Index

٨	A ailant 100
A a channel, 171-172	Agilent, 188
•	air gap – the distance, 219
a digital current sensor, 146	all linear electronic systems, 71
a model for computer simulation, 38	all of the terminal functions, 59
a quantitative examination, 3	Allegro Microsystems, 62, 86, 146-147, 173,
a silicon hall-effect transducer, 9	182, 192, 211
A/D converter, 166-167	Alnico magnet, 159-160, 162, 219
A/m, 219	Alnico-type magnets, 125
about the author, 233	Ampere – MKS unit, 219
ABS, xi, 151-152	Ampere, Andre A., 2
AC coupler, 170	Amperes/meter, 219, 224
AC coupling, 163-165	Ampere-turn – One ampere passing, 219
AC-coupled, 164-166, 170	amplifier, vi, 14-15, 20-21, 24, 32, 41, 43-44,
architecture, 164	48-54, 56-58, 62-63, 68, 75, 85, 148-149,
detection scheme, 166	170-171, 178-179, 223, 225
geartooth, 164-165	circuits, vi, 51, 53, 63
sensor, 165	an electrical transducer model, 36
scheme, 166, 170	an example current sensor, 145
accurate instruments, 191	analog,
accurate modeling of nonlinear behaviors, 200	ICs, 79
active area – the surface of a Hall-effect, 219	integrated circuits, 232
actual Hall-effect transducer, 227	temperature compensation, vi, 54-55
actual levels of B, 208	analog-to-digital converter (ADC), 66-67, 83
ADC, 67-68	analysis of slotted Toroid, 141-142
input, 67-68	AND function, 93
Additional,	Andre A. Ampere, 2
IR voltage losses, 133	Anisotropic, 219, 223, 225
signal processing, 152	Ansoft's MAXWELL simulator, 199-200
adjustable temperature compensation, 74	Appendix D: References and Bibliography,
AGC, 170-171	231

Appendix A: A Brief Introduction, 203	Bate, 231
Appendix B: Supplier List, 211	behavior of,
Appendix C: Glossary of Common Terms,	a digital-output Hall, 76
219	a switch, 77
application-specific,	B-H curve showing magnetic hysteresis, 207
devices, 62	В-Н, 143, 207-208, 220-221, 223, 225-226
Hall-effect, 185	B-H-series Hall transducer, 12
Sensors, 177	bias circuits, 42-43
art of electronics, 232	bias current, photolithographic processing, 17
ASIC, 177	bias voltages, 38
assembly costs, 184-185	bibliography, ix, 231-232
assortment of digital Hall-effect ICs available	binary-weighted encoding, 100
today, 81	Biot-Savart law, 203-204
ATE, 188	bipolar,
attenuation, 69	having two polarities, 220
automotive, xii, 15, 71-72, 79, 103, 151-152,	Darlington transistors, 95-96
155-156, 167-168, 180	input amplifiers, 50
auto-nulling,	switch, 78, 82, 125, 220, 228
a group of techniques, 220	transistor, 95, 220
circuit waveforms, 60	TTL, 90
linear Hall-effect IC, 63	blocks implementing Hall-effect, 62
auto-zeroing - see Auto-nulling, 220	blue LEDs, 93-94
AV, 149-150	Bode plot, 68-69
available,	Boltzmann's, 15
differential geartooth sensor ICs, 166-	BOP = BRP, 76-78, 86, 108, 110, 128, 146,
167	154, 161, 163-165, 169, 220, 223-224, 228
Hall switches, 124	BOP and/or BRP, 124
Hall-effect IC packages, 143	BOP of the Hall, 163
Hall-effect transducers, 32-33	BOP threshold, 86
available IC processes, 21	Bosch, 103
Avogadro, 6	boundary conditions, 200
	breadboards, 187-188, 190
В	BRP,
B axis of the flux density vs, 128	specifications, 78
B channel, 171-172	switch, 224
Baltes, 30, 231	threshold, 86
bandwidth, vi, 15-16, 48-50, 68-69, 102-103,	thresholds, 86, 161
173-174, 188-189, 220	values, 86, 128
basic arrangement of a voltage-biased Hall-	brushless DC motor, 183-185
effect, 41	brute-force constant-current bias circuit, 45
basic Hall-effect transducer, v, 29-31	built-in pull-up resistors, 90
batch nature of IC fabrication processes, 126	hulk transducers 16

bulk transducers, v, 16-17, 42	logic gate, 90
	logic inputs, 181
C	logic, 80, 90, 181, 228
calibrated Hall-effect ICs, 192	processes, 63-64
calipers and micrometers, 197	switches, 59
calipers, ix, 197	technologies, 80
CAN bus support, 103	transistors, 63-64
capacitance, 42, 96, 105, 190, 193-194, 220	CMRR, 49, 52
capacitive, 43, 105, 194	coercive force, 144, 208, 221, 223
capacitor CB, 53	coercivity, 221
case of,	coil – a, 96-97, 137, 151-152, 191, 194-196,
a Hall-effect transducer, 43	206, 222, 226
a linear Hall-effect, 63-64	color-scale maps, 201
a single-ended AC-coupled, 170	column V of the periodic table, 8
CMOS logic, 90	combining equations, 7
Hall transducers, 9	common,
the silicon Hall-effect transducer, 10	Hall transducer, 26
Castagnetti, 231	IC processes, 9
CGS-derived units, 220	magnet materials, 210
unit of magnetic field intensity, 225	target geometries, 155-156
unit of magnetic flux density, 222	mode rejection, 48-49, 53
unit, 222, 224-225	mode signal, 43, 48
chemical vapor deposition (CVD), 21	mode voltage, 43, 131-132
Cheng, 232	comparator, 221
Chih-wen, 232	comparison of Hall-effect speed sensing
chopper-stabilization circuitry, 173-174	methods because, 170-171
circuit designers, 36	comparison of various geartooth, 171
circuits, vi, xi-xii, 9, 25, 27, 36-38, 41-44, 47,	competitive technologies speed, 151
51, 53, 60-61, 63-64, 68, 71, 80-81, 83-86,	computer simulation, vi, 38-39, 199
91-95, 110, 170, 172, 180-181, 183, 187-	concentrator, 221
188, 190, 220, 223, 225, 227-228, 231-233	conductor geometry, 134-136
circular flux concentrator, 119-120	constant current sources, 46
clamp-on current probes, 189	construction of a Hall-effect transducer, 26
closed-form analytic solutions, 199	construction of the digital-output Hall-effect
closed-loop current sensors, viii, 148-149	ICs, 60
closed-loop, viii, 148-150, 220, 225	consumer devices, xi
CMOS, 25, 51, 59, 63-64, 80, 90, 181, 220,	contemporary devices, 68, 76, 79
228, 231	context of Hall-effect, 227
amplifier circuits, 63	continuous behavior of the Hall-effect, 1-2
digital inputs look, 90	contour maps, 201
Hall-effect sensor can, 63-64	contrast bipolar, 220, 228
inputs, 90, 181	contrast closed-loop, 225

contrast unipolar, 220, 228	demagnetization, 221
conventional Hall-effect transducer, 31	curve, 221
copper, 1, 6-9, 19-20, 137, 174-175, 221	demonstration of the Hall effect, 1
corner frequency FC, 69	design of a Hall-effect, 41
correcting transducer offset, 58	design of integrated circuits, 231
corrosion resistance, 210 CSA, 135-136	designing high-quality Hall-effect sensor assemblies, 202
C-shaped structure, 141-142	designing proximity sensors, vii, 126-127,
Cunife, 221	129
Cu-Ni-Fe, 221	desired output current IO, 89
curie temperature, 221, 224	development tools, 187
current consumption, 71	device,
current probe, 189	switches ON, 180
current sensing, vii, 131-133, 135, 145	technology VN, 51
current sensor, viii, 131-140, 143-150, 232	Dewar flask, 199
closed-loop, 148, 150	Dexter Magnetic Technologies, 231
digital, viii, 146	Dickinson, 232
PCB-based, 135	different technologies, 50
Toroidal, 144, 147-148	differential,
current sensors, vii-viii, 133-137, 139-141,	a difference, 221
145-149, 189, 217, 227	amplifier, 43-44, 48-49, 51-52, 62, 223
current through RS, 46	fixed-threshold, viii, 169-170
current-mode biasing, vi, 45, 47	gain, 43-44, 48-49, 52-53
current-sensing techniques, 131	geartooth sensors, 166-167
customer support, iv	variable-threshold, 170
CVD, 21	digital current sensor, viii, 146
	digital devices, vi, 61-62, 64, 66, 68, 70, 72,
D	74, 76, 78-82, 90, 103
D flip-flop, 173	Hall, 64, 79, 93, 108
DAC, 63-64, 73	Hall-effect devices, 76, 79
Darlington transistors, 95-96	Hall-effect sensor output, 80
DC,	Hall-effect sensor turns OFF, 226
average, 164	Hall-effect sensors, 88, 154
bias signal, 164	Hall-effect switch, 146, 153
brushless, 183-185	Hall-effect, 75-82, 88, 90, 93-96, 98-99
fan, 183-185	106, 112, 146, 153-154, 161-162, 171-
steady-state behavior of a loop, 148-149	173, 221, 223-226
steady-state, 148-149, 173-174, 200	linear Hall sensor, 64
DC-blocking filter, 165	digital,
DC-coupled differential sensor can, 167-168	on/off output, 75, 221
definition of switch, 76-77	output susceptible, 152
definition of switch vs. latch, 77	sensor reaction, 76

sensors digital devices, 79	effects of,
sensors, vi, 76-82, 88, 90, 93-95, 98-100,	excessive supply-line noise, 80
106, 108, 154, 171-172, 221	rotating bias, 59
digital-output threshold-triggered devices, 62	transistor VBE variation, 46
digital-to-analog,	EH, 5
converter, 63-64	electrical,
encoding, vii, 99, 101	model, vi, 14-15, 36-37, 39, 43, 73
direction sensing, viii, 171	offsets, 170
dirty environments, 152	transducer model to, 36
disadvantage of a simple AC-coupled scheme,	bench equipment, viii, 187, 189
165	electrons, 2-3, 5-6, 8, 15, 203, 219-220
disadvantage of the vertical Hall structure, 31	EMI, 181-182
discovery of the Hall effect, 1-2	encoder, 221
discrete implementation of switch, 87	encoding and serialization, vii, 98-99
discrete logic circuits, 92	encoding multiple digital hall-effect, 99
discrete logic, vii, 90-93, 103-104	encoding, vii, 98-101
discrete-transistor logic, 91	energy loss, 131-132
R. Helmholtz, 223	Engel, 232
DMMs, viii, 188-189	engineering electromagnetics, 232
doghouse magnet, 125	environmental chamber, 199
down side of Johnson noise, 15-16	Epi, 22-23
drift, vi, 5-7, 14, 19-20, 48, 57, 66, 78	epitaxial Hall-effect transducer, 21, 23
velocity, 6-7	epitaxial N-type silicon layer, 21
driving loads, vii, 42-43, 93, 182	equal-valued resistors, 101
DSP, 64, 166-167	equivalent model of linear Hall-effect sensor
D-type flip-flop, 172	output, 68
dual hall-sensors, 231	Erickson, 231
duty-cycle, 221	ESD, 181-182
DVMs, 90, 132, 195-196	Ethernet, 102
dynamic offset cancellation technique, vi,	Exact frequency response of the sensor IC,
58-59	173-174
dynamic threshold, 158-159, 163-165	Example,
	Current Sensor, viii, 145
E	of a commercial thin-film Hall trans-
earth, 107, 134, 162, 222	ducer, 19-20
ECKO, 151-152	of a Hall device, 23
E-core polepiece, 125	of a micropower Hall-effect switch, 178
Edwin Hall, xi, 1-2	of a silicon Hall-effect IC, 25
effect of clamping, 74	of a silicon Hall-effect transducer's, 33
effective air gap, 227	of a two-wire Hall-effect switch, 180-181
effective thickness of the reverse-biased P-N	of a typical Hall-effect, 151
junction, 22	of finite element mesh, 201

of liquid-level, 115	float-level sensor, 114-116
of miniature lathe, 198	flow meter, 155
of ring, 139	flux decay, 122
of system benefiting, 67	flux density, 38, 83, 108, 115-117, 122-123,
of ASICs, 177	125, 128, 140-141, 144, 158-160, 166-167,
of Hall Effect Transducers, v, 32-33	190-191, 201-202, 207-209, 220, 222-227
of sensor ICs, 170-171	flux leakage, 122-123, 141, 143, 224
of signals present, 60	flux maps of magnetic systems, 222
external connections, 53	flux variation, 117-119, 161, 163
external flux concentrators, 31	flux, 30-32, 38, 40, 65, 73, 76, 83, 107-112,
extraneous uniform fields, 138	115-123, 125, 127-129, 133-136, 138, 140-
extreme example of an application-specific	144, 146-149, 151-154, 156-168, 174-175,
Hall IC, 183	190-191, 201-203, 206-209, 220-227, 232
	fluxmeter, ix, 191-192, 195-196, 222, 226
F	force-sense bias circuit, 43-44
F.W. Bell, 12, 16, 19-20, 39, 231	formulae, 121
face of an Alnico magnet, 162	four Hall-effect devices, 138
fall time, 81	four Hall-effect transducers, 31-32
FEA, 199	four possible classes of Hall-effect-based,
feedback loop, 148-150	158-159
feedback, negative, 68, 148, 150, 220	four-way symmetric Hall-effect transducer, 58
feedback, positive, 87	Fowle, 231
ferrite, 222	Frederick E., 231
ferromagnetic article detector, 231	free-space,
ferromagnetic materials, 205	current sensing conceptually, 133
ferrous targets minimum, 152	current sensing, vii, 133, 135
FET input op-amps, 52	current sensors ii, 136
FET technology, 50	current sensors ii, vii, 135-137, 139
FETs, 49	frequency,
field-programmable,	counter, viii, 188-189
linear hall, 73	response of the Hall transducer, 173-174
linear hall-effect, 71-72	functional block diagram of fluxmeter, 192
linear sensors, vi, 71-72	functional block diagram of threshold-sensi-
film deposition, 17-18	tive hall IC, 75
filter - an electronic circuit, 222	fundamental limitations of traditional Hall-ef-
fine gain – a coarse gain setting, 72	fect transducers, 30
first-order system, 68-71	fundamental units, 227
fixed-threshold signal processing method, 169	
flexibility, 17, 83, 137, 158-159	G
float-level sensing one position-sensing	G/A, 16-17, 149
application, 114	gain - the incremental ratio of an output
float-level sensing, 114	signal, vi, 11, 37, 39-44, 48-50, 52-57,

62-69, 71-74, 83-86, 95, 118-119, 139-140,	experiments, xi
143-144, 146, 148-150, 170-171, 221-223,	hypothesis, 2
225, 227	question, 2
adjustment, 83-84	time, 2
of a Hall-effect transducer, 56-57	Hall-effect,
sensor, 227	applications, xi-xii, 31, 61-62, 66, 78
gate of a power MOSFET, 96	element, 19-20, 158
gate terminal of a MOSFET, 96	ferromagnetic article proximity sensor,
gauss, 7, 14, 16-17, 24, 32, 38-40, 66, 72-73,	232
87-88, 118, 134, 140, 143-147, 162, 181,	generator, 231
191, 194-195, 206, 208, 220, 222, 224, 227	home-position, 113-114
gaussmeter, 190-191, 208, 222, 224	IC manufacturers, 78, 192
geartooth sensor, viii, 151, 155-161, 163-168,	IC parameters, 127
170-171, 173, 200-201, 221-222, 226-227	IC, 25, 63, 78, 126-127, 129, 143, 156-
sensing, viii, 156-157, 170-171	157, 174-175, 181-182, 190, 192
sensor architecture, 157-158	latch, 77
sensor assembly, 151	physics, 1
sensor, differential, 166-168, 221	sensor assemblies, 187, 202
geometric interpretation of vector, 204	sensor elements, 190
Gilbert, 231	sensor IC packages, 174-175
GND, 40, 99	sensor IC, 25, 126, 156-157, 174-175,
gradient, 26, 109-110, 158-159, 166-168,	190
221-222	sensor ICs, 21, 66-67, 103, 107, 173- 174, 191
H	sensor system, 36
Hall-effect in metals, 5, 7	sensor's output saturation, 146
Hall-effect in semiconductors, v, 7	sensor's output voltage, 73
Hall,	sensors theory, iii
electric field, 5	sensors, i, iii, xi-xiii, 20-21, 35, 61-66,
generators, 231	71-72, 75-78, 80-84, 86, 88, 90, 93-95,
ICs, 62, 65, 71-72, 75, 110, 166-167,	98-99, 102-107, 111-112, 114-116, 118
173-174, 219	122, 131, 137, 139, 145, 154, 156-157,
output voltage, 43, 45, 59	177-178, 185, 221, 227-228, 233
sensor IC, 62, 64-68, 71-73, 76, 86, 89-	switch, 77, 88, 90, 122-126, 146, 153,
90, 93, 109, 122, 178, 183, 231	177-178, 180-183, 192
sensor's output, 89	switch's output, 90
switch, 110, 122, 180	switches, 88, 124-125, 146, 161-162,
transducer, 4-5, 7, 9, 12, 15-16, 19-20,	179-180, 182
26, 29-30, 40, 62-64, 75, 115-116,	transducer elements, 167-168
159, 173-174	transducer out of silicon, 20
Hall, Edwin, xi, 1-2	transducer's behavior, 11
Hall's.	vane switch assembly, 126

vane switch, 125-126	illustration of a Helmholtz, 194-195
version of a Rogowski, 137	IMC Hall-effect transducers, 32
voltage, 1-2, 15	IMCs, 31
based applications, 107	impedance, 15-16, 50-52, 68-69, 85, 223
based speed-sensing methods, 155	implement Linbus protocols, 103
Hall-offset, 57-58	inaccurate instruments, 191
handheld DVM, 132	incandescent lamps, vii, 94-96, 182
hardness, 210	increasing sensitivity with multiple turns, 144
head-on,	increasing sensitivity, viii, 66-67, 144
actuation mode, 108	individual characteristics of the sensor ICs,
actuation, 107-108	127
sensing, vii, 107-109	inductance, 190, 223
Hedeen, 232	inductive loads, vii, 96-97, 182
Helmholtz Coil, ix, 194-196, 223	inductive, vii, 96-98, 137, 151-152, 182, 189
Hewlett-Packard, 188	industrial controls, xi
Hideki, 231	infineon, 211
high BOP switch, 109	inhomogeneities, 13, 118
HIGH state, 86, 221	input and output resistances 14
high-coercivity materials, 207	input bias current, 48-49
higher bandwidth, 220	input offset voltage, 48-49, 57-58
high-pass hall voltage filter, 231	input resistance ROUT, 38
high-quality hall-effect transducers, xi, 25	instrumentation amplifier, 48, 50, 52-54, 57-
Hill, iv, 214, 232	58, 223
Horowitz, 232	instrumentation-grade Hall-effect sensor can,
Howland current source, 47	xiii
hypothetical lot-to-lot variation, 127	integrated,
hysteresis, xii, 76, 78, 86-88, 109, 113-114,	AND gate, 93
128-129, 166-167, 179, 181-182, 206-207,	current sensors, 147
220, 223	Hall transducers, 20
	Hall-effect devices, 83-84, 86, 88, 90,
I	92, 94, 96, 98, 100, 102, 104, 106
IC,	Hall-effect devices, vi
manufacturers, 23, 78, 126-127, 192	sensors: linear and digital devices, 61
processes, 9, 21, 29, 126	integration of flux, 136
specs, 129	interface issues—linear output sensors, 83
surface, 31-32	interfaces, vii, 83, 93
bandwidth, 173-174	interfacing to integrated hall-effect devices,
ICs, ix, xi-xii, 21, 28, 30, 60-62, 65-67, 71-	83
72, 74-75, 79, 81, 103, 107, 110, 117-118,	interfacing to standard logic devices, 90-91
126-127, 166-167, 170-171, 173-174, 177,	interfacing to switches and latches, 88
190-192, 194-195, 219-220	intrinsic carrier concentrations, 8
ideal Helmholtz, 195	intrinsic coercive force, 208, 223

irreversible losses, 223	140, 146
isotropic, 219, 223, 228	position sensing in addition, 115-116
	position sensing, vii, 109, 115-117
J	linear positioning slides, ix, 195-196
Johnson noise, 15-16	sensors, vi, 61-66, 68, 70-74, 76, 78, 80,
Jordan Hill, iv	82-84, 118, 137, 139, 145, 162, 227
	transfer curve, vi, 64-65
K	Linearity Because Hall-effect transducers, 14
Kawaji, 231	linear-output Hall transducer, 115-116
Keithley Instruments, 188	LOAD line, 99
Kelvin degree, 227	Load, 40, 42-43, 46-47, 65, 68-69, 87-88, 95-
•	99, 105, 155, 177
L	Logic,
lamp ON, 95	AND, 80, 92-93, 173
large DC common mode signal, 43, 48	HIGH, 90
large number of digital Hall-effect, 98	NOT functions, 93
large number of discrete Hall-effect, 137	NOT Output, 92
latches, vi-vii, 62, 71, 75, 79, 86, 88, 154,	NOT, vii, 92-93
171-173, 221	OR, 79, 91-93, 98, 103-104, 181
latch-type digital Hall-effect, 112, 154	Long-enough PCB trace, 135
lateral surface of a magnet, 232	Lorentz, 3, 31
layers of pure silicon, 9	LOW output, 59, 68-69, 87, 90, 221
leakage field, 122-123	Low trip-point accuracy, 115-116
LED,	LOW voltage, 26, 50, 98, 131-132
interfaces, 93-94, 192	LOW, 7-8, 14, 26, 42-43, 45, 50, 55, 57-60,
lights, 93	66, 68-69, 73-74, 80-81, 86-87, 90, 93,
voltage drop, 94	98, 102, 110, 115-116, 131-132, 152-156,
level of the HIGH/LOW threshold, 181-182	165-167, 170, 173, 177-179, 181-182, 188
like CMOS inputs, 90	190-191, 199, 219, 221-222
Linbus, 103	Lower ON resistances, 95
linear devices, vi, 62-64, 71, 74-76, 162	Lower right leg of the Wheatstone bridge, 59
linear Hall, 62, 64, 73, 75, 86, 227	low-frequency response of the first-order rc
linear Hall-effect, 62-68, 70-72, 74, 83-84,	filters, 164
86, 103, 118, 133, 137, 139, 145, 190, 192,	low-power hall-effect, 178
224,	•
IC, 63, 192	M
sensor IC, 190	machine tools, ix, 151, 197-199, 217
sensor transfer, 66	magnet,
linear,	conditioner – an instrument, 224
output devices, 62	conditioners the ability, 193
output hall, 86	conditioners, ix, 193-194
output, vi. 61-62, 65, 83, 86, 115-116.	material, 119, 153-154, 161, 191, 207,

219, 221, 224	manufacturers of LDOs, 105
null-point sensing, vii, 110-111, 113	manufacturers of linear Hall-effect devices,
magnetic,	71
BOP, 108, 220, 225	manufacturers, 20-21, 23, 53, 65, 71, 74-75,
domains, 206, 226	78, 104-105, 126-127, 143-144, 147, 178,
field intensity magnetic flux, 224	188, 192
fields come from magnetic fields, ix, 203	mass production each layer, 17
fields these applications all, 187	material carrier concentration, 8
flux density RIN, 38	material's B-H, 221
flux density, 38, 83, 117, 122, 141, 158,	material's BHmax, 208
166-167, 190, 202, 207, 220, 222, 224-	maximum BOP, 123, 128
227	maximum energy product, 208, 224
instrumentation, ix, 190-191, 193, 195,	maximum off-state output voltage, 81
215	maximum product of b, 208
linearity, 38	maximum service temperature - the maxi-
materials, 205	mum temperature, 221, 224
null-points, 111	maxwell - cgs unit of magnetic flux, 224
sensors, xii-xiii, 28, 107, 133, 135, 148,	Maxwell's equations, 135-136
187, 190, 231	measuring AC, 137
simulation software, ix, 199-201, 215-216	mechanical tolerance Hall-effect sensor IC
magnetic targets, viii, 153	manufacturers, 126
view film, 193	mechanical Tools One aspect of magnetic
magnetics, 118, 123-126, 129, 187, 203-	sensor development, 195-196
206, 208, 210, 214, 232	mechanical tools, ix, 195-197
magnetism, 232	Melexis, 21, 25, 32, 61, 63-64, 166-167, 173,
magnetizer, 224	178, 180-184, 212
magnetizers and magnet conditioners, 193	metalization, 23
magnetizers, ix, 193-194	metallurgy of soft magnetic materials, 232
magnetizing force, 206-208, 223-224	metals, v, 1-2, 5-10, 173-174, 220
magnets, 74, 107, 110-112, 115-118, 121-122,	methods of creating magnetic null-points, 111
124-125, 127, 153-156, 162, 170, 179, 191,	Meyer, 231
193, 200, 205, 207, 210, 213, 219, 222-226	MGOe, 208, 210
magnet-to-sensor, 109-110, 154	microcontrollers, 80, 102-104
magnitude detection schemes, 158	micrometers, ix, 197
magnitude of the hall effect, xi	Micronas, 64, 182, 212
major instabilities, 150	Microphotograph of an IMC Hall-effect
make Hall-effect transducers, 7, 13	transducer, 32
make ICs, 220	micropower hall-effect devices, 178
make NPN transistors, 22	micropower switches, viii, 177, 179
make reasonably sensitive Hall-effect trans-	millivolt-level output signals, 9
ducers, 23	minimal Hall-effect, 35
manual, 57, 148-149, 197, 231	minimum 65 85 115-116 123 126-129

144, 152, 160-161, 164, 166-167, 181, 227	open-collector output, 80
mini-networks, vii, 102-103	N-type, 8-10, 21-22
MKS unit, 219, 224, 227	material, 8, 21-22
model for computer simulation, vi, 38-39	semiconductor, 8
modern Hall-effect, 60, 71, 78	silicon, 9-10, 21
modern power MOSFETs, 96	N-type,
monolithic Hall-effect ICs, xii	
monolithic IC, 62	0
MOSFET, 80, 95-96	Oersted, 206, 215, 220, 224-225
Motorola, 103	OFF,
MTBF, 184-185	LED driver, 94
multiple outputs, 188	region, 110
multiple turns there, 144	state, 76-77, 81, 128
multiple turns, viii, 144, 148-149	states, 76, 79, 81, 128-129
multitude of available bop, 86	switch, 122, 146, 166-167, 178, 220
Mu-Metal – A high-permeability magnetic	off-center current causes leakage flux, 141
alloy, 225	OFF-ON transition, 113
	offset and gain adjustment, vi, 71-72, 83-85,
N	118
N data lines, 98	offset error – a type of measurement error,
N+, 6, 9-10, 22-23, 98, 145, 149, 195, 213,	225
220	offset of the Hall, 67-68
narrow PCB trace, 135	offset of the Hall-effect transducer, 57
N-channel MOSFET, 80, 95	off-the-shelf Hall-effect ICs, 126
NdFeB, 74, 117-118, 225	Ohm's Law, 225
neodymium-iron-boron, 225	Ohmic offset, v, 11-14, 16-17, 24, 26, 31,
new CMOS Hall angular position sensor, 231	57-60
newer linear Hall-effect sensors offer user-	old-style bipolar Hall sensor, 66
adjustable, 83-84	ON,
newer linear Hall-effect, 65, 83-84	close, 109
noise, v-vi, 11, 14-16, 24, 48, 50-51, 67-68,	LED Driver, 94
71, 79-80, 85, 91, 104, 156-157, 180-182,	output, 12-15, 59, 65, 73, 75-76, 79, 81,
225	90, 93, 98, 113, 183, 221
Differential gain, 48	region, 110, 226
In addition, 15, 50	resistance, 27-28, 95
model of amplifier, 51	state output voltage, 81
nonuniformity, 170	state, 76, 79, 81, 89, 96, 179
north magnetic pole, 76-77	switch, 87, 98, 122-123, 146, 156, 177-
north-pole switches, 78	179, 220, 228
novel aspect of the IMC, 31	On/Off, 75-76, 79, 81, 89, 100, 112, 117-118,
NPN, 22, 80, 220	128-129, 146, 178, 184, 221
bipolar transistor, 80	on-state,

field, 122-123	part of standard IC fabrication processes, 9
flux density, 123	particular Hall IC, 129
flux field, 123	particular MOSFET, 95
op-amp voltage gain, 149	PC, 191
open-collector, 80-81, 88, 90, 182	PCB, 134-136, 139
open-loop, 225	substrate, 135-136
operational amplifier, 225	surface, 135-136
optical bench, ix, 195-196	traces, 134-135
OR output open collector outputs, 93	PCB-based, 135-136
ordinary PCB plated-though, 135	P-channel MOS transistors, 220
oscilloscope, viii, 80-81, 90, 188-189	peak-hold geartooth, 166
output,	permalloy – a high-permeability, 225
characteristics, vi, 67-68, 146	permanent,
drivers, vi, 80	magnet catalog, 231
of a digital Hall-effect, 96	magnet guidelines, 232
of a Hall-effect, xii, 66-67	magnet materials, ix, 143-144, 210, 221,
of a linear Hall-effect, 67-68, 83	232
of a typical Hall-effect switch, 88	permeability, 125, 141-145, 203, 206, 225
of the Hall, 90	phase shift, 70, 154-155
of the linear Hall-effect, 86	Philips, 103, 145
offset voltage – A DAC, 73	physical layout, 139
off-state leakage, 81	physics of a Hall-effect transducer, 11
ON, 76	PLDs, 91
pull-up resistor, 88	Plug of high concentration N-type, 22
resistances, 14	P-N junctions, 21
saturation voltages, 65	PNP device, 106
signal of just VH, 29	PNP versions, 220
state of the Hall-effect sensor, 178	polarity probe, ix, 192
switches HIGH, 87	pole piece, 231
thresholding, vii, 83, 85-87	pole, 76-78, 107, 110-112, 116, 122, 153-155.
triad, 180	159, 162-163, 171-172, 179-180, 192-193,
voltage, 100-101	203, 205, 208, 222, 225, 227-228, 231
	pole-counts, 154
P	polepiece, e-core, 125
P type, 10	polepiece, sensor-backing, 125
packaging of most Hall-effect, 111-112	polepiece, wrap-around, 125
paddlewheel type, 155	POPMAX, 128
pair of,	POPMIN, 128
different colored LEDs, 192	popular interface standards, 191
digital Hall-effect, 173	positioning of differential transducer, 167
parallel wiring structure, 29	positive y, 121
parameter, 48, 75, 81, 208, 227	power + brains = smart motor control, viii,

183, 185	RA/RB divider network, 47
power devices, viii, 182	Racz, 231
power management, vii, 103-105	rare-earth magnet, 226
power management, vii, 103-105	ratio BY/BX, 121
power MOSFET, 95-96	ratiometric,
power N-channel MOSFET, 95	Hall-effect, 67
power supplies, 187	output Hall, 67-68
power supply requirements for digital sensors,	ratiometry, vi, 66-67
vi, 79	raw BX, 121
power supply requirements for linear sensors,	Raymond K. Jr., 231
vi, 71	red LED, 93-94
powered ON, 165, 178	reference magnets, 226
power-on recognition – the ability of a	references and bibliography, ix, 231-232
geartooth, 226	relationship of BOP, 78
power-on recognition, 157-158, 226	relay ON, 97
practical devices, 4, 10	relays, solenoids, and inductive loads, 96
practical transducers, 11	relays, vii, 96-97, 182
previous description of the Hall effect, 7	RESET input of the flip-flop, 76
primary feature of a Helmholtz, 195	resistance, 11
process variation, 27, 56	of RA, 57
product of B, 208, 224	of the Hall transducer, 9
profibus, 102	resistive current sensing, vii, 131-133
programmable BOP/BRP, 146	response of four-probe, 139
property of the Hall-effect transducer, 58	response of hall-effect home-position, 114
proximity sensor – a device, 226	resulting Hall voltage, 7
proximity-sensing techniques, 107	resulting sensor ICs, 75
P-type,	reverse-battery protection, 79
isolation walls, 21	RF, 42
material, 8, 21	ring magnet, 114-116, 153-157, 171-172,
substrate, 21	179, 226
pull-up resistor, vii, 80-81, 88-90, 92-93	rise, 4, 54, 67, 81, 90, 98
-	RMS, 16, 71
Q	noise measurements, 71
quad cell, v, 27, 29	voltmeter, 71
quadrant ii, 223	Robison Electronics, 146, 217
quadrature, 173, 226	Rogowski Coil, 137
quantitative examination, v, 2-3	Rogowski, 137
quiescent output voltage, 226, 228	rotary position sensing, vii, 32-33, 118-119
QVO, 65, 226, 228	121
	rotary table, ix, 195-197
R	RPM, 173-174, 189
RA resistors, 44, 47, 52	

S	having dual hall IC, 231
Samarium-Cobalt,	IC manufacturers, 126-127
a rare-earth compound, 226	IC, 67-68
magnet, 159-160	ICs, 21, 30, 65-67, 71-72, 75, 103, 107,
saturation, 38, 65, 81, 95, 100-101, 106, 121,	117-118, 126-127, 166-167, 170-171,
144, 146, 194, 200, 208, 223, 226	173-174, 191
magnetic, 226	OFF, 93, 95, 110, 162, 164, 226
voltage, 81, 95, 100-101	ON, 20-21, 73-74, 90, 93, 95, 128, 138,
sauber, 232	146, 164, 166, 174-175, 225
schematic representation of power-cycled	status output voltage, 100
Hall, 178	maximum BOP, 123
schematic top, 17	minimum BRP, 123
schematic view of a Hall-effect-based float-	sensor-backing polepiece, 125
level, 114	Sentron AG, 32
Schott, 231	serial,
SCRs, 193-194	data out, 99
self-demagnetization, 208, 226	shift-register, 99
semiconductor, 227	serialization, vii, 98-99
sensors, 231-232	service temperature, 210, 221, 224
from, 7	SET input, 76
sense resistor RS, 47	setting,
sensing of flux, 232	BOP, 86
sensitive axis of the Hall, 109	RF, 42
sensitive hall transducers, 8	sharp tools, 187
sensitive symmetric latch-type Hall ICs, 110	shift, 31, 70, 87, 99, 154-155
sensitivity, v, viii, 5, 7, 9-14, 16-17, 19-20,	Shinjuku-ku, 211
23-24, 26, 30-33, 37-41, 65-69, 72, 83-84,	SI (the international system of units), 7, 227
87-88, 106, 115-116, 119, 121, 134-135,	side of the Hall transducer, 4
139-140, 143-147, 160, 162-163, 167-168,	signal correction, 119
191, 194, 202, 227	silicon Hall-effect,
ohmic, v, 11	sensor IC, 25
temperature, v, 11-12, 14, 121	transducer, v, 9-10, 33, 61
of a given Hall transducer, 5	silicon, v, xi-xii, 7-10, 20-25, 27-28, 30-31,
of a Hall transducer, 7	33, 61, 147, 173-174, 184-185, 220, 227
of a Hall-effect transducer, 11-12	silicon ICs, 21
of a toroidal Hall-effect, 146-147	similar wiring schemes, 29
the degree of response, 227	simple,
sensor, viii, xiii, 11-14, 16, 20-21, 24-26,	AC-coupled scheme, 165-166
30-31, 35-36, 38, 41, 57-58, 62-77, 79-81,	circuit-level models, 36
83-84, 86-93, 95-96, 98-104, 107-129, 131-	continuous position sensors can, 115-116
171, 173-175, 177-185, 187-192, 194-202,	Hall-effect transducers, xii
219-228, 231-233	sensor network, 102

SPICE model, 40	and timing sensors, 151
single,	sensing, viii, 151-152, 170-171
D-type flip-flop, 172	sensor, 151-153, 155-157, 162-163, 169
Hall-effect transducer element, 158	171, 179, 227
point/dynamic threshold •, 159	SPI, 103
point/fixed threshold •, 159	developed, 103
point sensing, viii, 159, 163, 167-168	functionality, 103
point/dynamic-threshold schemes, 163	SPICE (simulation program with integrated
slide-by,	circuit emphasis), 37-41
a proximity-sensing mode, 227	input file, 41
actuation mode, 109	language, 39
sensing another common, 109	view of the world, 38
sensing, vii, 109	SPICE-compatible circuit, 38
Slope dV/dB, 65	sputtering, 18-19, 31-32
small,	standard,
differential Hall output voltage riding, 43	IC packaging, xii
Helmholtz, 194-195	logic devices, vii, 90-91
portable optical benches, 195-196	logic IC, 91
regions of an IC, 28	specifications, 232
size of Hall-effect, xii	three-wire type of hall switch, 180
SmCo, 117-118	state of the D input, 172
SMD, 227	static threshold, 158-159
Smithsonian,	Stauth, 232
Institute Physical Tables, xi	stepped magnetic field, 174
Institution, 231	structure of epitaxial resistor, 22
Physical Tables, 231	subsequent circuitry, 151-152, 160
Soclof, 231-232	suitable rectifier diodes, 98
soft ferrites, 222	supplier list, ix, 211-217
software, magnetic simulation, ix, 199-201,	surface of the IC, 28, 30
215-216	surface-mount device, 89, 227
SOIC face, 32-33	surface-mount IC packages, xii
solderless breadboard, 190	switch, 59, 78, 146
solenoids, vii, 96-97, 182	OFF, 166-167
some permanent magnet materials, 210	ON, 87, 98, 122-123, 146, 156, 177-179
some thoughts on designing proximity sen-	220, 228
sors, 126	switches and latches, vi-vii, 62, 75, 86,
south magnetic pole, 76-77	88, 221
spatial size, 153	switches, vi-viii, xi, 59, 62, 71, 75, 78, 86-88,
specialty magnetic materials, 214	122-125, 146, 155-156, 161-162, 177, 179-
specific BOP, 86	182, 221
speed,	switching,
and direction sensing, 171	network, 60, 63-64

power, 96, 105, 177-178	160, 163-164, 166-168, 173-174, 178-179,
current levels, 177	222, 227
switchpoint stability, vi, 78	thin-film,
switch-type digital Hall, 108	Hall-effect transducer, 17
symbol H, 206	processing sequence, 19
symmetric bias circuit, 43	processing techniques, 19-20
system diagram of feedback, 150	thin-film transducers, v, 17, 19, 42
systems, xi, 10, 16, 20, 71, 73, 79, 84, 102,	thoughts on designing proximity sensors, vii,
105-106, 109-110, 112-113, 131-132, 148-	126-127, 129
149, 151-152, 154, 165, 167-168, 173-174,	three-op-amp differential amplifiers, 52
181-182, 188-189, 199-200, 202, 217, 222	three-wire Hall-effect switch, 180
	threshold, 62, 75-76, 78, 86-87, 146, 158-159
T	163-165, 169-170, 178, 181-183, 223
targets, viii, 62, 131, 152-153, 155-156, 160,	through-hole 1/4w resistor, 89
162-163, 166-167, 173-174, 177, 189, 195-	tilting, 170
198, 221	time hall, xi, 2
Technisches Messen, 231	timing sensors, viii, 151-152, 154-156, 158,
technology advantages drawbacks hall, 152	160, 162, 164, 166, 168, 170, 172, 174
tempco - see temperature coefficient, 227	timing sensor, 167-168, 227
temperature coefficient,	tools, mechanical, ix, 195-197
the fraction, 227	toroid, vii-viii, 140-150, 219, 227
of ohmic offset like sensitivity, 14	a donut-shaped flux concentrator, 227
of resistance, 15	material selection and issues, viii, 143
of sensitivity, 12	slotted, vii, 141-142, 144
temperature of the packaged IC, 28	magnetic gain, 149
temperature range, vi, xii, 15, 66, 71-72, 128,	toroidal current sensors, vii, 140-141, 217
156, 210	traditional Hall-effect transducer, 30, 31
operating, 128	transducer,
temperature stability, 12-13, 48, 54, 162, 210	bulk, 16
temperature stable proximity sensor, 232	device, 228
temperature-compensated amplifier, 54	gain AH, 149
temperature-induced variations, 78	geometry, v, 26
terms of the B-H, 208	interfacing, vi, 35-36, 38, 40, 42, 44, 46,
Tesla, 227	48, 50, 52, 54, 56, 58, 60
testing ICs, 66, 194-195	placement, 162
Texas Instruments, 105	TRIACs, 193-194
the Hall effect in semiconductors, 7	TTL (transistor-transistor logic), 228
the pull-up resistor, 88	input, 90
the quad cell, 27	logic input, 90
the transducer, xi-xii, 4-5, 9-10, 12-17, 19-21,	TTL, 80, 90, 181, 228
23-32, 35-38, 41-48, 50, 52, 54, 56-64, 74,	turn OFF, 224
111-112, 118-119, 121, 144, 148-149, 158-	turn ON 78 96 98 146 162 179 224-225

228	switch magnetic architectures, 124
TUV, 135-136	switch operation, 122
two Hall-effect transducers, 158, 166-167	switch, vii-viii, 122-125, 155
two of the simpler, 204	variations on the basic Hall-effect transducer
two of the wires, 43-44	v, 29-31
two simple circuits, 94-95	variety of LEDs, 93-94
two terminal multiplexable sensor, 232	various digital Hall-effect, 82
two-wire, viii, 180-182, 228	various fixtures, 195-196
Hall-effect switches, 180, 182	vast array of Hall-effect, 25
interface – an electrical interface, 228	vector notation, 203
switches transmitting data signals, 180	vertical Hall-effect transducer, 30-31
switches, viii, 180-182	very inexpensive handheld DMMs, 188-189
typical,	vicinity of the Hall-effect transducer, 163
auto-nulling Hall IC, 63	view film, ix, 193
DC brushless fan, 183	views of thin-film Hall-effect transducer, 17
digital devices, vi, 81	voltage, vii, 1-5, 7, 9, 12-15, 21-22, 24, 26-
Hall-effect-based, 126	27, 29, 31, 36-38, 40-51, 54, 57-60, 62,
leakage paths, 135-136	65-68, 71-74, 78-81, 83-85, 87-91, 93-98,
linear devices, vi, 74	100-101, 103-106, 131-133, 135-137, 149,
magnetic responses, 159	151-152, 180-182, 187-188, 191, 193-194,
typical noise performance of various opera-	222, 225-226, 228, 231
tional amplifiers, 51	bias circuits, 42
typical organization of a linear architecture	regulation, vii, 103-105
linear Hall IC, 62	power management, vii, 103-105
typical red LED, 93-94	voltage-mode biasing, vi, 41
typical values, 82	voltage-mode Hall-effect, 41
Spion funció, or	voltmeters, viii, 188
U	and DMMs, 188
UL, 135-136	volts, 9, 11-12, 43, 46, 65, 73, 79, 84, 96-98,
unloaded digital Hall-effect sensor, 80-81	140, 194, 220, 222
USA Linacre House, iv	, ,
use of,	W
Alnico, 118	Wheatstone Bridge, 58-59
CMOS technology, 63-64	where magnetic fields come from, 203
DSP, 166-167	whole IC, 22
Hall-effect digital switch, 153	width of the,
user I/O ports, 39	ON region, 110
and a o posse, o	PCB trace, 135
V	wired,
value of H, 223	AND, 93
vane, vii-viii, 122-126, 155-157, 228	OR Output, 93
switch flux map, 123	OR, vii, 93
1	•

```
wiring reduction, 102
schemes, 98
World War II, 188-189
wrap-around pole piece, 125

X
X direction, 116
X field, 31-32

Z
Z-axis, 31-32
Zero-flux,
intercept, 65
output voltage, 66-67, 228
Z-field components, 32
```