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Clocking in Modern VLSI Systems

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Clocking in Modern VLSI Systems

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Thucydides Xanthopoulos
Editor

Clocking in Modern VLSI Systems

 Springer

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Στη Μαργαρίτα, το Νικόλα και τη Μαρία-Ελένη που μας έπιασε στα μισά



To Margarita, Nicholas and Maria-Helen who joined us half-way
through this book



Preface

... εἰωθότες οἱ ἄνθρωποι οὗ μὲν ἐπιθυμοῦσιν ἐλπίδι ἀπερισκέπτῳ διδόναι, ὃ δὲ μὴ προσίενται λογισμῶ ἀυτοκράτορι διωθεῖσθαι.

THUCYDIDIS HISTORIAE IV:108
C. Hude ed., Teubner, Lipsiae MCMXIII

ἽΟι ἄνθρωποι, ἄλλωστε, συνειθίζουσι νὰ ἐμπιστεύωνται εἰς τὴν ἀπερίσκεπτον ἐλπίδα ἐκεῖνο ποὺ ἐπιθυμοῦν καὶ ν' ἀποκρούουσι δι' αὐθαιρέτου συλλογισμοῦ ἐκεῖνο ποὺ ἀποστέργουν.

ΘΟΥΚΥΔΙΔΟΥ ΙΣΤΟΡΙΑΙ Δ:108
Κατὰ Μετάφρασιν Ἑλευθερίου Βενιζέλου
Δ. Κακλαμάνος Ἐκδ.
Σμυρνιακάκης, Αθήνα

It being the fashion of men, what they wish to be true to admit even upon an ungrounded hope, and what they wish not, with a magistral kind of arguing to reject.

Thucydides (the Peloponnesian War Part I), IV:108
Thomas Hobbes Trans., Sir W. Molesworth ed.
In *The English Works of Thomas Hobbes of Malmesbury, Vol. VIII*

I have been introduced to clock design very early in my professional career when I was tapped right out of school to design and implement the clock generation and distribution of the Alpha 21364 microprocessor. Traditionally, Alpha processors exhibited highly innovative clocking systems, always worthy of ISSCC/JSSC publications and for a while Alpha processors were leading the industry in terms of clock performance. I had huge shoes to fill. Obviously, I was overwhelmed, confused and highly confident that I would drag the entire project down. When a few years later

Carl Harris asked me to do a book on clocking for the Springer Integrated Circuits and Systems Series, I readily agreed with the hope that I could save young and aspiring clock designers substantial time and frustration by providing leads and maybe answers to the questions that I had when I was embarking on the Alpha clock design quest. As my choice of opening quotation would suggest, clock design can be a minefield of misconceptions based on little more than a reluctance to apply Kirchhoff's laws, basic constituent relationships, and a little bit of common sense.

In addition to my personal design experience, the choice of material for this book has been heavily informed by my long tenure in the International Solid-State Circuits Conference (ISSCC) program committee. The subjects covered reflect to a large extent the collective interests and foci of both industry and academia with respect to clocking based on ISSCC submissions. The only exception is that there is no coverage of phase locked loop design since there are a number of recent texts available on this subject matter.

It is my hope that this book will help engineers and students interested in clock design obtain the appropriate mental models and design viewpoints, capture design trends that have appeared over the last few years, and provide a comprehensive list of references for further study. I am indebted to my co-authors for providing precise, structured and complete coverage in their respective chapters in addition to maintaining a viewpoint that is very up to date and highly reflective of current trends in the industry. I hope that the reader will not find "ungrounded hopes" and "magistral arguings" in this book.

Carl Harris and Katelyn Stanne of Springer deserve special thanks for helping me throughout the preparation of the manuscript. I wish to acknowledge a number of colleagues at Cavium Networks for their helpful and stimulating discussions and excellent feedback: Scott Meninger, Ethan Crain, David Lin, and Suresh Balasubramanian. I would like to thank my bosses at Cavium Networks Anil Jain and Syed Ali for building a great semiconductor company from the ground up and an excellent working environment that fosters creativity and innovation in addition to maintaining a sharp focus on product development and company value. I would especially like to thank Anil Jain for entrusting me with the Alpha clocking project while being my boss at Compaq Computer which helped me acquire the background and skills necessary to produce this book. Above all, I would like to thank my wife Margarita not only for putting up with my constant working on this book but also for typesetting the entire manuscript in \LaTeX and retouching figures as needed. I could not have done this without her.

Contents

1 Introduction and Overview

<i>Thucydides Xanthopoulos</i>	1
1.1 The Clock Design Problem	2
1.2 Some Subjective Milestones in the History of Microprocessor Clocking	4
1.2.1 Integrating the PLL	4
1.2.2 Clock Distribution Moves to the Forefront: The Dawn of the GHz Race	4
1.2.3 Delay Lock Techniques	5
1.2.4 Exploiting Inductance for Oscillation and Distribution	5
1.2.5 Variable Frequency (and Voltage)	5
1.2.6 Frequency Increase (or Supply Lowering) Through Resiliency ...	6
1.3 Overview of this Book	6
References	7

2 Modern Clock Distribution Systems

<i>Simon Tam</i>	9
2.1 Introduction	9
2.2 Definitions and Design Requirements	10
2.2.1 Setup and Hold Timing Constraints	11
2.2.2 Clock Attributes	13
Static and Dynamic Clock Uncertainties	14
Distribution Delay	19
Duty Cycle	19
2.2.3 Clock Distribution Power	19
2.3 Clock Distribution Topologies	21
2.3.1 Unconstrained Tree	21
2.3.2 Balanced Tree	23
2.3.3 Central Spine	25
2.3.4 Spines with Matched Branches	25
2.3.5 Grid	26
2.3.6 Hybrid Distribution	29
2.4 Microprocessor Clock Distributions	30

2.5	Clock Design for Test and Manufacturing	36
2.5.1	Global and Local Clock Compensations	36
2.5.2	Global Clock Compensation Architecture	37
2.5.3	Local Clock Compensation Architecture	43
2.6	Elements of Clock Distribution Circuits	44
2.6.1	Clock Duty Cycle	44
2.6.2	Power Supply	47
2.7	Clock DFX Techniques	48
2.7.1	Optical Probing	48
2.7.2	On-Die Measurement	49
2.7.3	Locating Critical Path	52
2.7.4	On-Die-Clock Shrink	52
2.8	Multiclock Domain Distributions	54
2.8.1	Multicore Processor Clock Distribution	55
2.9	Future Directions	58
2.10	Conclusion	58
	References	59
3 Clocked Elements		
	<i>James Warnock</i>	67
3.1	Introduction	67
3.2	CSE Design Issues	68
3.2.1	Latency	68
3.2.2	Hold Time	69
3.2.3	Power	70
3.2.4	Scan Design for CSEs	71
3.3	Static Latch Designs	72
3.3.1	Master–Slave Latches	72
3.3.2	Two-Phase Level-Sensitive Latches	76
3.3.3	Pulsed-Clock Static Level-Sensitive Latches	78
3.4	Flip-Flop Designs	80
3.4.1	Sense-Amp Style Flip-Flop	80
3.4.2	Hybrid Latch Flip-Flop	82
3.4.3	Semi-Dynamic Flip-Flop	83
3.5	Test and Debug Considerations	85
3.6	CSE Design for Variability	88
3.6.1	Variability-Induced Frequency Degradation	88
3.6.2	Variability-Induced Functional Failures	89
3.7	Reliability Issues	91
3.7.1	Soft Error Rate Considerations	91
3.7.2	End of Life Considerations for CSE Design	93
3.8	Conclusion	96
	Acknowledgements	96
	References	97

4 Exploiting Inductance

Nestoras Tzartzanis 105

4.1 Introduction 105

4.2 Monolithic Inductance 106

 4.2.1 Spiral Inductors 106

 4.2.2 Transmission Lines 110

4.3 Inductor-Based Clock Generation 115

 4.3.1 Differential LC VCO 115

 4.3.2 Quadrature LC VCO 118

 4.3.3 Distributed VCO 120

 4.3.4 Poly-Phase Circularly Distributed VCO 121

4.4 Clock Distribution Using Inductance 123

 4.4.1 Rotary Traveling-Wave Oscillator Arrays 123

 4.4.2 Standing Wave Oscillator and Grid 124

 4.4.3 Inductor-Based Resonant Global Clock Distribution 128

4.5 Conclusion 131

Acknowledgments 131

References 132

5 Phase Noise and Jitter

Scott Meninger 139

5.1 Introduction 139

5.2 Timing Error in the Time Domain: Jitter 140

 5.2.1 Phase Jitter 141

 5.2.2 Period Jitter 141

 5.2.3 Cycle-to-Cycle Jitter 142

5.3 Timing Error in the Frequency Domain: Phase Noise 142

 5.3.1 Relationship Between Phase Noise and Jitter 143

5.4 Frequency Domain Modeling of PLLs 144

 5.4.1 PLL Phase Noise 144

 5.4.2 PLL Intrinsic Noise: VCO 145

 5.4.3 PLL Intrinsic Noise: Feedback Divider 146

 5.4.4 PLL Intrinsic Noise: Phase Detector 146

 5.4.5 PLL Intrinsic Noise: Charge Pump 148

 5.4.6 PLL Intrinsic Noise: Loop Filter 150

 5.4.7 PLL Extrinsic Noise: Reference Clock 151

 5.4.8 PLL Extrinsic Noise: Supply Noise 152

 5.4.9 PLL Extrinsic Noise: Buffer Delay and Noise 152

 5.4.10 PLL Phase Noise Filtering 153

 Some Intuition on Reference Clock Phase Noise
 (or Jitter) Filtering 155

 5.4.11 Phase Noise to Period Jitter and Phase Noise to C2C Jitter 156

 5.4.12 Phase, Period, and C2C Jitter Examples 159

 Phase Jitter 159

 Period Jitter 160

 C2C Jitter 160

5.5	Reference Clock Jitter Transfer Example: Microprocessor	161
5.5.1	A Proposed Core Clock Methodology Using Mean Time Between Failures (MTBF)	161
5.6	Non-Random Jitter Distributions	166
5.6.1	Reference Spurs in PLLs	167
5.6.2	Duty Cycle Distortion (DCD)	169
5.6.3	Power Supply Noise	170
5.6.4	Inter-Symbol Interference (ISI)	171
5.6.5	Including Deterministic Jitter in Analysis	172
5.7	Reference Clock Jitter Transfer Example: Serial Link	173
5.7.1	Serial Link Budgeting	173
5.7.2	Bit Error Rate	174
5.7.3	Serial Link Block Diagram	174
5.8	Delay Locked Loops (DLLs) and Jitter	178
5.9	Conclusion	179
	Acknowledgements	179
	References	180
6 Digital Delay Lock Techniques		
	<i>Thucydides Xanthopoulos</i>	183
6.1	Introduction	183
6.2	What Constitutes a Digital Delay Locked Loop?	183
6.3	An Overview of DLL Applications	186
6.4	Phase Detectors	187
6.4.1	Metastability	191
	An Example of Phase Detector Failure Calculation	201
6.5	DCDL Design	202
6.5.1	Gate-Delay DCDLs	203
	Synchronous vs. Asynchronous Operation in Coarse DCDLs	207
6.5.2	Subgate-Delay DCDLs	209
6.5.3	Resolution vs. Dynamic Range in DCDLs	211
6.6	Control	216
6.6.1	Sensitivity to Initial Phase	217
6.6.2	Dynamic Range Increase	219
6.6.3	Stability and Bandwidth	219
6.6.4	Lock Acquisition	226
6.7	Putting it All Together	229
6.8	Noise Considerations	229
6.9	Advanced Applications	236
6.9.1	Duty Cycle Correction	236
6.9.2	Clock Multiplication	236
6.9.3	Infinite Dynamic Range	238
6.9.4	Clock-Data Recovery	239
6.9.5	On-Chip Temperature Sensing	241

6.10 Conclusion	242
Acknowledgments	242
References	242
7 Clocking and Variation	
<i>James Tschanz</i>	245
7.1 Introduction	245
7.2 Variation Reduction Through Design	245
7.2.1 Skew and Jitter-Tolerant Design	246
7.2.2 Time Borrowing for Datapath Variation Reduction	246
7.3 Variation Reduction Through Tuning	251
7.3.1 Manufacturing Techniques	252
7.3.2 Active Clock Deskew	252
7.3.3 Dynamic Frequency	255
7.4 Variation Reduction Through Resiliency	261
7.4.1 Timing Error Detection – Error Detection Sequentials	262
7.4.2 Timing Error Correction and Recovery	266
7.4.3 Results: Guardband Reduction Through Resiliency	268
7.5 Conclusion	272
Acknowledgments	273
References	273
8 Physical Design Considerations	
<i>Georgios Konstadinidis</i>	275
8.1 Introduction	275
8.2 Clock Skew Components	276
8.2.1 Setup Time Skew	281
8.2.2 Hold Time Skew	283
8.2.3 Half-Cycle Setup Skew	283
8.2.4 Multiple-Cycle Setup Skew	283
8.2.5 Grid or H-Tree?	283
8.3 Transistor Variation	284
8.3.1 Channel Length Variation	284
Photolithography Challenges	286
Poly Flaring and Poly Pullback	287
Line Edge Roughness	288
Channel Length Variation Control	288
8.3.2 Dopant Fluctuation	290
8.3.3 Well Proximity Effect	291
8.3.4 Strain	292
Stress Memorization and Tensile Stress Liner	293
SiGe and Compressive Stress Liner	293
Shallow Trench Isolation	295
New Materials	296
Guidelines	296

8.3.5 Long Term Effects on Variation	296
NBTI	296
Hot Carrier Injection	298
8.4 Voltage Variation	298
8.5 Temperature Variation	300
8.6 Interconnect Variation	301
8.7 Conclusion: Clock Design and Analysis Guidelines:	
Putting All Together	307
8.7.1 Clock Analysis	307
8.7.2 Minimizing Variation	307
Acknowledgments	308
References	308
Index	317

List of Figures

1.1	Microprocessor transistor number trend over time	2
1.2	Microprocessor frequency trend over time	3
1.3	Microprocessor power trend over time	3
2.1	Processor clock frequency trend	10
2.2	Sequential structure bounded by flip-flops	10
2.3	Sequential path showing explicit clock distribution	11
2.4	Timing diagram for the setup constraint	12
2.5	Timing diagram for the hold constraint	12
2.6	Statistical nature of clock arrival times	13
2.7	Clock skew and jitter definitions	14
2.8	Factors affecting clock skew	15
2.9	Clock skew as percentage of cycle time vs. processor frequency	16
2.10	Pk-pk clock jitter as a fraction of clock cycle time vs. processor frequency	16
2.11	Sample clock distribution for skew and jitter model	17
2.12	Clock duty cycle	19
2.13	Clock loading multiplier of a clock distribution	20
2.14	Normalized clock stage power vs. stage number	21
2.15	Unconstrained tree clock network	22
2.16	Balanced H-tree clock network	23
2.17	Variations on the balanced tree topology	24
2.18	Binary tree clock distribution	24
2.19	Binary tree clock distribution with intermediate shorting	25
2.20	Central clock spine distribution	26
2.21	Multiple clock spines with matched branches	26
2.22	Clock grid with 2-dimensional clock drivers	27
2.23	Clock grid with 1-dimensional drivers	28
2.24	Recombinant tile clock structure	28
2.25	Effect of shorting on clock skew	29
2.26	Hybrid clock distribution consisting of balanced H-Tree and Grid	30
2.27	Asymmetric clock tree distribution network based on delay matching ...	30

2.28	Asymmetric clock tree distribution with multiple regions	31
2.29	Multilevel symmetric H-Tree distribution	32
2.30	Delay characteristics of a multilevel tree-grid distribution	32
2.31	Centralized clock drivers with grids on three generations of the Alpha® microprocessor	33
2.32	Recombinant clock tiles on a 90nm processor	33
2.33	Pentium® 4 processor clock distribution using centralized spines with delay matched final branches	34
2.34	Clock distribution of a low power IA processor consisting of binary trees embedded in the centralized spines	34
2.35	Hybrid spine-grid clock distribution in a dual-core processor	35
2.36	Local clock distribution of the hybrid spine-grid clock distribution	36
2.37	Dual-zone deskew architecture	37
2.38	Deskew delay line structure	38
2.39	Deskew zones in the itanium® processor	38
2.40	Clocking architecture of the first itanium® processor	39
2.41	Deskew controller and deskew buffer design	40
2.42	Pentium® 4 processor deskew architecture	40
2.43	Before and after skew profile of the Pentium® 4 processor	41
2.44	Hierarchical deskew architecture of a dual-core processor	41
2.45	H-tree deskew topology	42
2.46	Mesh deskew topology	43
2.47	Local clock compensation	44
2.48	F_{\max} shift caused by duty cycle distortion in a phase-path dominated design	45
2.49	Duty cycle distortion due to asymmetric edge propagation between a buffer-based clock distribution and an inverter-based clock distribution	46
2.50	Duty cycle corrector	46
2.51	Duty cycle corrector circuits	47
2.52	Clock buffer design with power-supply filters	47
2.53	On-die clock tree filter circuit	48
2.54	Back-side optical probing technique (a)	49
2.55	Back-side optical probing technique (b)	49
2.56	Skew and jitter measurement circuit	50
2.57	Sampled delay pattern of the skew and jitter measurement circuit	50
2.58	Vernier delay line	51
2.59	Vernier delay line timing example	51
2.60	On-die-clock shrink architecture	52
2.61	ODCS clock waveform	53
2.62	ODCS capabilities	54
2.63	Globally asynchronous and locally synchronous architecture	55
2.64	Multidomain clocking in a dual-core processor	56
2.65	Clock distribution of an 80-tile processor design	57
3.1	Latency ($d - q$ time) vs. data arrival time for two hypothetical CSE designs	69

3.2	Power vs. input data switching factor for two hypothetical CSE designs	70
3.3	Basic scan design. Scan data flow is indicated by the <i>dotted lines</i>	71
3.4	Master–slave latch	72
3.5	MSL hold time vs. total MSL latency as the cycle boundary overlap of dclk and lclk is varied	73
3.6	Scannable MSL	74
3.7	Sample set of clock waveforms for scan shifting and for functional operation, for the MSL of Fig.3.6	75
3.8	MSL with scan MUX in feedback path	75
3.9	Basic two-phase level-sensitive latch scheme, with sample local clock waveforms	76
3.10	Scannable level-sensitive latch	77
3.11	Simple non-scan pulsed-clock latch	78
3.12	Scannable pulsed-clock latch with built-in MSL-mode fallback	79
3.13	Sense-Amp flip-flop	81
3.14	Improved scannable sense-Amp flip-flop, with asynchronous reset	82
3.15	Hybrid latch flip-flop	82
3.16	Semi-dynamic flip-flop with embedded dynamic logic	84
3.17	Scannable semi-dynamic flip-flop	85
3.18	Scan test configurations	86
3.19	Sample clock waveforms for AC test using MSL from Fig.3.6	87
3.20	Programmable delay line defining the trailing edge of a local clock pulse	90
3.21	DICE latch topology	92
3.22	Scannable pulsed-clock DICE latch	93
3.23	Razor master–slave latch	94
3.24	Transition detection scheme	95
4.1	Common 2-turn spiral inductor shapes	107
4.2	Spiral inductor narrowband lumped model	108
4.3	Transmission line lumped model	111
4.4	Finite-length transmission line with termination	112
4.5	Microstrip transmission line with and without ground shield	113
4.6	Coplanar transmission line with and without ground shield	114
4.7	U-shaped coplanar waveguide	115
4.8	Coplanar differential transmission line without ground shield	115
4.9	Differential LC VCO circuit topologies	116
4.10	Quadrature LC VCO block diagram	118
4.11	Parallel-coupled quadrature LC VCOs	119
4.12	Series-coupled quadrature LC VCOs	120
4.13	Parallel-coupled quadrature LC VCO with 90° phase shift in the coupling phase	120
4.14	Distributed oscillator	121
4.15	Circular distributed oscillator	122
4.16	Circular distributed oscillator with clock direction control	123

4.17 Rotary traveling-wave arrays	124
4.18 Standing wave oscillator	125
4.19 Coupled standing wave oscillators used for clock distribution network	126
4.20 (a) Standing-wave oscillator with inductive loads and (b) Multiple oscillators magnetically coupled	127
4.21 Circular standing wave oscillator	128
4.22 Global clock distribution with resonant load	129
4.23 Lumped circuit model of the clock sector	129
4.24 Distributed differential global clock network	130
5.1 Jitter definitions	140
5.2 Phase noise	142
5.3 Phase noise decomposition into carrier and L(f)	143
5.4 PLL block diagram with noise sources included	144
5.5 VCO noise modeling	145
5.6 Tri-state phase-frequency detector (PFD)	147
5.7 Modified tri-state phase-frequency detector (PFD)	148
5.8 Charge-pump architecture	149
5.9 Charge-pump operation	149
5.10 Typical charge-pump PLL passive RC filter	150
5.11 PLL noise analysis model proposed in [1]	153
5.12 PLL noise analysis model proposed in [1]	154
5.13 Reference clock phase noise to jitter modeling	157
5.14 Phase to period and C2C jitter difference functions	158
5.15 Reference clock to phase jitter model	159
5.16 Reference clock to period jitter model	160
5.17 Reference clock to C2C jitter model	161
5.18 Reference clock jitter to period jitter model	162
5.19 Number of σ in peak-to-peak calculation for normal distribution	163
5.20 Example transfer functions for period jitter calculation	164
5.21 Example reference clock $\Phi_{n_{ref}}^2$ and filtered $\Phi_{n_{ref}}^2$	165
5.22 Example transfer functions for period jitter calculation with added pole	166
5.23 Example reference clock $\Phi_{n_{ref}}^2$ and filtered $\Phi_{n_{ref}}^2$ with added pole	167
5.24 PLL phase noise spectrum showing reference spurs	168
5.25 Deterministic jitter histogram due to reference spurs	169
5.26 Duty cycle distortion	170
5.27 Random data signal filtering by a channel	171
5.28 Eye diagram of filtered data signal	172
5.29 Eye diagram	173
5.30 Serial link with separate TX and RX reference clocks	175
5.31 Serial link with common reference clock	176
5.32 Serial link model with common reference clock and skew	176
5.33 Cancellation of reference clock noise in common clock architecture 1 ...	177
5.34 Cancellation of reference clock noise in common clock architecture 2 ...	178

6.1	Generalized DLL block diagram	184
6.2	Phase detector transfer function	185
6.3	Digitally controlled delay line transfer function	185
6.4	DLL applications	186
6.5	Symmetric phase detector out of asymmetric flops	188
6.6	Bang–bang phase detector	189
6.7	CMOS inverter voltage transfer function	193
6.8	CMOS inverter voltage transfer function parametrization	193
6.9	Metastable state in CMOS cross-coupled inverters	194
6.10	Voltage in metastable state	194
6.11	Small signal model of cross-coupled inverters	195
6.12	Valid node voltage region for Eq. (6.17)	197
6.13	Exponential trajectory towards a stable state	198
6.14	Determining the probability of entering metastability	200
6.15	Determining MTBF with a spice simulation	202
6.16	NAND-based registered-controlled 4-stage delay line	204
6.17	NAND-based telescopic 4-stage delay line	205
6.18	Inverter-based logarithmic 4-stage delay line	205
6.19	Inverter-based differential 4-stage delay line	206
6.20	Inverter-based conditional-output 4-stage delay line	206
6.21	DCDL spurious output transition	208
6.22	Duplicating DCDLs for glitch suppression	209
6.23	Dual output DCDL for glitch suppression	209
6.24	RC-based fine DCDL stages	210
6.25	Fine DCDL based on delay differences	211
6.26	Full swing phase interpolator ($\log_2 n$ -bit control)	213
6.27	Phase interpolator equivalent circuits	214
6.28	Phase interpolator normalized voltage output for $\Delta t = 0.5, 1, 2$	215
6.29	Phase interpolator transfer function for varying Δt	216
6.30	DLL control options	217
6.31	DLL FSM example for initial condition flexibility	218
6.32	Doubling DLL dynamic range using conditional inversion	220
6.33	Analog DLL frequency domain model	221
6.34	DLL limit cycles as a function of N_d	225
6.35	DLL loop stabilization using N_{bw}	226
6.36	DLL phase error tracking of SS clock as a function of N_{bw}	227
6.37	DLL lock acquisition profiles	228
6.38	Jitter as a function of supply noise frequency and insertion delay	234
6.39	Jitter as a function of insertion delay and supply noise frequency (2D)	235
6.40	Duty cycle correction in a DLL environment	237
6.41	Multiperiod DCDL locking for high output frequency clock multiplication	238
6.42	Dual DLL architecture for virtually infinite phase capture range	239
6.43	DLL-based clock-data recovery loop	241

7.1	(a) Standard master–slave flip-flop. (b) Creation of a time-borrowing flip-flop by inserting transparency window inverters	247
7.2	NTB and TB N-cycle interconnects	248
7.3	Timing for a 2-cycle TB interconnect and PDF of stage-delay mismatch for determining optimal transparency window	249
7.4	Active and average energies per cycle vs. mean F_{MAX} change from NTB to TB N-cycle interconnect	250
7.5	Maximum mean F_{MAX} gain from NTB to TB N-cycle interconnect vs. N	251
7.6	Clock distribution topology for a 0.18 μm , IA-64 microprocessor	253
7.7	Deskew buffer (DSK) architecture and DSK variable delay circuit	254
7.8	Experimental skew measurements	254
7.9	Clock system architecture for the 90 nm Itanium® processor (Montecito)	255
7.10	SLCB architecture and RAD SLCB/comparator connections	256
7.11	Dynamic frequency divider (DFD) and phase compensator state machine (PCSM) block diagram	257
7.12	Regional voltage detector (RVD) details	257
7.13	Oscilloscope trace of clock system VFM response to 150 mV droop at 2.27 GHz, 1.2 V	258
7.14	Measured variable-frequency mode (VFM) (%) Frequency increase over fixed-frequency mode for multiple test cases	258
7.15	Overview of 90 nm TCP/IP Processor test chip with dynamic voltage, frequency, and body bias	259
7.16	Details of dynamic adaptation method	260
7.17	Dynamic clocking system details	260
7.18	Measured dynamic frequency response to a voltage droop	261
7.19	Razor error-detection flip-flop	263
7.20	Error-detection sequential circuits	264
7.21	Timing diagram for the transition-detection with time-borrowing (TDTB) technique	265
7.22	Details of the Razor-II sequential design	265
7.23	Timing diagram for the Razor-II design	266
7.24	Instruction-replay error-recovery design for one error-detection sequential (EDS)	267
7.25	Details of the test chip clock generation	268
7.26	Overview of 0.13 μm , 64-bit, 7-stage alpha processor design incorporating Razor-II error-detection sequentials and instruction replay	269
7.27	Measured Razor-II energy consumption and distribution of energy savings	269
7.28	Measured energy per instruction and error rate for the Razor-II processor	270

7.29 Measured throughput and error rate versus clock frequency for resilient design with TDTB EDS circuits for two different path activation examples	271
8.1 Setup and hold time skew definitions considering variation	276
8.2 Die to die and within die random and systematic variation distributions	278
8.3 Correlated vs. noncorrelated parameters and their spatial dependencies	279
8.4 Simplified clock network	280
8.5 Threshold voltage variation vs. channel length at $V_{DS}=0.05V, 1.0V$...	285
8.6 Minimum device size trend and the exposure wavelength used over time	286
8.7 “What you draw is not necessarily what you get on silicon”	287
8.8 Threshold voltage variation vs. line-edge roughness and transistor width	288
8.9 (a) Line-edge roughness reported by various labs and ITRS (b) Threshold voltage variation vs. channel length, random dopant fluctuation and LER	289
8.10 Threshold variation due to dopant fluctuations vs. transistor width and channel length	290
8.11 (a) Ion scattering at the photoresist edge is the cause of the well proximity effect (WPE) (b) Drive current degradation due to WPE vs. gate to well edge distance (SC)	291
8.12 Well to gate distance (SC) definitions	292
8.13 Stress induced mobility enhancement techniques: stress memorization and tensile liner for NMOS, SiGe, and compressive stress liner for PMOS	293
8.14 TEM photograph of PMOS with SiGe compressive stress, and NMOS with tensile liner stress in a 45nm node	294
8.15 Definition of various gate to diffusion and well distances that impact stress magnitude and consequently transistor performance	294
8.16 Impact of STI stress effect on transistor drive current vs. active size	295
8.17 NBTI shift dependency on gate material	297
8.18 Dynamic voltage drop vs. time, clock, flop, and combinational gate activity	299
8.19 Thermal map of a multi-core microprocessor under worst case workload conditions	301
8.20 Sheet resistance nonlinear behavior vs. interconnect width	302
8.21 Impact of SPA on interconnect width on silicon vs. normalized drawn width and spacing	303
8.22 Interconnect sheet resistance dependency on width and spacing due to SPB and CMP effects	303
8.23 SPB impact on RC delay vs. interconnect width and spacing	304
8.24 Cross section of interconnect stack of a 45nm process	304

List of Tables

2.1	Sources of static and dynamic clock uncertainties	15
2.2	Clock distribution topologies	22
2.3	Clock distribution characteristics of commercial processors	43
2.4	Clock synchronization categories	54
6.1	Truth table for bang–bang phase detector internal nodes	190
6.2	State sequence for CLKOUT lagging CLKIN	190
6.3	State sequence for CLKOUT leading CLKIN	190
6.4	Example MTBF calculation for the circuit of Fig. 6.15	202
6.5	Characteristics of coarse DCDLs	206
6.6	Variable resistance DCDL branch sizing	210
6.7	DLL behavioral model design parameters	224

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Introduction and Overview

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Clock frequency is a major attribute of any microprocessor design. Early on, during product definition, it constitutes a major business or marketing decision and it is usually the result of a trade-off among customer needs, competitive landscape, and time-to-market. As soon as the frequency target is handed down the food chain to silicon implementation, it will affect all project design aspects from the day that the project is kicked off until it tapes out (and in most cases well beyond this point too). It is not surprising therefore that the job of generating, distributing, and analyzing the clocks in complex chips is considered to be an important and visible assignment. Clock design has traditionally been an area of innovation and has been in the spotlight in technical conferences and journals.

Why is clock frequency such an important microprocessor aspect? For a number of applications it is only loosely correlated with performance with other design aspects such as memory system, parallelism, and hardware acceleration being equally or even more effective. Nevertheless, it is a single number that is widely understood by both technical and nontechnical audiences and in certain situations has strong correlation with single-thread performance.

Clock frequency, although very important, is only one aspect of clock design. Other aspects include power dissipation, efficient clock signal distribution in large and complex chips, coping with variation and uncertainty, managing multiple clock domains in the context of highly integrated system-on-a-chip (SoC) designs, and multicore integration, providing good voltage/frequency scalability to support a wide product roadmap, tuning capabilities for yield enhancement and postsilicon optimization, and sophisticated active power management features.

The purpose of this book is to introduce a designer to important aspects of state-of-the-art clock design by exposing methodology steps and analytical modelling techniques, providing design examples and case studies and enumerating a long list of references for further study.

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