

## Table of Contents

Foreword .....	7
1. INTRODUCTION .....	9
1.1 Sensing and monitoring in digital manufacturing.....	9
1.1.1 From Industry 1.0 to Industry 4.0 .....	11
1.1.2 Smart sensors for Industry 4.0.....	14
1.2 Metrology and measurements.....	18
2. SIGNALS AND MEASUREMENTS .....	22
2.1 Signals and disturbances .....	22
2.1.1 Signals.....	22
2.1.2 Disturbances.....	28
2.1.3 Signal sampling.....	29
2.2 Measurements methodology.....	31
2.2.1 Classification of measurement methods.....	31
2.2.2 Means of measurement .....	36
2.2.3 Measures .....	36
2.3 Measuring Devices .....	37
2.3.1 Fundamentals of measuring devices.....	37
2.3.2 Classification of measuring devices .....	39
2.3.3 Block diagrams of measuring devices .....	40
2.3.4 Metrology requirements of measuring devices .....	42
2.3.5 Measurement and source errors .....	49
3. TEMPERATURE SENSORS .....	54
3.1 Physics laws for sensing application .....	54
3.2 Basics of temperature measurement .....	58
3.3 Contact sensors for temperature measurement .....	60
3.3.1 Thermistors .....	60
3.3.2 Thermocouples.....	62
3.3.3 Resistance thermometers .....	66
3.3.4 Semiconductor-based sensors .....	69
3.4 Non - contact sensors for temperature measurement .....	70

3.4.1 Thermal detectors.....	71
3.4.2 Quantum detectors .....	74
3.5 Advanced temperature detectors .....	75
4. TRANSDUCING CIRCUITS .....	80
4.1 Basics of transducers .....	80
4.2 Temperature transducers circuits .....	84
4.2.1 Thermistor transducer circuit .....	85
4.2.2 Thermocouples transducer circuit .....	86
4.2.3 Resistance thermometer transducer circuit .....	88
4.2.4 Diode sensor temperature transducer circuit .....	89
4.2.5 IR sensor temperature transducer circuit .....	90
5. DIGITAL MEASUREMENTS SYSTEMS .....	92
5.1 Basics structure of a digital measurement system .....	92
5.1.1 DMS with serial/parallel communication.....	92
5.1.2 DMS with data acquisition card .....	93
5.2 Signal conditioning.....	94
5.3 Signal Multiplexing .....	97
5.4 Memory circuits .....	100
6. MONITORING APPLICATIONS .....	102
6.1 Sensing and controlling temperature in resistance heating .....	102
6.2 Sensing temperature in microwave heating .....	108
6.3 Differential thermal analysis.....	112
6.4 Digital monitoring of temperature in silos.....	117
7. VIRTUAL INSTRUMENTATION .....	121
7.1 Introduction in virtual instrumentation .....	121
7.2 Virtual instrumentation for temperature sensor .....	126
7.2.1 NI-DAQmx application for contact temperature sensor .....	126
7.2.2 Signametrics 2064 PCI for contact temperature sensor.....	129
7.2.2 IMAQx application for non-contact temperature sensor.....	132
Reference .....	135