

Contents

1	Introduction	1
1.1	Power Electronics Systems	1
1.2	Digital Control Circuits for Power Electronics Systems	3
1.2.1	Analog Versus Digital Control Circuit	4
1.2.2	Causal and Noncausal Circuits	5
1.2.3	LTI Discrete-Time Circuits	6
1.2.4	Digital Filters	7
1.2.5	Hard Real-Time Control Systems	9
1.2.6	Sampling Rate	11
1.2.7	Simultaneous Sampling	11
1.2.8	Number of Bits	11
1.3	Multirate Control Circuits	12
1.4	Active Power Filters	13
1.5	Digital Class D Power Amplifiers	16
1.6	Symbols of Variables	17
1.7	What is in This Book	18
	References	19
2	Analog Signals Conditioning and Discretization	23
2.1	Introduction	23
2.2	Analog Input	23
2.2.1	Galvanic Isolation	23
2.2.2	Common Mode Voltage	24
2.2.3	Isolation Amplifiers	25
2.3	Current Measurements	30
2.3.1	A Resistive Shunt	30
2.3.2	Current Transformers	31
2.3.3	Transformer with Hall Sensor	33
2.3.4	Current Transformer with Magnetic Modulation	36
2.3.5	Current Transducer with Air Coil	36
2.3.6	Comparison of Current Sensing Techniques	38
2.4	Total Harmonic Distortion	38
2.5	Analog Signal Sampling Rate	41

2.6	Signal Quantization	44
2.7	Noise Shaping Technique	46
2.8	Dither	48
2.9	Signal Headroom	50
2.10	Maximum Signal Frequency versus Signal Acquisition Time	52
2.11	Errors in Multichannel System.	54
2.12	Amplitude and Phase Errors of Sequential Sampling A/D Conversion	56
2.13	Synchronization of Sampling Process	57
2.14	Sampling Clock Jitter	59
2.15	Effective Number of Bits	61
2.16	A/D Converters Suitable for Power Electronics Control Circuits	63
2.16.1	A/D Converter with Successive Approximation	63
2.16.2	A/D Converter with Delta Sigma Modulator	64
2.16.3	Selected Simultaneous Sampling A/D Converters.	65
2.16.4	ADS8364	65
2.16.5	AD7608	66
2.16.6	ADS1278	68
2.16.7	TMS320F28335	69
2.17	Conclusions.	70
	References	70
3	Selected Methods of Signal Filtration and Separation and Their Implementation	73
3.1	Introduction.	73
3.2	Digital Filters	74
3.2.1	Digital Filter Specifications	74
3.2.2	Finite Impulse Response Digital Filters.	75
3.2.3	Infinite Impulse Response Digital Filters	77
3.2.4	Designing of Digital IIR Filters	80
3.3	Lattice Wave Digital Filters	82
3.3.1	Comparison of Classical IIR Filter and Lattice Wave Digital Filter	85
3.3.2	Realization of LWDF	86
3.4	Modified Lattice Wave Digital Filters	89
3.4.1	First-Order Sections	89
3.4.2	Second-Order Sections	92
3.5	Linear-Phase IIR Filters	94
3.6	Multirate Circuits.	100
3.6.1	Signal Interpolation	101
3.6.2	Signal Decimation	103
3.6.3	Multirate Circuits with Wave Digital Filters	106
3.6.4	Interpolators with Linear-Phase IIR Filters	107

3.7	Digital Filter Banks	108
3.7.1	Strictly Complementary Filter Bank	110
3.7.2	DFT Filter Bank	112
3.7.3	Sliding DFT Algorithm.	114
3.7.4	Sliding Goertzel Algorithm	117
3.7.5	Moving DFT Algorithm	117
3.7.6	Wave Digital Lattice Filter Bank	121
3.8	Implementation of Digital Signal Processing Algorithms	126
3.8.1	Basic Features of the DSP.	129
3.8.2	Digital Signal Processors: SHARC Family	136
3.8.3	Digital Signal Controller: TMS320F28xx Family	138
3.8.4	Digital Signal Processor: TMS320C6xxx Family	139
3.9	Conclusions.	140
	References	140
4	Selected Active Power Filter Control Algorithms	145
4.1	Introduction.	145
4.2	Control Circuit of Shunt APFs.	146
4.2.1	Synchronization	147
4.3	APF Control with First Harmonic Detector	150
4.3.1	Control Circuit with Low-Pass 4-Order Butterworth Filter.	150
4.3.2	Control Circuit with Low-Pass 5-Order Butterworth LWDF	154
4.3.3	Control Circuit with Sliding DFT.	154
4.3.4	Control Circuit with Sliding Goertzel	157
4.3.5	Control Circuit with Moving DFT	159
4.4	The $p - q$ Theory Control Algorithm for Shunt APF	160
4.5	Shunt APF Classical Control Circuit	164
4.6	Dynamics of Shunt APF.	171
4.7	Methods of Reducing APF Dynamic Distortion.	176
4.7.1	APF Output Current Ripple Calculation	178
4.8	Predictive Control Algorithm for APF	180
4.8.1	Experimental Results	181
4.8.2	Step Response of APF	184
4.9	Selected Harmonics Separation Methods Suitable for APF	186
4.9.1	Control Circuit with MDFT.	188
4.9.2	Control Circuit with IPT Algorithm	188
4.10	Multirate APF	188
4.10.1	Analog Input Circuit	192
4.10.2	Output Inductors	195
4.10.3	APF Simulation Results	197
4.11	Conclusion	201
	References	202

5	Digital Signal Processing Circuits for Digital Class D Power Amplifiers	205
5.1	Introduction.	205
5.2	Digital Class D Power Amplifier Circuits	206
5.3	Modulators for Digital Class D Power Amplifiers	207
5.3.1	Oversampled Pulse Width Modulator	212
5.4	Basic Topologies of Control Circuits for Digital Class D Power Amplifiers.	213
5.4.1	Open Loop Amplifiers	213
5.4.2	Amplifiers with Digital Feedback for Supply Voltage.	215
5.4.3	Amplifiers with Analog Feedback for Output Pulses	215
5.4.4	Amplifiers with Digital Feedback.	218
5.5	Supply Units for Class D Power Amplifiers	219
5.6	Click Modulation.	221
5.7	Interpolators for High Quality Audio Signals.	223
5.7.1	Single-Stage Interpolators	224
5.7.2	Multistage Interpolators	225
5.8	Class D Audio Power Amplifiers.	229
5.8.1	Digital Crossovers	230
5.8.2	Loudspeaker Measurements.	233
5.9	Class D Power Amplifier with Digital Click Modulator	236
5.9.1	Digital Crossovers	238
5.9.2	Realization of Digital Click Modulator.	240
5.9.3	Experimental Results	245
5.10	Digital Audio Class D Power Amplifier with TAS5508 DSP.	248
5.10.1	TAS5508-5121K8EVM.	249
5.10.2	Three-way Digital Crossover.	251
5.10.3	Experimental Results	253
5.11	Conclusions.	253
	References	254
6	Conclusion	259
6.1	Summary of Results	259
6.2	Future Work	261
	References	262
	Index	263