Contents

Chapte	er 1: Hall-Effect Physics	1
1.1	A Quantitative Examination	3
1.2	Hall Effect in Metals	5
1.3	The Hall Effect in Semiconductors	7
1.4	A Silicon Hall-Effect Transducer	9
Chapte	er 2: Practical Transducers	11
2.1	Key Transducer Characteristics	11
	Sensitivity	11
	Temperature Coefficient of Sensitivity	12
	Ohmic Offset	13
	Temperature Coefficient of Ohmic Offset	14
	Linearity	14
	Input and Output Resistances	14
	Temperature Coefficient of Resistance	15
	Noise	15
2.2	Bulk Transducers	16
2.3	Thin-Film Transducers	17
2.4	Integrated Hall Transducers	20
2.5	Transducer Geometry	26
2.6	The Quad Cell	27
2.7	Variations on the Basic Hall-Effect Transducer	30
2.8	Examples of Hall Effect Transducers	33

vi *CONTENTS*

Chapte	r 3: Transducer Interfacing	35
3.1	An Electrical Transducer Model	36
3.2	A Model for Computer Simulation	38
3.3	Voltage-Mode Biasing	41
3.4	Current-Mode Biasing	45
3.5	Amplifiers	48
3.6	Amplifier Circuits	51
3.7	Analog Temperature Compensation	54
3.8	Offset Adjustment	57
3.9	Dynamic Offset Cancellation Technique	58
Chapte	r 4: Integrated Sensors: Linear and Digital Devices	61
4.1	Linear Sensors	62
4.2	Linear Transfer Curve	65
4.3	Drift	66
4.4	Ratiometry	67
4.5	Output Characteristics	68
4.6	Bandwidth	69
4.7	Noise	71
4.8	Power Supply Requirements for Linear Sensors	71
4.9	Temperature Range	72
4.10	Field-Programmable Linear Sensors	72
4.11	Typical Linear Devices	74
4.12	Switches and Latches	75
4.13	Definition of Switch vs. Latch	77
4.14	Switchpoint Stability	78
4.15	Bipolar Switches	78
4.16	Power Supply Requirements for Digital Sensors	79
4.17	Output Drivers	80
4.18	Typical Digital Devices	81
Chapte	r 5: Interfacing to IntegratedHall-Effect Devices	83
5.1	Interface Issues—Linear Output Sensors	83
5.2	Offset and Gain Adjustment	84

	5.3	Output Thresholding	86
	5.4	Interfacing to Switches and Latches	88
	5.5	The Pull-Up Resistor	88
	5.6	Interfacing to Standard Logic Devices	90
	5.7	Discrete Logic	91
		Logic NOT Output	92
		Wired OR Output	93
		AND function	93
	5.8	Driving Loads	93
	5.9	LED Interfaces	93
	5.10	Incandescent Lamps	94
	5.11	Relays, Solenoids, and Inductive Loads	96
	5.12	Wiring-Reduction Schemes	98
	5.13	Encoding and Serialization	98
	5.14	Digital-to-Analog Encoding	99
	5.15	Mini-Networks	102
	5.16	Voltage Regulation and Power Management	104
C1.	antai	r 6: Proximity-Sensing Techniques	107
CI.	iapici		—
CI.	6.1	Head-On Sensing	
CI.	_		107
CI.	6.1	Head-On Sensing	107 109
CI.	6.1 6.2	Head-On Sensing	107 109 110
CI	6.1 6.2 6.3	Head-On Sensing	107 109 110
CI	6.1 6.2 6.3 6.4	Head-On Sensing	107 109 110 114
CI	6.1 6.2 6.3 6.4 6.5	Head-On Sensing Slide-By Sensing Magnet Null-Point Sensing Float-Level Sensing Linear Position Sensing	107109110114116
CI	6.1 6.2 6.3 6.4 6.5 6.6	Head-On Sensing	107109110114116118
	6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8	Head-On Sensing	107109110114116122
	6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8	Head-On Sensing Slide-By Sensing Magnet Null-Point Sensing Float-Level Sensing Linear Position Sensing Rotary Position Sensing Vane Switches	107109110114116122126
	6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8	Head-On Sensing	
	6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8	Head-On Sensing	
	6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8 napter 7.1 7.2	Head-On Sensing Slide-By Sensing Magnet Null-Point Sensing Float-Level Sensing Linear Position Sensing Rotary Position Sensing Vane Switches Some Thoughts on Designing Proximity Sensors r 7: Current-Sensing Techniques Resistive Current Sensing Free-Space Current Sensing	
	6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8 napter 7.1 7.2 7.3	Head-On Sensing Slide-By Sensing Magnet Null-Point Sensing Float-Level Sensing Linear Position Sensing Rotary Position Sensing Vane Switches Some Thoughts on Designing Proximity Sensors 7: Current-Sensing Techniques Resistive Current Sensing Free-Space Current Sensing Free-Space Current Sensors II	

viii CONTENTS

	7.6	Toroid Material Selection and Issues	143
	7.7	Increasing Sensitivity with Multiple Turns	144
	7.8	An Example Current Sensor	145
	7.9	A Digital Current Sensor	146
	7.10	Integrated Current Sensors	147
	7.11	Closed-Loop Current Sensors	148
Cl	napter	8: Speed and Timing Sensors	151
	8.1	Competitive Technologies	151
	8.2	Magnetic Targets	153
	8.3	Vane Switches	155
	8.4	Geartooth Sensing	157
	8.5	Geartooth Sensor Architecture	158
	8.6	Single-Point Sensing	159
	8.7	Single-Point/Fixed-Threshold Schemes	161
	8.8	Single-Point/Dynamic-Threshold Schemes	163
	8.9	Differential Geartooth Sensors	167
	8.10	Differential Fixed-Threshold	169
	8.11	Differential Variable-Threshold	170
	8.12	Comparison of Hall-Effect Speed Sensing Methods	171
	8.13	Speed and Direction Sensing	171
	8.14	How Fast Do Speed Sensors Go?	173
Cl	haptei	r 9: Application-Specific Sensors	177
	9.1	Micropower Switches	177
	9.2	Two-Wire Switches	180
	9.3	Power Devices	182
	9.4	Power + Brains = Smart Motor Control	183
Cł	napter	· 10: Development Tools	187
	10.1	Electronic Bench Equipment	
		Power supplies	
		Voltmeters and DMMs	188
		Oscilloscope	189
		Frequency Counter	189

	Clamp-On Current Probes	189
	Solderless Breadboard	190
10	0.2 Magnetic Instrumentation	190
	Gaussmeter	190
	Fluxmeter	191
	Calibrated Hall-Effect ICs	192
	Polarity probe	192
	Magnetic View Film	193
	Magnetizers and Magnet Conditioners	193
	Helmholtz Coil	195
10	0.3 Mechanical Tools	196
	Optical Bench	196
	Linear Positioning Slides	196
	Rotary Table	197
	Calipers and Micrometers	197
	Machine Tools	198
	Environmental Chamber	199
10	0.4 Magnetic Simulation Software	199
Appe	endix A: A Brief Introduction	203
Α.	.1 Where Magnetic Fields Come From	203
A.	2 Magnetic Materials	205
A.	.3 Some Permanent Magnet Materials	210
Appe	endix B: Supplier List	211
Appe	endix C: Glossary of Common Terms	219
Appe	endix D: References and Bibliography	229
Abou	at the Author	231
Index	X	233