable Antenna will be designed, fabricated and tested which intern helps to develop wireless systems (Wi-Fi Wi-Max and Bluetooth Application)

MEMS Resonator

MEMS resonators are small electromechanical structures that vibrate at high frequencies. They are used for timing references, signal filtering, mass sensing, biological sensing, motion sensing, and other diverse applications. They follow the standard CMOS compatible fabrication steps of patterning and transferring.

Design and development of an efficient MEMS Resonator with considerably high-Quality factor, higher frequency stability with minimum losses required to work efficiently in the field of communication. MEMS based on-chip resonators have shown significant potential for sensing and high frequency processing applications.

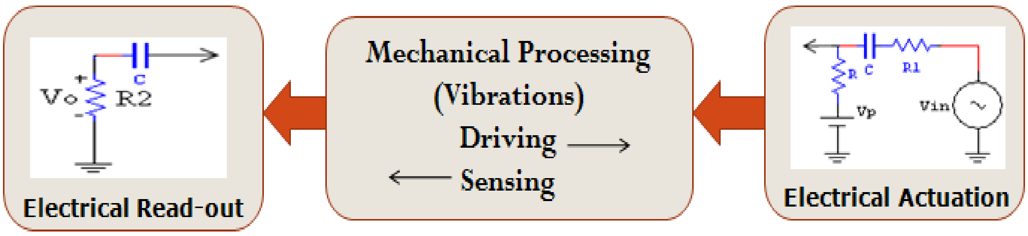

Fig.8. Block Diagram of MEMS Resonator

Fig.8 shows the block schematic of MEMS Resonator along with appropriate bias, excitation and sensing circuitry. A resonator structure can be beam / disk / comb etc., a drive electrode which serves as a capacitive transducer to induce resonator vibration. If the frequency of input voltage is within the band width of micromechanical resonator then input voltage will result in excitation of resonator and structure starts to vibrate with its natural frequency. Vibration will create a time varying capacitor between conductive resonator and sense electrode, which then sources an output current. This current can be measured by appropriate read out technique.
Design and development of MEMS Resonator (Clamped-Clamped/Disk/Comb) for higher frequency range with considerably good Quality factor which may be further used in Communication viz. GSM, is proposed. It is also projected to enhance the bandwidth of designed Resonator so that it can cover maximum range for communication. Resonators have generally a lower gain which is not sufficient for many applications. Hence High gain which provides larger coverage is targeted for development. Once the design is optimized, Micro resonator fabrication, characterization in terms of Capacitance-Voltage (C-V), Current-Voltage

(I-V) and stressing is proposed to validate our goal of developing a resonator with high Quality factor. Reliability characterization of these resonator will be carried out in this center.

MEMS Switch

Electrical and Mechanical Switches play an essential role in directing the converted or controlled power in various switching applications like Switch Mode Power Supply. A power switch with greater current handling capacity and least possible on state resistance are desired along with high off-state resistance and capability of withstanding high standoff voltages. MEMS Cantilever Switches are playing a very significant role in the developing the world of miniaturization while maintaining the required qualities of switches. Its design and development to replace semiconductor devices along with the advantages of batch fabrication is the need and subject of interest.

Depending on the feature size, the current handling capacity of MEMS cantilever switches ranges in few milli-Amperes (less the feature size, less is the amount of current handling.

MEMS switches as shown in fig. 9. for RF communication will be designed, developed in this work. Reliability characterization also be carried out.

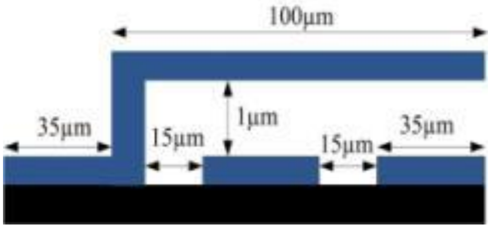

Fig 4: Cantilever Switch

Reconfigurable Multiband Antenna

The reconfigurable nature of an antenna system is the most essential characteristics which has been the focus area of current research. The high-performance and innovative antenna systems are needed due to a great demand of bandwidth and service quality in advanced wireless communication systems. With the incorporation of RF switches in the reconfigurable microstrip antenna design gain and radiation efficiency increase while over in some cases the bandwidth increases. Reconfigurable RF switch-based antenna system is the optimum choice to meet the needs of present wireless networks and communications. RF switches are vital components of all reconfigurable antenna systems as they are capable of redirecting the signals and current paths. This redirection of current changes the antennas electrical length and because of which change in resonating frequency is observed. RF MEMS switch-based fractal U-slot reconfigurable antenna is shown in Fig10. This antenna radiates similar radiation pattern over wide frequency range and also provide multi band and wide band characteristics with enhanced bandwidth. For achieving the best performance of the switch in antenna, the high isolation and low insertion loss plays the vital role. This antenna covers the range of various wireless applications such GSM, Wi-Fi and Wi-Max etc. The design will be fabricated using the facility avail through this project.

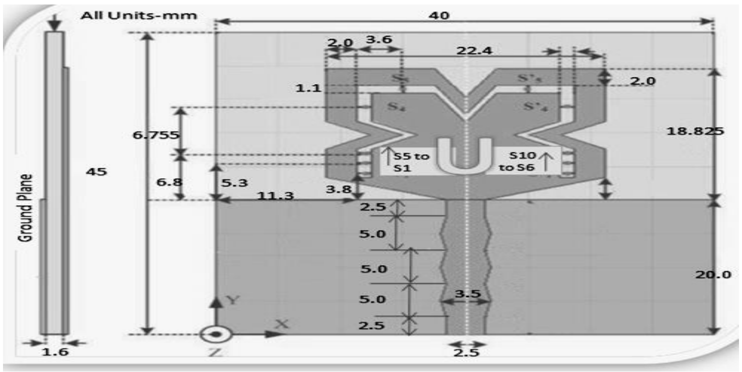

Fig 5 .Reconfigurable Antenna using MEMS Switches

Return loss, gain, Bandwidth, radiation efficiency measurement will be carried out to verify the functionality of the device.

MEMS Filter

Emerging Miniature RF devices find numerous applications in wireless communication, military and consumer electronics and automotive sensors. High-performance low-power RF transceivers are the integral part of many of these devices. Components with high Quality Factor (exceeding 30), which are required for high-frequency selectivity in communication systems are difficult to achieve using conventional IC technology. The most widely used filters in communication systems are band pass filters and low pass filters. The main characteristics of these filters are the insertion loss, bandwidth and out-of-band rejection ratio. We are targeting to examine the behavior and estimate the performance of MEMS lumped components with regard to parameters such as tuning, actuation voltage, quality factor, temperature, etc. and then evaluate and optimize their response when integrated to form a filter.

Design of high-performance MEMS passive band pass filter, consisting of L and C with improved quality factor and insertion loss is proposed. The target is to design 2nd order band pass filter with 2.4 GHz center frequency and 83MHz bandwidth for Bluetooth application and is a π structure of Five Pole LC-band pass filter.

Thus, full product cycle from device design to electrical testing will be carried out. Micro-sensors, energy scavengers and RF MEMS devices will be designed, manufactured and tested using the facilities created in this Centre which in turn will help the Department to provide testing and consultancy services to the industries and R & D organizations in the fields of microsystems.

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