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Exploring Smart Sensors and Their Application in Pioneering Industries

20 February 2024 | Technical Topic Webinar

Presented by:

Dr. Ali Marzoughi
EIT Lecturer and Unit Coordinator

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Introduction - Presenter

Dr. Ali Marzoughi

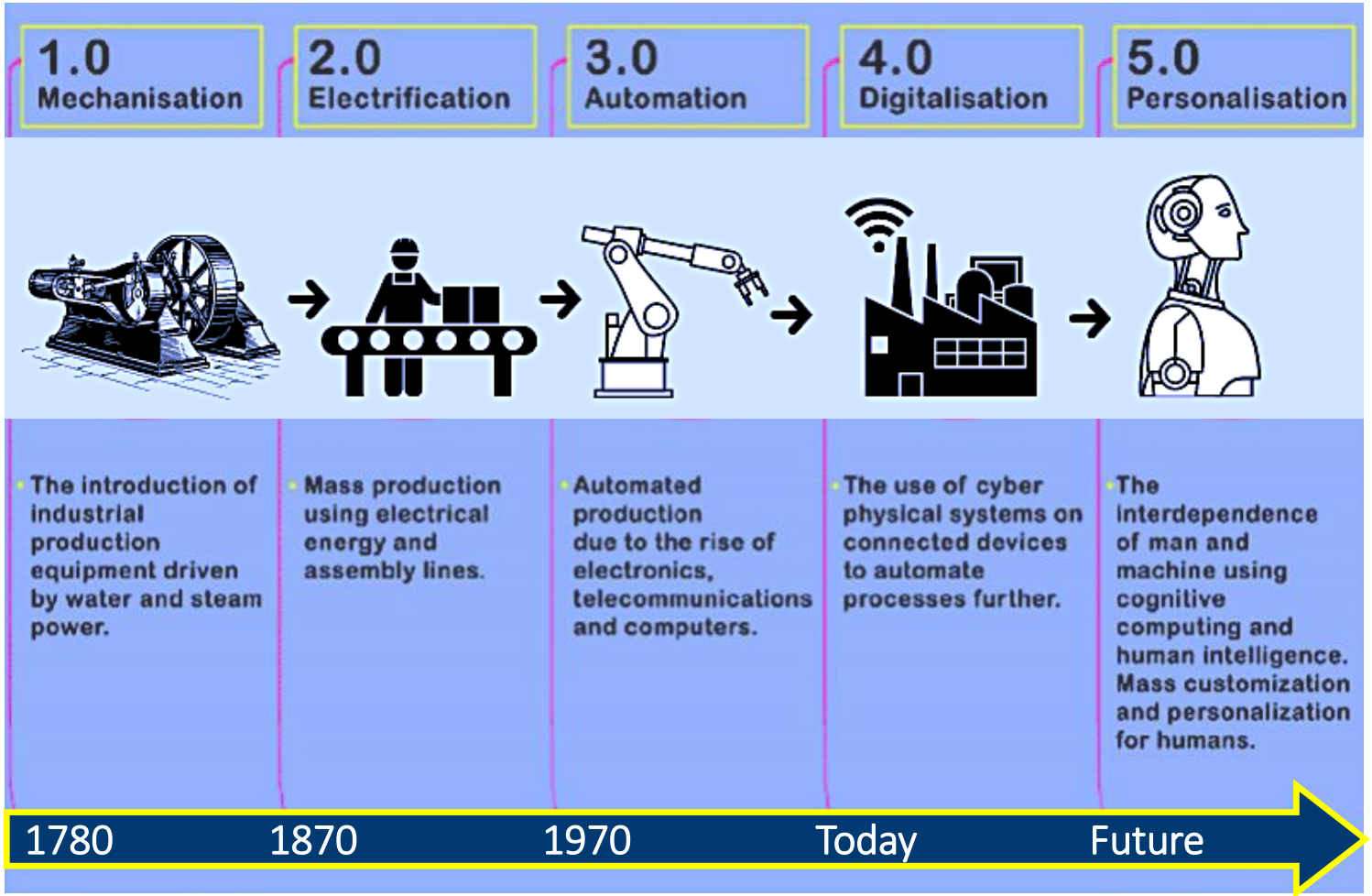
- Bachelor's degree in Electrical/Electronics Engineering
- Worked as an Instrumentation Engineer in the oil and gas industry
- Promoted to a significant role in an EPC consortium, managing supply for refinery upgrades
- Earned a Master's degree in Mechatronics and Automatic Control
- Worked as a Test and Inspection Engineer in Malaysia and Singapore
- Pursued a Ph.D. in Robotics and Automatic Control at the University of New South Wales in Australia
- Held diverse roles including Production Supervisor and Service Engineer
- Contributed to academia at universities like UTM and UNSW
- Currently a Lecturer and Unit Coordinator at the Engineering Institute of Technology (EIT) since 2019
- Expertise in instrumentation, automation, robotics, and mechatronics
- Passionate about contributing to industry advancements and academic excellence

Agenda

1	Welcome and Introduction
2	Introduction to Sensors and Smart Sensors
3	Standard Sensors' Interface Signals
4	Integrated Smart Sensors
5	Smart Sensors Evolution
6	Application of Smart Sensors
7	Conclusion and Q&A

Introduction to Sensors and Smart Sensors

The Stages of the Industrial Revolution:

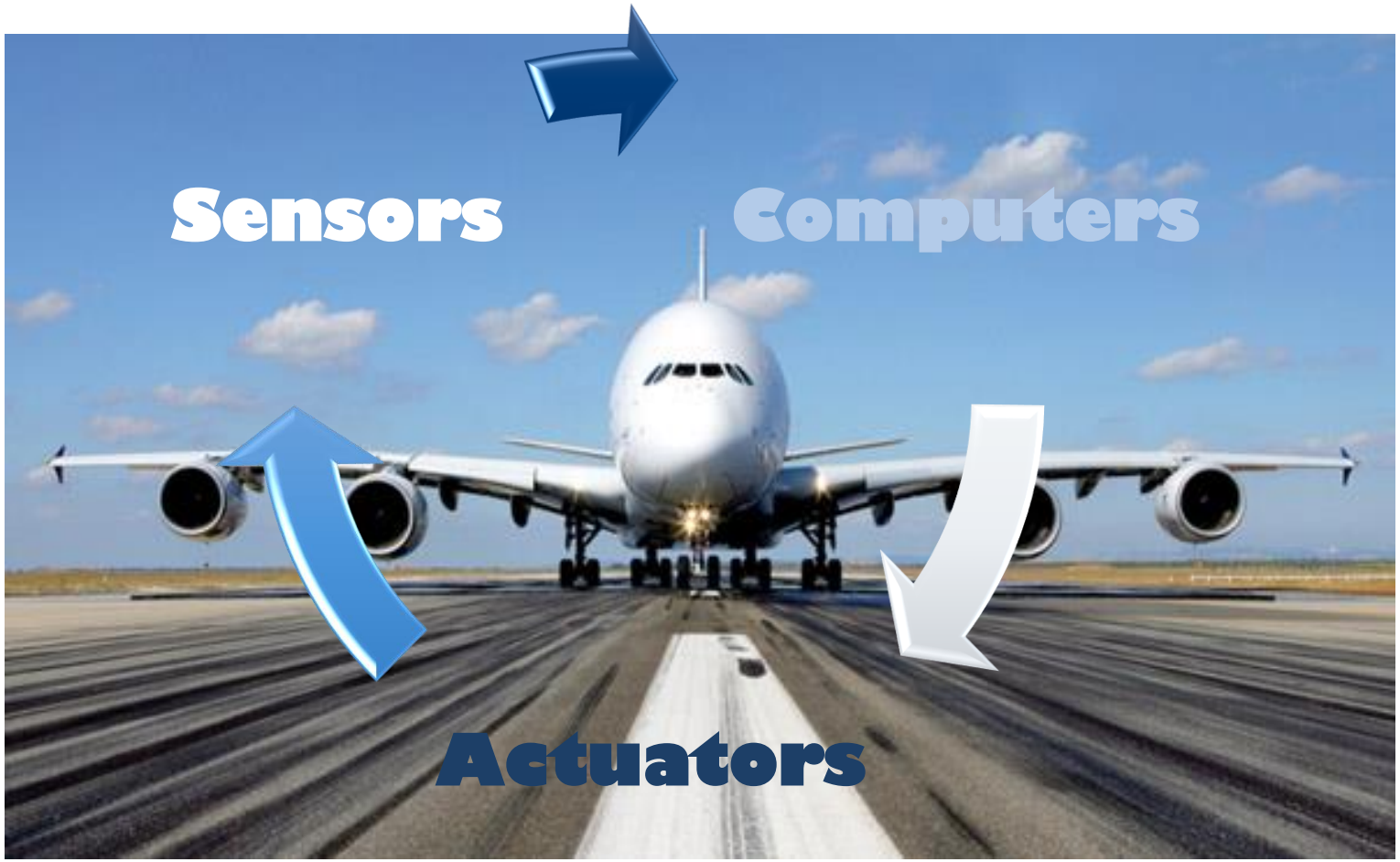


The stages of the industrial revolution [1]

Introduction to Sensors and Smart Sensors

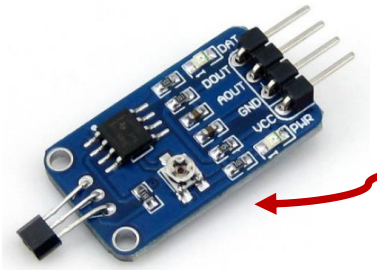
Automation has 3 main phases:

1. Mechanisation
2. Informatisation
3. Sensorisation



Introduction to Sensors

- Sensors convert signals originating from various energy realms into the electrical domain.
- Signals are classified into six distinct domains.

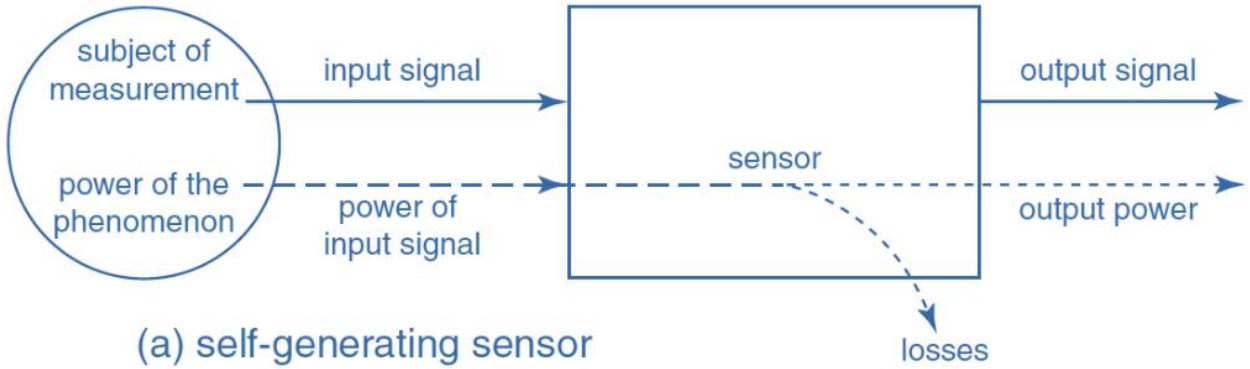


Introduction to Sensors

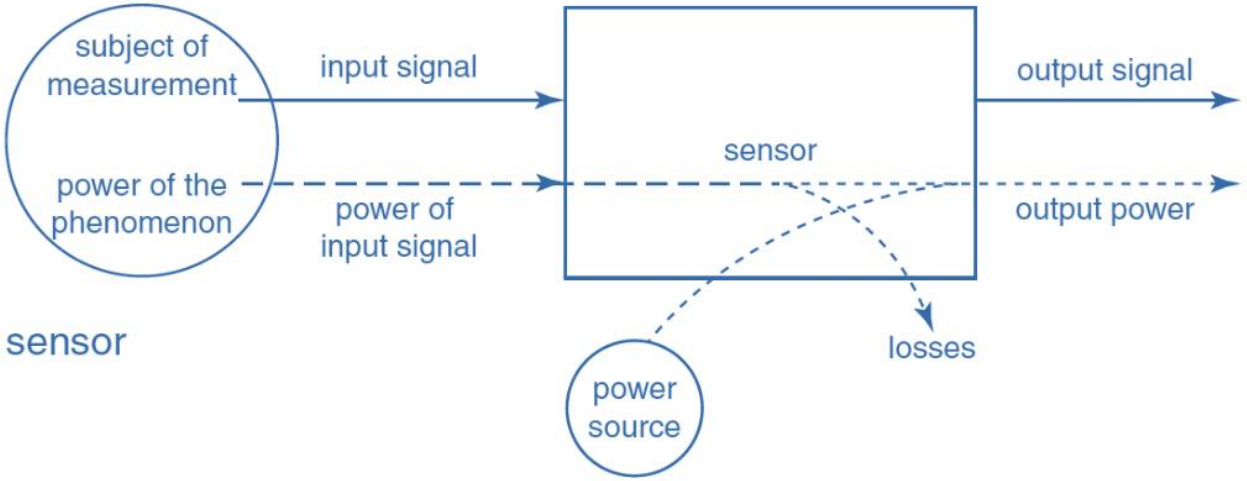
Physical sensor effect [2]

In/Out	Radiant	Mechan.	Thermal	Electrical	Magnetic	Chemical
Rad	Photo-luminan.	Radiant pressure	Radiant heating	Photo-cond.	Photo-magn.	Photo-chem.
Mech.	Photo-elastic effect	Conservation of moment	Friction heat	Piezo-electricity	magneto-striction	Pressure-induced explos.
Therm.	Incan-descence	Thermal expansion	Heat conduction	Seebeck effect	Curie-Weiss law	Endotherm raction
Electr.	Inject. Luminan.	Piezo-electr.	Peltier effect	PNjunction effect	Ampere's law	Electrolysis
Magn.	Faraday effect	Magneto-striction	Ettinghausing effect	Hall effect	Magnetic induction	
Chem.	Chemo-lumin.	Explosion reaction	Exothermal reaction	Volta effect		Chem. reaction

Introduction to Sensors



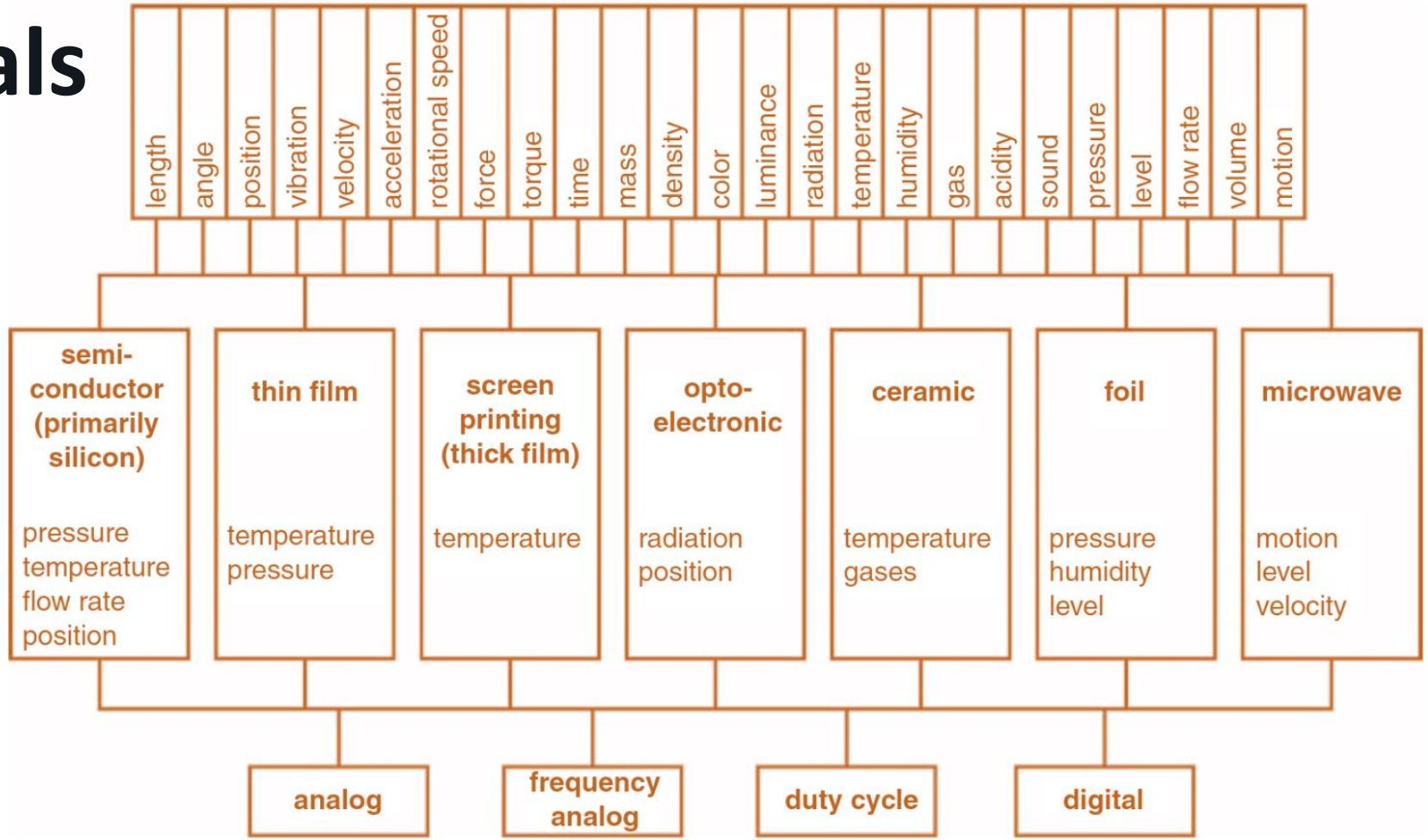
(a) self-generating sensor



(b) modulating sensor

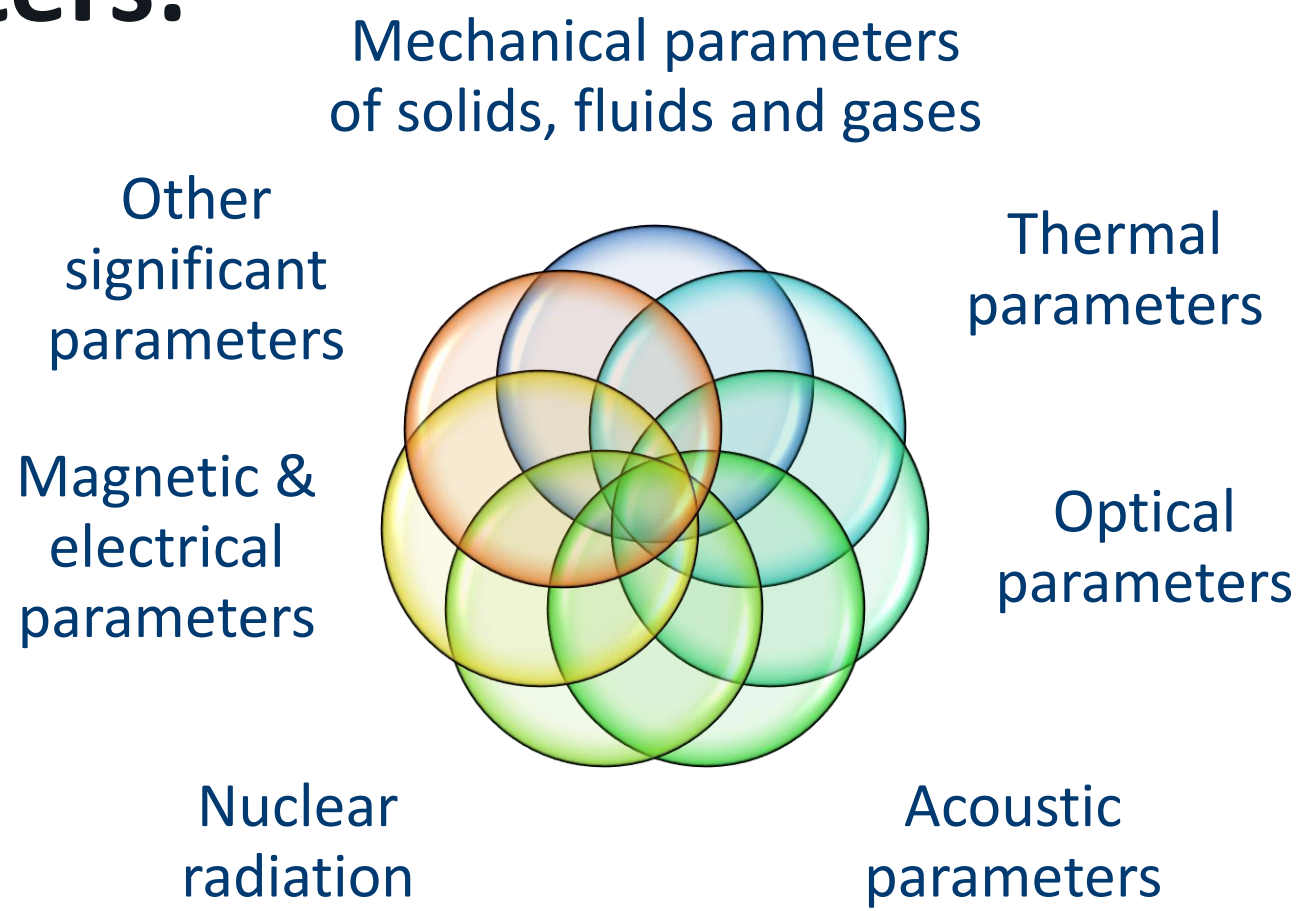
Introduction to Sensors

Sensors' Materials



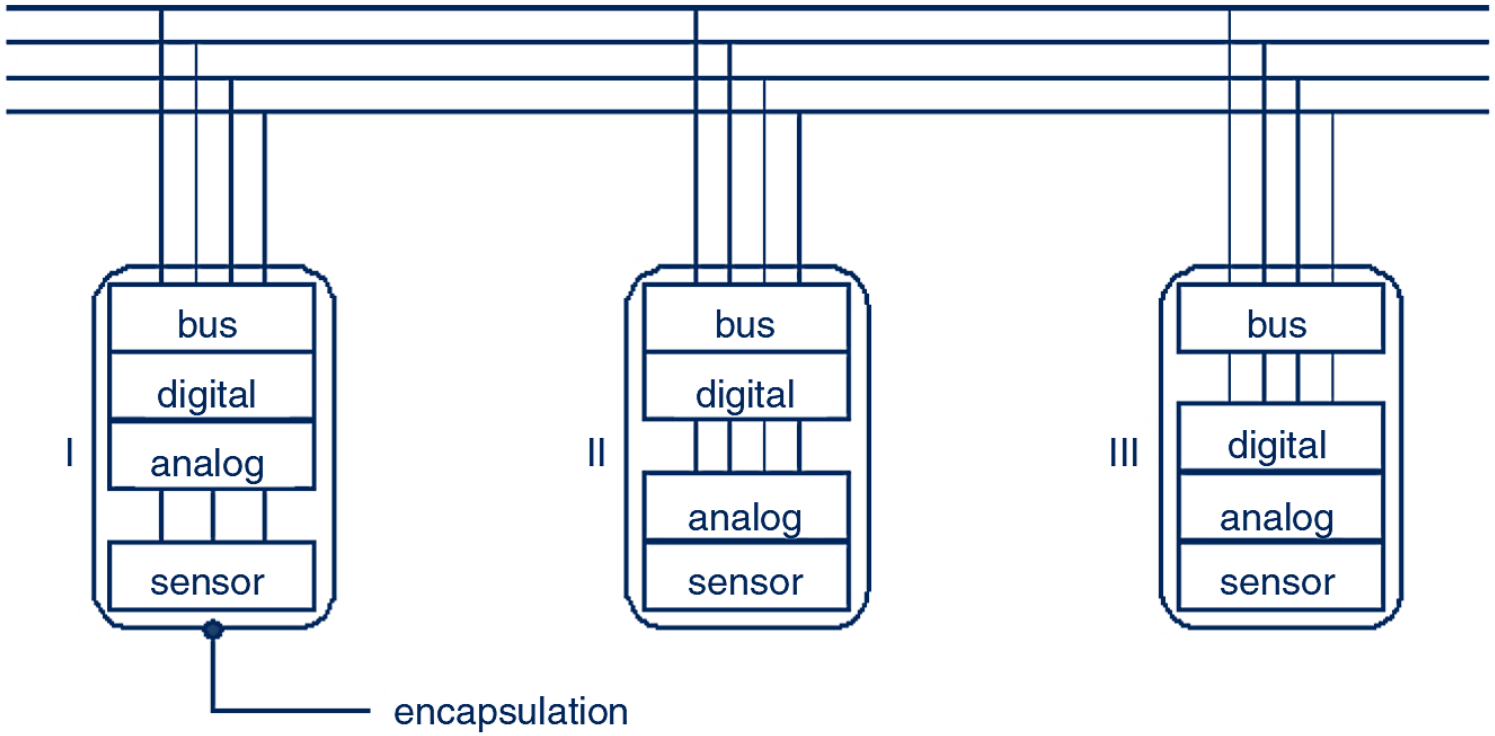
Introduction to Sensors

Sensors' Parameters:



Introduction to Smart Sensors

When a sensor, an analogue interface circuit, an analogue-to-digital converter (ADC), and a bus interface are integrated into a single enclosure, we obtain a smart sensor.

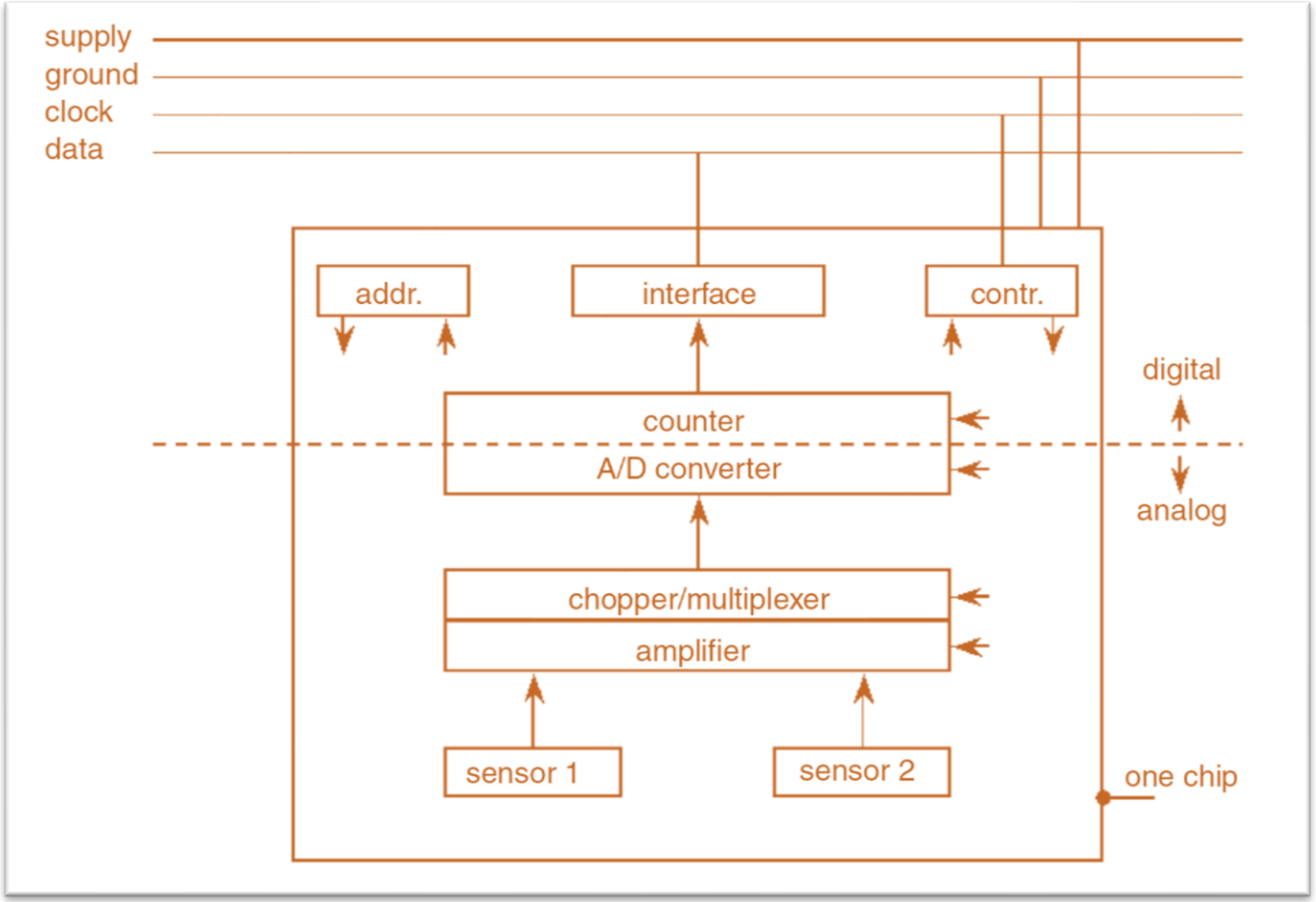


Standard Sensors' Interface Signals

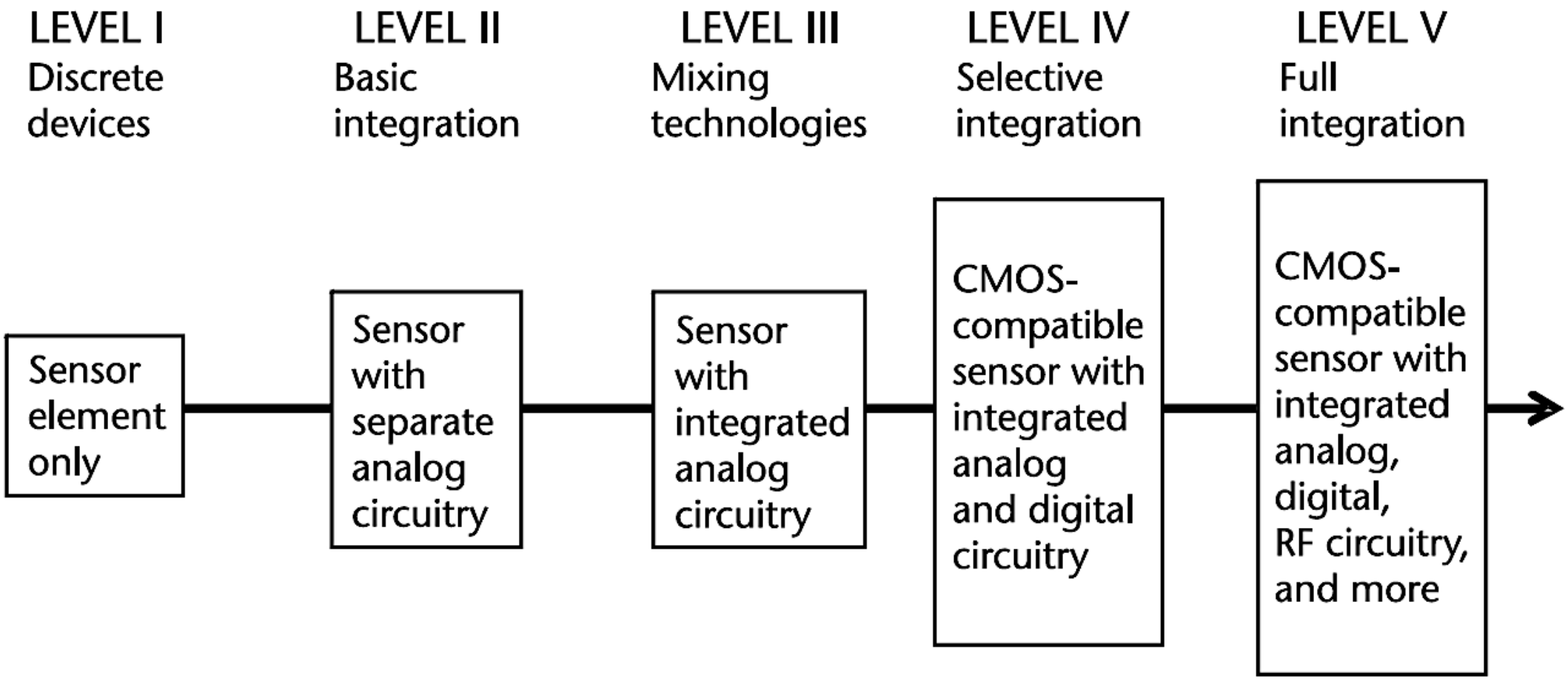
Sign. Cond.:	Analog Voltage	0.5 V to 4.5 V
	Analog Current	4 mA to 20 mA
Sign. Conversion:	Frequency	2 kHz to 22 kHz
	Duty Cycle	10 % to 90 %
	Bit Stream	
	Bites	
Bus Output:	IS^2, I^2C	
	D^2B, Field, CAN	

Integrated Smart Sensors

When all functions from the sensor to the bus interface are combined into a single chip, we achieve an integrated smart sensor.

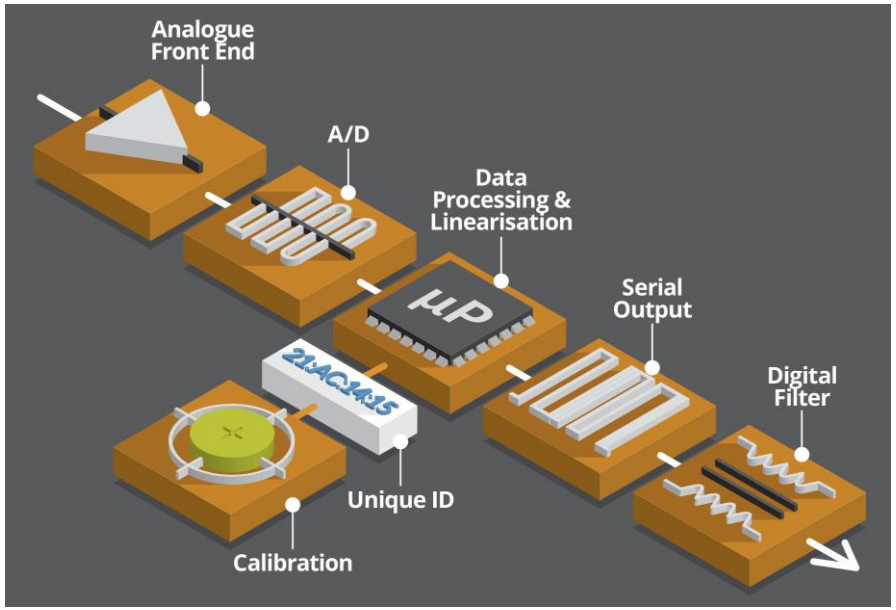


Integrated Smart Sensors

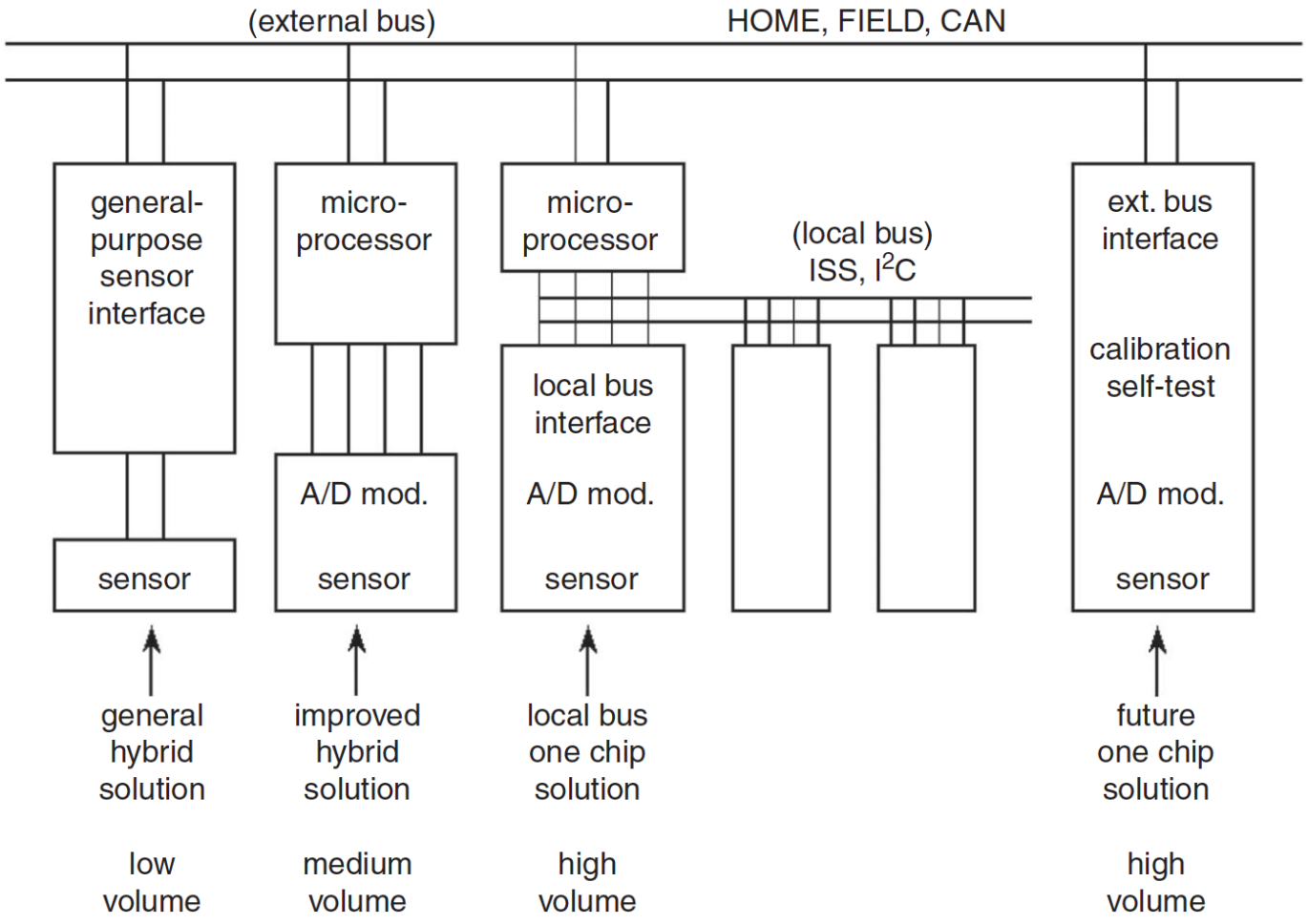


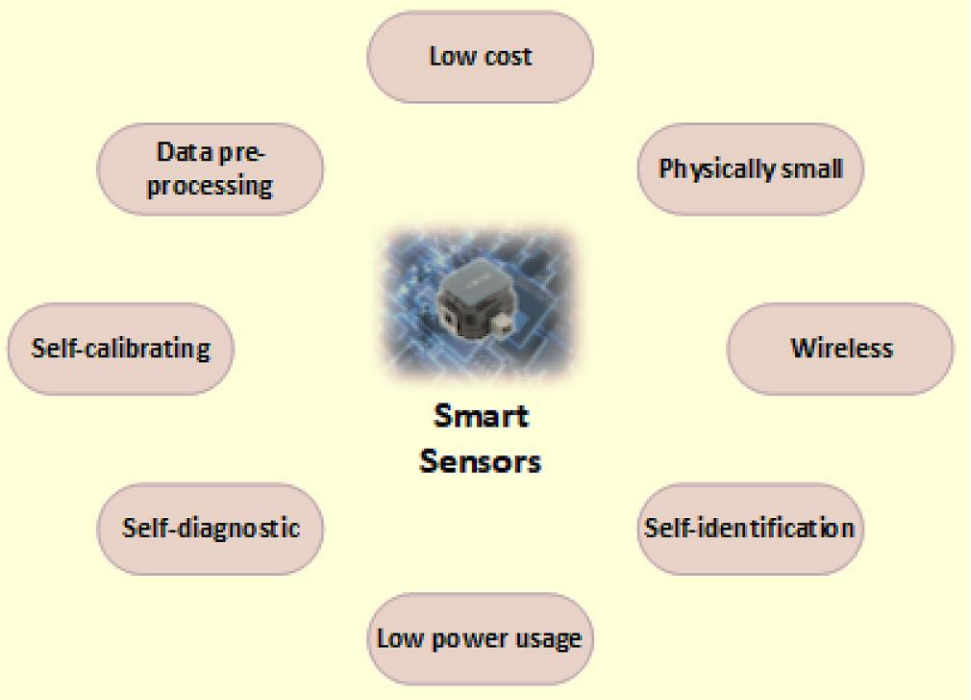
Summarising of Integrated Smart Sensors

Technology:	Low-power opamps, Low-power ΣΔADC's, Smart sensor bus system, Selftesting and Autocalibration
• Medical:	DNA Sensors, Multi-blood sensor, Catheter locating system
• Scientific:	Optical spectrometer, Adaptive mirror and LC systems, Wavefront sensor
• Industrial:	Universal transducer interface, Capacitive fingerprintsensor, Thermal windmeter, Absolute temperature sensor, High-Speed Chemical Analyzer, Spinning Current Hall Sensors, Accelerometer
• Computer Interface:	Capacitive human interfaces



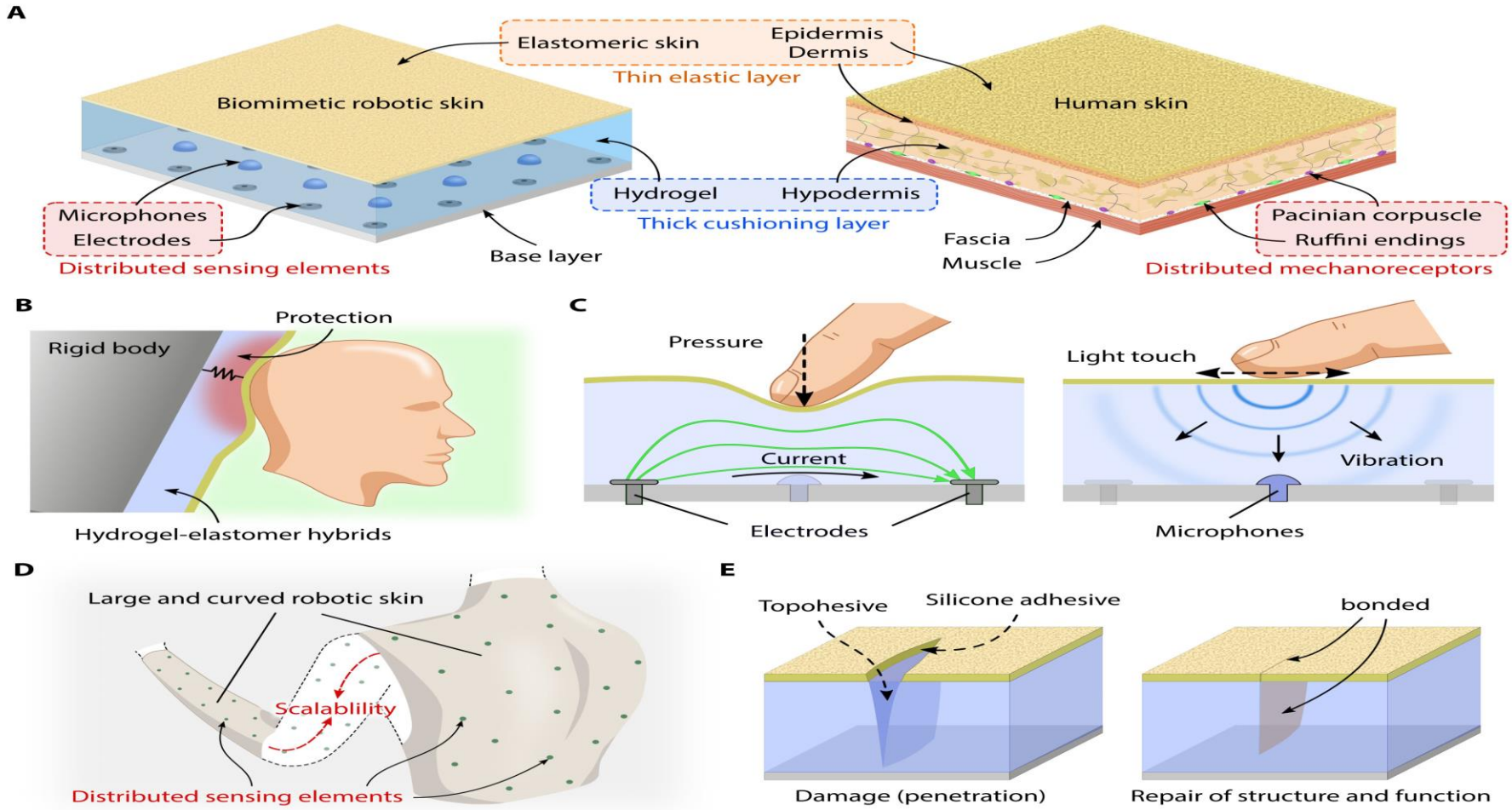
Smart Sensor System Evolution





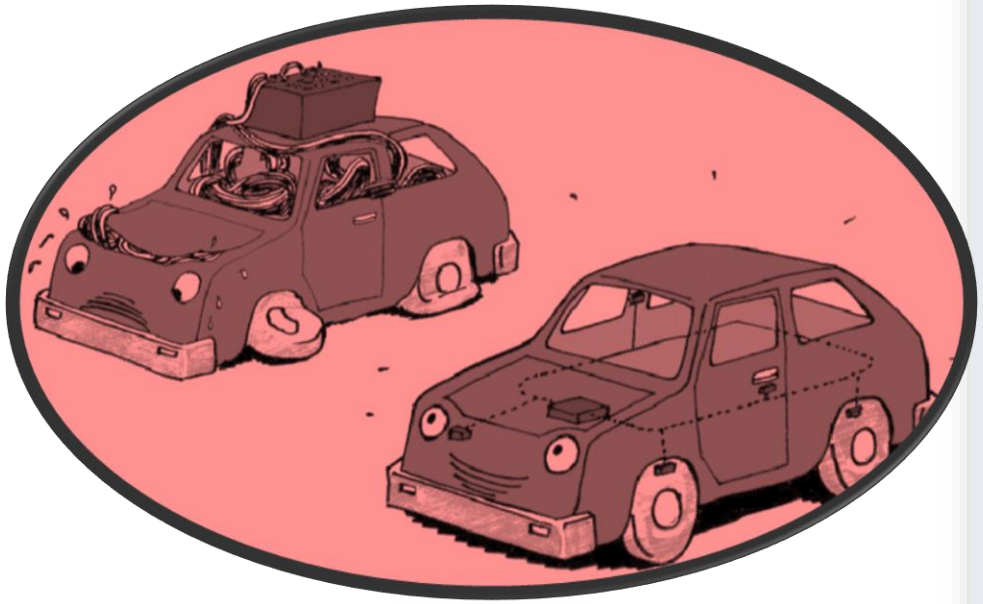
Application of Smart Sensors

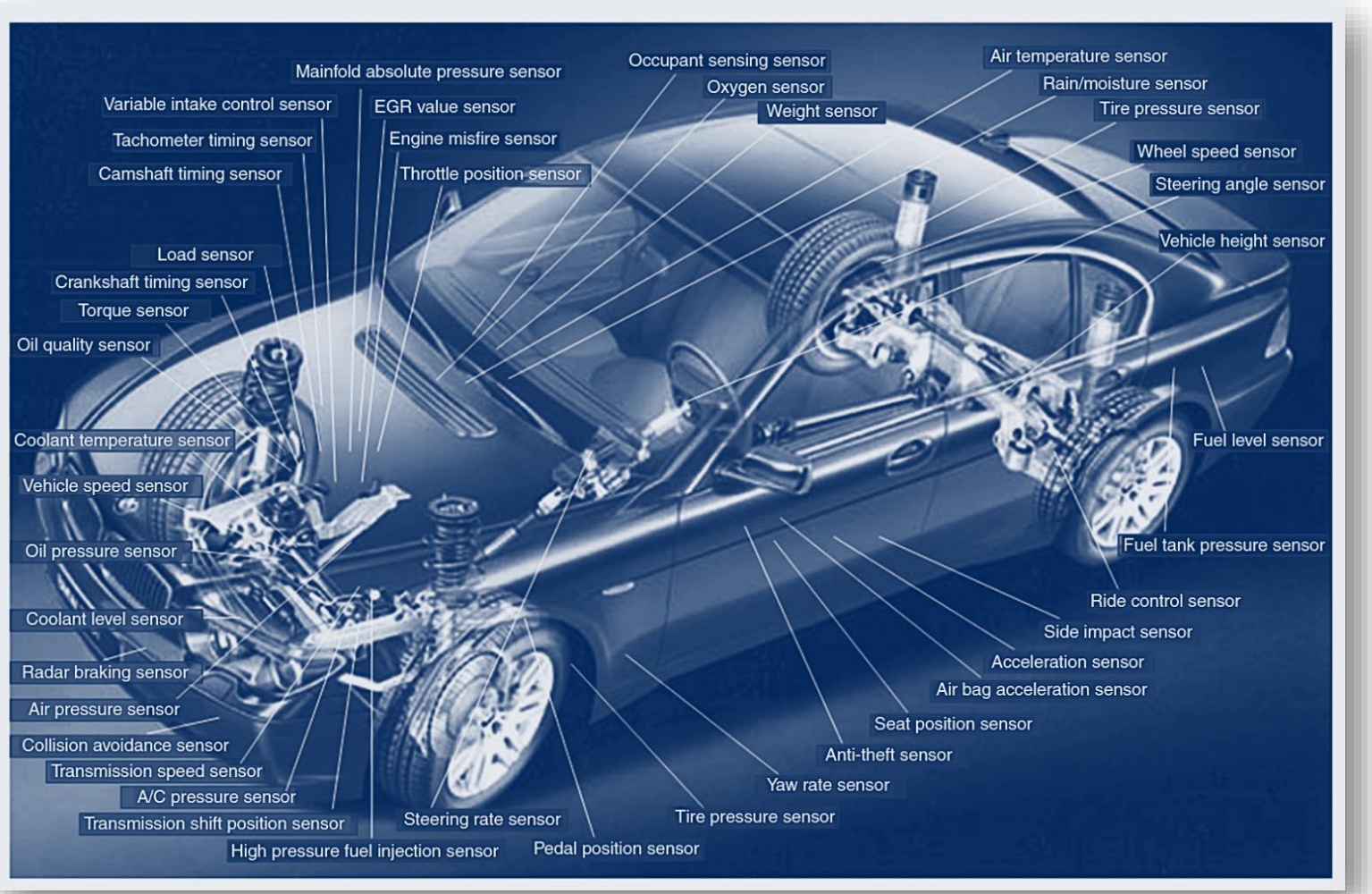
Biosensors:



Application of Smart Sensors

Smart Cars





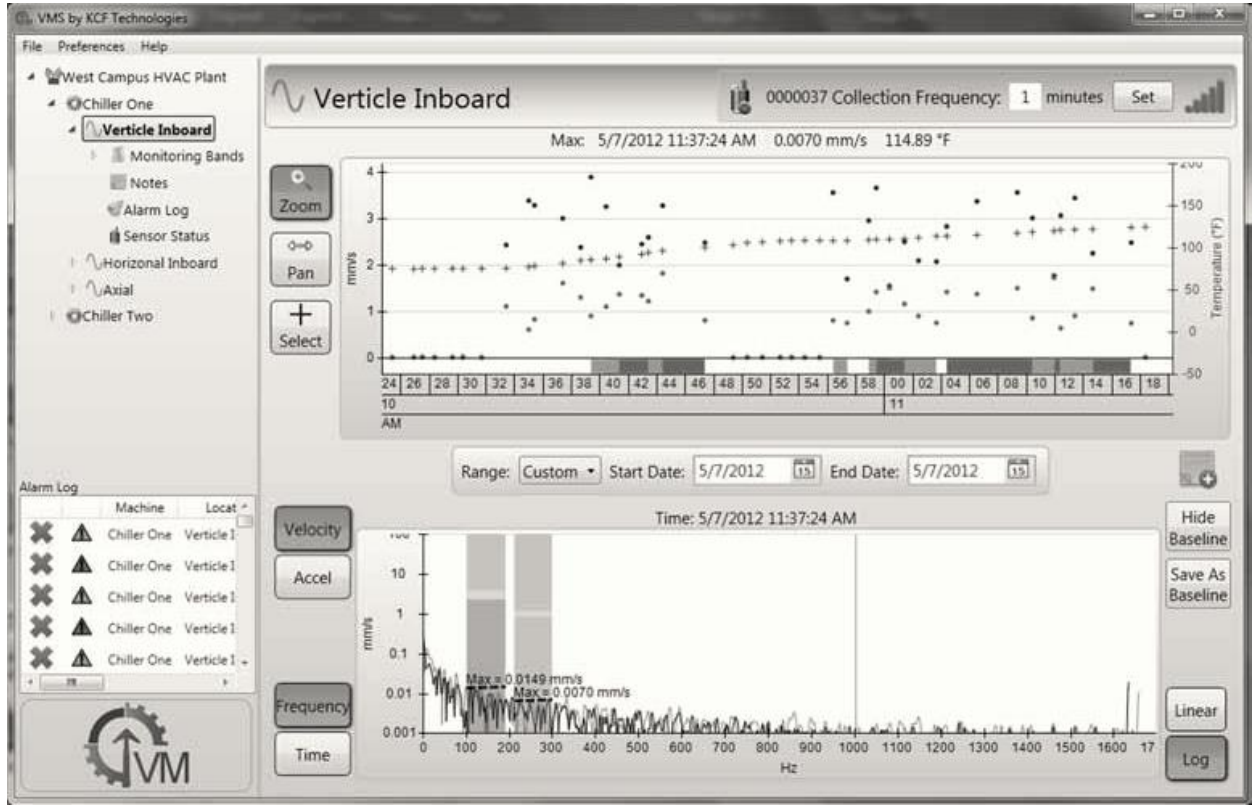
Application of Smart Sensors

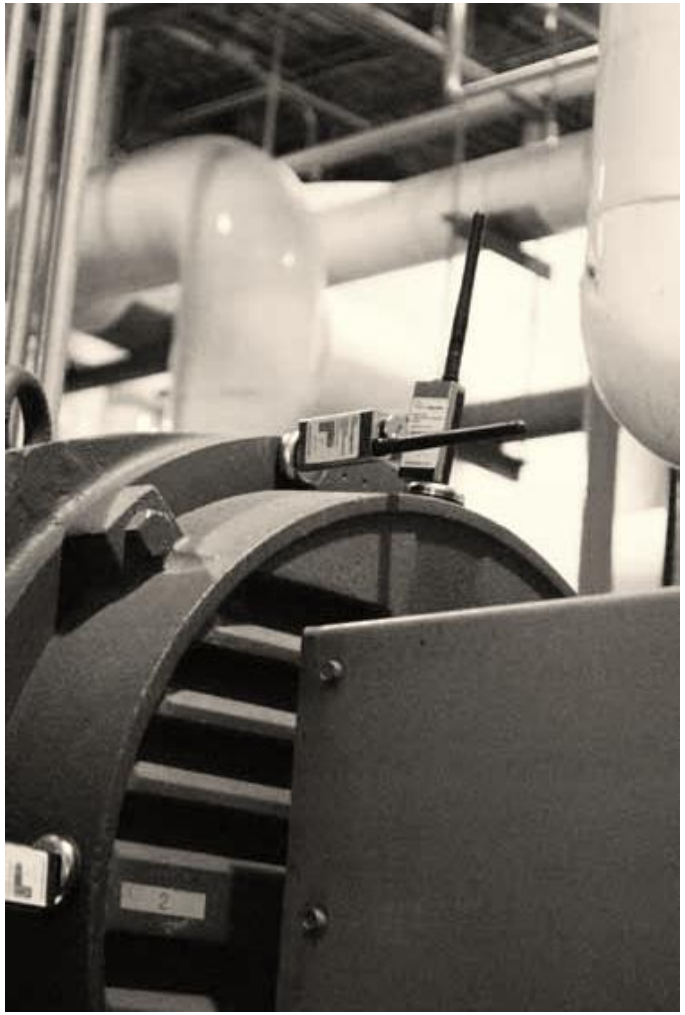
Smart Homes

Source: https://www.fierceelectronics.com/components/comfort-health-and-convenience-are-roles-sensors-smart-home

Industrial application- a case study

- KCF Technologies' wireless vibration monitor is mounted on an industrial chiller. (Courtesy of KCF Technologies, Inc.)



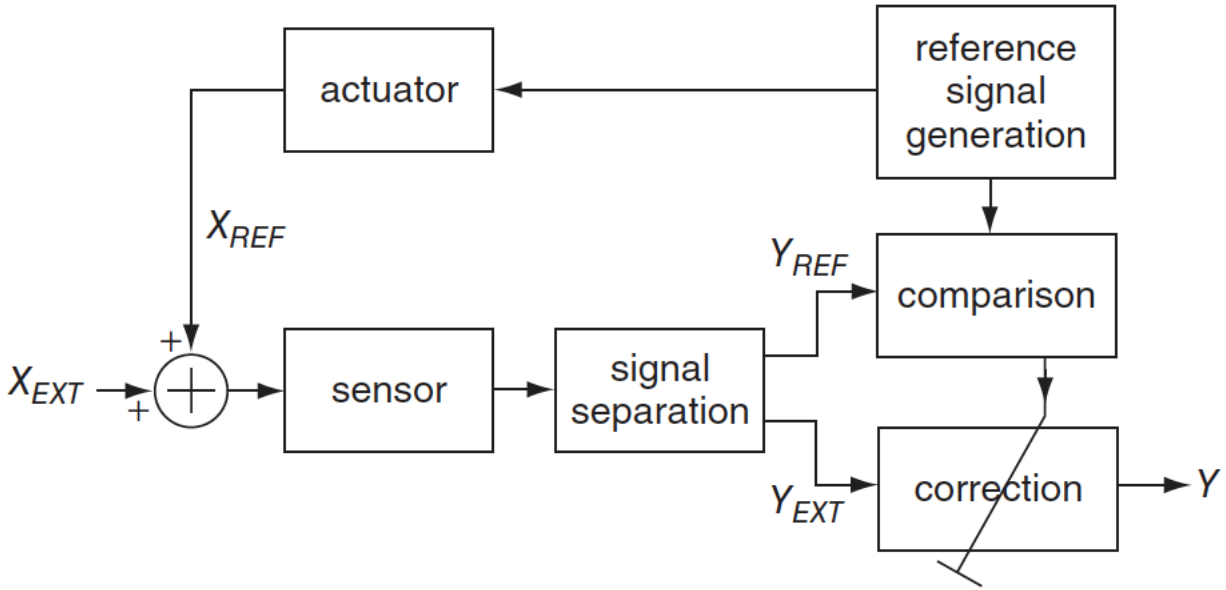


Cost saving using smart sensors

System Benefits	*Cost Savings*
Delays periodic system rebuilds	$82,000 (per occurrence)
Prevents component damage	$18,000 to $38,000
Reduces overtime labor maintenance costs	$50,000
Prevents losses to inventory, batches, and associated downtime	$500,000
Reduces catastrophic failures and personal injuries	>$1,000,000

Self-calibration of Sensactors

This figure illustrates an example of what is commonly referred to as a "sensactor," which is a combination of a sensor and an actuator.
The actuator produces a calibration signal X_{REF}, which is combined with the external measurand X_{EXT} at the sensor's input.
Subsequently, at the sensor's output, its response Y_{REF} to the reference signal is isolated and juxtaposed with the expected response based on the signal applied to the actuator.



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[1] Sarfraz, Zouina & Sarfraz, Azza & Iftikar, Hamza & Akhund, Ramsha. (2021). Is COVID-19 pushing us to the Fifth Industrial Revolution (Society 5.0)?. Pakistan Journal of Medical Sciences. 37. 10.12669/pjms.37.2.3387.

[2] Middelhoek, S. and Audet, S.A. (1989). Silicon Sensors, Academic Press. Reproduced by permission of S.Middelhoek.

[3] Kalsoom, T.; Ramzan, N.; Ahmed, S.; Ur-Rehman, M. Advances in Sensor Technologies in the Era of Smart Factory and Industry 4.0. Sensors 2020, 20, 6783. https://doi.org/10.3390/s20236783

[4] Park, Kyungseo & Yuk, H & Yang, M & Cho, J & Lee, H & Kim, J. (2022). A biomimetic elastomeric robot skin using electrical impedance and acoustic tomography for tactile sensing. Science robotics. 7. eabm7187. 10.1126/scirobotics.abm7187.

[5] Smart sensor systems: emerging technologies and applications / edited by Gerard C.M. Meijer, Michiel Pertijs, Kofi Makinwa, Understanding Smart Sensors, Third Edition, Randy Frank

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