

1 Sensors Fundamental.....	1
Introduction.....	1
1.1 Sensor Classification.....	1
1.2 Thermal Sensors.....	3
1.2.1 Thermistors.....	4
1.2.2 Thermocouple.....	5
1.2.3 Resistance Temperature Detectors (RTD).....	6
1.3 Humidity Sensors.....	8
1.3.1 Resistive Humidity Sensors (RHS).....	8
1.3.2 Capacitive Humidity Sensors (CHS).....	8
1.3.3 Thermal Conductivity Humidity Sensors (TCHS).....	9
1.4 Capacitive Sensors.....	10
1.5 Planar Interdigital Sensors.....	11
1.6 Planar Electromagnetic Sensors.....	13
1.7 Light Sensing Technology.....	16
1.7.1 Photometric Sensors.....	16
1.7.2 Light Dependent Resistors (LDR).....	16
1.7.3 Pyranometers.....	17
1.8 Moisture Sensing Technology.....	18
1.8.1 Frequency Domain Reflectometry (FDR) Soil Moisture Sensor.....	18
1.8.2 Time Domain Reflectometry (TDR) Soil Moisture Sensor.....	19
1.8.3 Gypsum Blocks.....	19
1.8.4 Neutron Probes.....	20
1.9 Carbon Dioxide (CO ₂) Sensing Technology.....	20
1.9.1 Solid State Electrochemical (SSE) CO ₂ Sensors.....	20
1.9.2 Non-dispersive Infrared (NDIR) CO ₂ Sensors.....	21
1.10 Sensors Parameters.....	22
1.10.1 Range.....	22
1.10.2 Sensitivity.....	23
1.10.3 Accuracy.....	23
1.10.4 Stability.....	23
1.10.5 Repeatability.....	23
1.10.6 Static and Dynamic Characteristics.....	24
1.10.7 Energy Harvesting.....	24

1.10.8 Compensation Due to Change of Temperature and Other Environmental Parameters.....	24
1.11 Selection of Sensors	24
1.12 Suggested Further Reading	25
2 Interfacing of Sensors and Signal Conditioning.....	29
Introduction.....	29
2.1 Change of Bias and Level of Signals	29
2.2 Loading Effect on Sensor's Output	30
2.3 Potential Divider	31
2.4 Low-Pass RC Filter	33
2.5 High-Pass RC Filter	35
2.6 Practical Issues of Designing Passive Filters	36
2.7 Op-Amp Based Instrumentation.....	37
2.7.1 Differential Amplifier.....	38
2.7.2 Common Mode Rejection.....	39
2.7.3 Single-Resistance Controlled Instrumentation Amplifier.....	40
2.8 Current-to-Voltage Converter	41
2.9 Comparator.....	42
2.10 A Few Guidelines to Design Signal Conditioning Circuit	45
2.11 Factors Affecting Performance of Sensors.....	46
2.11.1 Revisit of the Specification of Sensors	46
2.11.1.1 Accuracy.....	47
2.11.1.2 Overall Accuracy.....	48
2.11.1.3 Standard Deviation	49
2.12 Effect of Temperature	50
2.13 Degradation of Sensors	51
2.14 Suggested Further Reading.....	52
3 Wireless Sensors and Sensors Network.....	55
Introduction.....	55
3.1 Frequency of Wireless Communication	57
3.2 Development of Wireless Sensor Network Based Project	58
3.2.1 Wireless Sensor Based on Microcontroller and Communicating Device.....	58
3.2.2 Wireless Sensor Network Based on Microcontroller and Zigbee Communicating Device	63
3.3 Wireless Sensor Network Based on Only Zigbee	67
3.4 Suggested Further Reading	67
4 Power Supplies for Sensors.....	71
Introduction.....	71
4.1 Power Sources.....	72
4.1.1 Power from Mains Supply	72
4.1.2 Battery	73
4.1.2.1 Selection of Batteries.....	73

4.1.2.2	Alkaline Batteries	74
4.1.2.3	Lithium Battery	74
4.1.2.4	Lithium-Ion Battery	75
4.1.2.5	Nickel-Metal Hydride (NiMH) Battery	75
4.1.2.6	Lead Acid Battery	76
4.2	Energy Harvesting	76
4.2.1	Solar Energy	77
4.3	Further Investigation into Solar and Lead Acid Batteries	80
4.4	Wind Energy	84
4.5	RF Energy Harvesting	84
4.6	Energy Harvesting from Vibration	86
4.7	Thermal Energy Harvesting	86
4.8	Energy Management Techniques	87
4.8.1	Routing Protocol	87
4.8.2	Introduction of Sleep Mode	87
4.8.3	MAC Protocol	88
4.9	Calculation for Battery Selection	88
4.10	Suggested Further Reading	89
5	Software Design for Data Reception and Analysis.....	91
	Introduction	91
5.1	Set-Up of the Wireless Sensor Network	92
5.2	Steps to Configure the ZigBee Radio Modules	94
5.2.1	ZigBee Explorer USB	94
5.2.2	Preparation of the Coordinator (Base Station Radio)	94
5.2.3	Configuring the Remote ZigBee (Sensing Device #1 Radio Module)	96
5.3	Brief Description of API Mode Data Transmission	96
5.4	Testing the Communication between Coordinator and Remote XBee....	100
5.4.1	Example 1	100
5.5	Design and Development of Graphical User Interface for Receiving Sensor Data Using C#	102
5.5.1	Creating a New Visual Studio C# Program	102
5.6	Changing Component Names	107
5.7	Add Program Statements to a Visual Studio C# Application	109
5.7.1	Coding Steps for Receiving Sensor Data through Serial Port	110
5.8	The Complete Program(<i>Form1.cs</i>) with Explanation in the Form of Comments is Given Below	111
	References	118
6	Sensors Signal Processing Techniques.....	119
	Introduction	119
6.1	A Brief Review of Signal Processing Techniques for Structural Health Monitoring	119
6.1.1	Normalization	121

- 6.1.2 Feature Extraction122
 - 6.1.3 Dimensionality Reduction125
 - 6.1.4 Collaborative Damage Event Detection (CBED) Method127
- 6.2 Signal Processing Techniques for Information Extraction from Sensor Data127
 - 6.2.1 Deriving Information from Sensor Data: Daily Activity Recognition Models.....128
 - 6.2.1.1 The Hidden Markov Model (HMM).....128
 - 6.2.1.2 The Conditional Random Field (CRF).....131
 - 6.2.1.3 The Skip Chain Conditional Random Field (SCCRF)....133
 - 6.2.1.4 Emerging Patterns (EP).....133
 - 6.2.2 Finding Patterns in Sensor Data135
 - 6.2.3 Classifying Sensor Data.....136
 - 6.2.4 Detecting Trends136
 - 6.2.5 Characterizing Sensor Data137
 - 6.2.6 Annotation Methods137
- References.....138

7 Description of a Few Projects.....141

- Introduction.....141
- 7.1 WSN Based Physiological Parameters Monitoring System141
 - 7.1.1 Measurement of Human Body Temperature143
 - 7.1.1.1 Temperature Sensor.....144
 - 7.1.1.2 The Heart-Rate Sensor147
 - 7.1.1.3 Impact Sensor150
 - 7.1.1.4 Communication between Sensor Unit and Micro-controller152
 - 7.1.1.5 Software and Algorithms.....153
 - 7.1.1.6 Temperature Sensor Algorithm153
 - 7.1.1.7 Impact Sensor Algorithm153
 - 7.1.1.8 Heart Rate Sensor Algorithm154
 - 7.1.1.9 Receiver Algorithms.....154
- 7.2 Intelligent Sensing System for Emotion Recognition155
 - 7.2.1 Aim of the Emotion Recognition System.....155
 - 7.2.2 Development of Intelligent Sensing System for Emotion Recognition156
 - 7.2.3 Experimental Results and Analysis160
 - 7.2.4 Observations and Discussion.....165
- 7.3 WSN Based Smart Power Monitoring System.....166
 - 7.3.1 System Overview.....166
 - 7.3.1.1 Voltage Measurement166
 - 7.3.1.2 Current Measurement167
 - 7.3.1.3 Power Measurement168
 - 7.3.1.4 Experimental Results.....172
- 7.4 Suggested Further Reading173