

Contents

Preface	ix
1. Introduction to Measurements	1
2. Fundamentals of Electrical Measurements	13
2.1. Main Terms and Definitions	13
2.1.1. Basic terms of measurement technique	13
2.1.2. The main methods of measurements	18
2.2. Uncertainty of Measurements	26
2.2.1. Errors, uncertainty, and reliability of signal processing	26
2.2.2. Basic statistical terms and concepts	34
2.2.3. Methods of evaluation and correction of the uncertainty related to limited accuracy of measuring devices	40
2.2.4. The estimation of uncertainty in measurements	52
2.3. Standards of Electrical Quantities	57
2.3.1. Standards, etalons, calibration and validation	57
2.3.2. The standards of electrical quantities referred to the physical phenomena and laws	58
2.3.3. Material standards of electrical quantities	63
2.3.4. The reference multimeters and calibrators	69
References	71
3. Classic Electrical Measurements	73
3.1. Indicating Measuring Instruments	73
3.1.1. Electromechanical instruments versus digital measuring systems	73
3.1.2. The moving coil meters	74
3.1.3. The moving iron meters	81
3.1.4. Electrodynamic meters – wattmeters	82
3.1.5. Induction type watt-hour meters	86
3.2. Recording and Displaying Measuring Instruments	88
3.2.1. Fundamentals of oscilloscopes	88
3.2.2. Recorders and data storage devices	93
3.3. Bridge Circuits	94
3.3.1. Balanced and unbalanced bridge circuits	94
3.3.2. Null-type DC bridge circuits	96

3.3.3. The AC bridge circuits	99
3.3.4. The transformer bridge circuits	104
3.3.5. The unbalanced bridge circuits	107
3.3.6. The alternatives for bridge circuits – Anderson Loop	112
3.4. Potentiometers and Comparators	114
References	118
4. Processing of the Analogue Measurement Signals	121
4.1. Signal Conditioning	121
4.1.1. Analogue measurement signals	121
4.1.2. Conditioning of resistance, capacitance and inductance	126
4.1.3. AC/DC conversion	131
4.1.4. Voltage to frequency conversion	141
4.2. Amplification of the Signals	143
4.2.1. Differential, operational and instrumentation amplifiers	143
4.2.2. Isolation amplifiers	147
4.2.3. Amplifiers of very small DC signals	150
4.2.4. Amplifiers of very small AC signals	154
4.2.5. Amplifiers of very large input resistance (electrometers)	159
4.2.6. The function amplifiers	161
4.3. Negative Feedback in the Measuring Technique	169
4.4. The Improvement of the Quality of the Analogue Signals	179
4.4.1. The noises and interferences of the analogue signals	179
4.4.2. The connection of the measuring signal to the amplifier	184
4.4.3. The analogue filtering of the signals	191
References	201
5. Digital Processing of the Measurement Signals	205
5.1. Analogue-to-Digital Converters	205
5.1.1. Sampling, quantization and coding of signals	205
5.1.2. Analogue-to-digital converters ADC	218
5.1.3. The main specifications of analogue-to-digital converters	234
5.2. Digital-to-Analogue Converters	238
5.2.1. The reconstruction of the analogue signal	238
5.2.2. The digital-to-analogue converters DAC	242
5.2.3. The main specifications of digital-to-analogue converters	247
5.3. Methods and Tools of Digital Signal Processing	249
5.3.1. The main terms of digital signal processing	249
5.3.2. The Discrete Fourier Transform DFT and Fast Fourier Transform FFT	259
5.3.3. Short-time Fourier Transform and Wavelet transform	268
5.3.4. Digital filters	275

5.4. Examples of Application of Digital Signal Processing in Measurements	287
5.4.1. The spectral analysis	287
5.4.2. Digital signal synthesis	297
5.4.3. Improvement of the signal quality and the signal recovery	303
5.5. Digital Measuring Instruments	312
5.5.1. Digital multimeters and frequency meters	312
5.5.2. Digital oscilloscopes	318
5.5.3. Digital measurement of power and energy	323
5.6. Intelligent Data Analysis	326
5.6.1. The artificial intelligence in measurements	326
5.6.2. The adaptive filters	327
5.6.3. Artificial neural networks	331
5.6.4. Fuzzy Logic	340
References	344
6. Computer Measuring Systems	349
6.1 Introduction	349
6.2. Input Circuits of the Measuring Systems	353
6.2.1. Circuits for data conditioning and acquisition	353
6.2.2. The sensors with built-in interface – intelligent sensors	354
6.2.3. Analogue and digital transmitters	356
6.2.4. Data loggers	357
6.2.5. IEEE P1451 standard – smart sensors	359
6.3. Data Acquisition Circuits – DAQ	362
6.3.1. Plug-in data acquisition board	362
6.3.2. External data acquisition board	365
6.4. Data Communication in Computer Measuring Systems	367
6.4.1. Interfaces, buses and connectors	367
6.4.2. Serial interfaces: RS-232C and RS-485	368
6.4.3. Serial interfaces: USB and FireWire	373
6.4.4. Parallel GPIB interface (IEEE-488/IEC-625)	377
6.4.5. Wireless interfaces: IrDA, Bluetooth and WUSB	382
6.4.6. Mobile telephony systems GSM and UMTS as a tool for data transfer	385
6.4.7. Radio data acquisition and transfer	389
6.4.8. Computer systems using Ethernet and Internet	392
6.4.9. Dedicated interfaces: CAN, I ² C, MicroLAN, SDI-12	396
6.4.10. HART interface and the 4 – 20 mA standard	400
6.4.11. Industrial communication standards – Fieldbus, Profibus, SCADA	401
6.4.12. Modular systems – VXI, PXI	406
6.4.13. Standard command for measuring devices – SCPI	408

6.5. Measuring Systems Basing on the Signal Processors	410
6.5.1. Microcontrollers and signal processors in measuring technique	410
6.5.2. Microinterfaces – SPI and UART	418
6.6. Virtual Measuring Systems	421
6.6.1. What is the virtual measuring device?	421
6.6.2. TestPoint	424
6.6.3. Agilent VEE Pro	428
6.6.4. LabVIEW of National Instruments	431
6.7. The Examples of Computer Measuring Systems	438
6.7.1. The measuring system for testing of magnetic materials	438
6.7.2. The arbitrary wave excitation systems	442
6.7.3. The scanning device for magnetic field imaging	449
References	452
Symbols used in the Book	455
Abbreviations used in the Book	457
Index	461