SMART SENSORS

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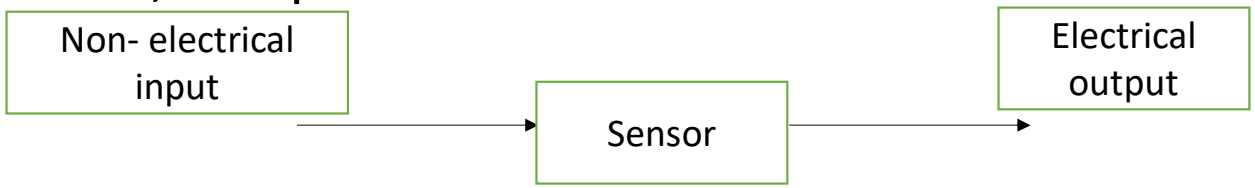
Integrated Sensor

- **Sensor-** Standalone device that detects physical properties (like temperature, pressure, light, etc.) and converts them into signals that can be read and interpreted. Examples include thermocouples, photodiodes, and pressure sensors.



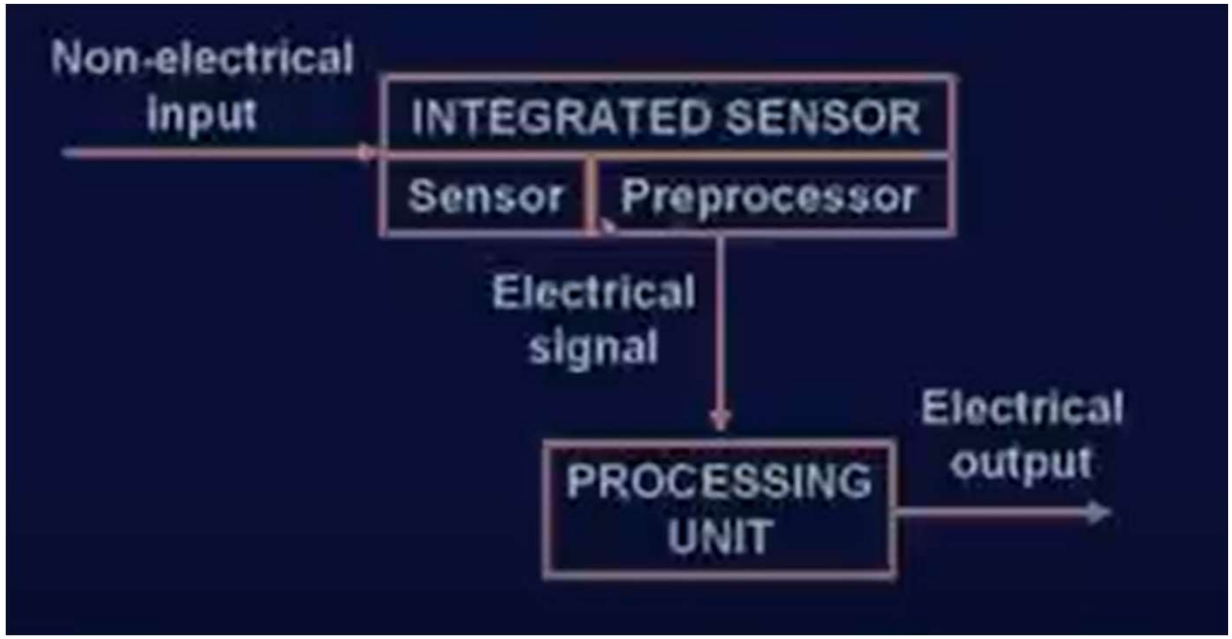
- **Integrated Sensor –**
  - Sensor that is combined with additional circuitry, often on a single chip.
  - Compact
  - Built-in signal conditioning, data processing

Integrated Senor (Cntd…)

Preprocessing includes-

- Amplification
- Filtering
- A/D conversion

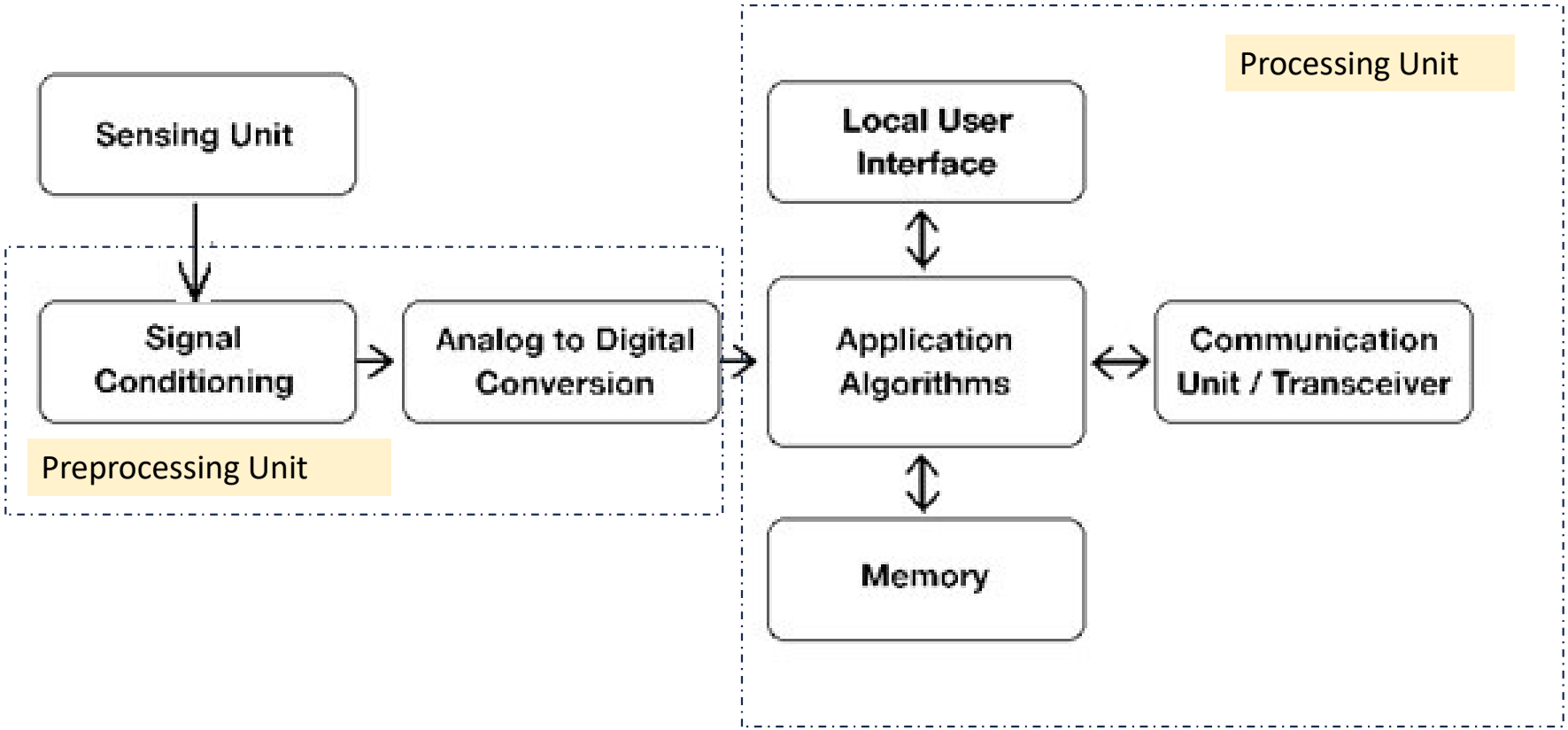
Example – MEMS, integrated temp. sensors



Smart Sensors

- Smart sensors are revolutionary devices that combine sensing capabilities with advanced processing and communication functionalities. They play a crucial role in various applications, enabling real-time data acquisition, analysis, and decision-making.
- Smart sensors can communicate wirelessly or through wired systems and are often integrated into larger networks like the Internet of Things (IoT).
- Combination of hardware & software.

Architecture of Smart Sensors



Architecture of Smart Sensors (Cntd…)

- **Sensing Unit –**
  - Function - This unit detects changes in physical parameters such as temperature, pressure, humidity, motion, or light. & generates electrical signals equivalent to it.
  - Types- Thermistors for temperature or piezoelectric materials for pressure.
- **Signal Conditioning –**
  - Function: Processes the raw signal generated by the sensing element. It typically includes amplification, filtering.
  - Purpose - Cleaning up the raw data and converting it into a usable form. Noise removal and signal scaling also occur here, ensuring that the processed signal is accurate.

Architecture of Smart Sensors (Cntd…)

- **ADC–**
  - Function – To convert analog signal into its digital form & send to microprocessor for further analysis.
- **Microprocessor/ Microcontroller -**
  - Function- Provides computational power to handle data processing tasks such as filtering (if required), error detection, and compensation.
  - Comprises of application algorithms & memory.
  - Memory is included to store firmware, calibration data & sensor readings. Typically, it will have some form of non-volatile memory (like flash memory) for long-term data storage and volatile memory (such as RAM) for real-time operations.
  - May include embedded software that controls the sensor's operation, including communication protocols.

Architecture of Smart Sensors (Cntd…)

- **Communication Interface -**
  - Function – To communicate with other devices or systems.
  - Types -
    - Wired communication: Interfaces like I2C, SPI, or serial communication.
    - Wireless communication: Protocols such as Bluetooth, Zigbee, Wi-Fi etc.
- **Local User Interface -**
  - Function- The local user interface or LUI is a panel-mounted device used to allow building operators to monitor & control system equipment.
  - Can be mobile app, remote or display.

Architecture of Smart Sensors (Cntd…)

- **Power Management -**
  - Function – Efficient power management is critical, especially for battery-operated or energy-harvesting smart sensors.
  - Includes mechanisms to reduce power consumption, such as sleep modes, or adaptive power usage based on the sensor's operational status.
  - Some sensors have optional solar power charging.
- **Actuation (optional) -**
  - May trigger a mechanical actuation like speed variation of fan or heater based on temp. sensor readings.

Characteristics of Smart Sensors

- **Self Calibration-**
  - Calibration refers to correction or adjustment in sensor parameters such as gain, offset, or both.
  - Traditional sensors require manual recalibration but smart sensors automatically adjust their measurements to compensate for environmental changes, sensor aging, or drift.
  - Benefit-
    - Consistent performance without requiring frequent manual recalibration,
    - Improved reliability
    - Reduced maintenance costs.

Characteristics of Smart Sensors (Cntd..)

- **Self Diagnostics -**
  - Monitor own health and operation through built-in self-diagnostics.
  - Calculate the minimum and maximum values for the measured quantity and store multiple measured values near a setup point. The effect of a sensor fault on the measured quantity is measured using uncertainty techniques.
  - Benefit-
    - Increases the system's reliability by reducing the likelihood of undetected failures
    - Allows predictive maintenance.
- **Computation –**
  - Obtain the average, variance, and standard deviation measurements etc.
  - Benefit – allows one to compensate for environmental changes

Characteristics of Smart Sensors (Cntd..)

- **Signal Processing -**
  - Does on-board filtering, noise reduction, signal amplification, and transformation of raw data into a more usable format.
  - Benefit-
    - Reduces the amount of data that needs to be transmitted, saving bandwidth and processing power.
    - It also improves the quality and accuracy of the data collected.
- **Adaptability & learning –**
  - AI/ML allows sensors to adapt & learn from historical data.
  - Benefit-
    - Improved efficiency
    - Improved decision making

Characteristics of Smart Sensors (Cntd..)

- **Decision-making Capabilities-**
  - Can analyze the information and trigger specific actions.
  - Benefit-
    - Human intervention is reduced
    - Error handling becomes easy
    - Improved efficiency