

Index

A

Adaptation

- frequency, 172–173
- on-chip ageing monitoring (*see* Ageing monitoring)
- supply voltage, 172

Adaptive architectures

- voltage and frequency scaling
 - adaptive voltage scaling implementations, 173–174
 - frequency adaptation, 172–173
 - supply voltage adaptation, 172

Adaptive body bias (ABB)

- vs.* AVFS, 176–177
- back body bias concept, 175
- classic approach, 174–175
- FBB and RBB, 175
- F_{max} distribution, 176

Ageing-aware logic synthesis

- BTI, 113
- CMOS lifetime reliability, 113
- See also* Logic synthesis

Ageing-aware transformation

- gate-level optimization, 138–143
- logic restructuring, 126–132
- technology mapping, 132–138

Ageing effects

- BTI-induced performance degradation, 35
- CMOS threshold, 113
- extra-functional properties, 3
- hierarchical levels, 151
- NBTI, 6
- oxide traps, 19
- SER, 36
- technology node, 31

Ageing mitigation

- BTI (*see* Bias temperature instability)
- cache memories, 98–103
- discussion, 87–89
- evaluation, 84–87
- high-level data control, 69–70
- instruction cache-based PUF, 103–109
- MOSFET devices, 91
- NBTI/PBTI, 67, 92
- proposed technique
 - application-level BTI balancing, 82–84
 - ATPG, 82
 - SBST, 67
 - SP (*see* Signal probability)
 - SRAM (*see* Static random-access memory)

Ageing models

- accurate prediction, 3
- critical path determination, 30–31
- explicit trap, 19–20
- extra-functional properties, 3
- FDIV bug, 4
- mission scenarios, 8–9
- MOSFET transistor basics, 10–12
- phenomena, 6–8
- stochastic trap, 20–23
- system's performance, 3–4
- terminology, 4–6

Ageing monitoring

- CMOS transistor' sizes, 150
- NBTI and HCI, 152–156
- NTV, 149
- performance (*see* Performance)
- and reliability monitors (*see* Reliability)
- reliability of systems, 149

- Ageing monitoring (*cont.*)
 - topology
 - circuitry, 188–190
 - digitizer block, 193–195
 - DRO, 190, 191
 - monitoring methodology, 191–193
- Aging monitors
 - bit-line slice modifications, 183
 - BTI and HCI, 181
 - ECCs, 182
 - embedded ring oscillators, 182
 - experimental results, 195–196
 - IDDQ current, 182
 - manufacturing testing operations, 195
 - memory cell BTI degradation, 183
 - nMOS transistors, 184
 - SRAM memory cells, 181, 184
- Anti-ageing software, 80, 86–89

- B**
- Bias temperature instability (BTI)
 - ageing modelling for (*see* Circuit-level analysis)
 - behaviour, 12
 - gate-level stress balancing, 77–81
 - logic gates and circuits (*see* Logic gates)
 - reaction-diffusion model, 13
 - and RTN, 17
 - SER (*see* Soft error rate)
 - stress analysis (*see* Stress analysis)
- Bit-flips, 94, 98–101, 109

- C**
- Canary FF, 213–215
- Capture-emission time (CET)
 - abstraction, 24–27
 - ageing modelling, 22
 - behaviour, 23
 - individual trap distribution, 21
 - threshold voltage, 21–22
- Circuit-level analysis
 - BTI-induced degradation, 38
 - logic gate, 39
 - MOS transistors, 36–37
 - nMOS transistors, 37
 - operating time, 40
 - transistor threshold voltage variation, 37, 38
- CMOS circuits
 - OR gate, 71
 - SER (*see* Soft error rate)
- Combinational logic
 - BTI-induced SER, 53–55
 - n/pMOS transistor, 48
 - PMOS transistor, 71
 - and storage elements, 36
 - symmetric
 - minimum-sized NOT gate, 49–51
 - NOR and NAND gates, 51–53
 - velocity saturation, 49
 - voltage glitch, 47
- Cost-efficient aging
 - delay fault detection, 211
 - ICs, 211
- Critical path
 - block-based, 30
 - BTI-balancing program, 87
 - BTI selection, 70–71
 - determination, 30–31
 - DMEDS implementation (*see* Differential multiple error detection sensor)
 - estimation of ageing, 29
 - logic designs, 212
 - near-critical path, 212
 - path-based, 29
 - sensor architecture, 158
 - SP(0) distribution, 71–75
 - sub-circuit, 70

- D**
- Delay
 - BTI-induced delay shift, 116
 - combinational circuits, 36
 - degradation functions, 30
 - logic gates and circuit (*see* Logic gates)
 - measurement monitors, 161–162
 - path degradation, 81, 116
 - post-ageing, 124
 - propagation path, 5, 161
 - self-oscillating paths, 157
- Differential multiple error detection sensor (DMEDS)
 - advantages, 215
 - cost comparison, 222
 - operating principles, 215–217
 - system level design, 219–222
 - transistor level design, 218–219
- Differential ring oscillator (DRO), 190, 191
- Digital circuits, 6, 23, 28, 91, 143, 167
- Digitizer
 - block, 193–195
 - efficiency, 206–207
- Double sampling with time borrowing (DSTB), 159

E

Explicit trap model, 19–21, 27

F

Flip-flops (FF)
 canary monitor, 161, 213–215
 and latches, 156
 level-sensitive latch, 159
 Razor, 212–213
 SETs, 56
 type sensors, 222
 Functional faults, 5, 6

H

High-k devices, 6, 7, 11, 17
 High-level worst-case estimation, 29–30
 Hot carrier degradation (HCI)
 and BTI, 7
 CET approach, 22
 digital library cell performance, 151
 hot electrons, 18
 mechanism, 185
 NBTI, 152–156
 transistor's threshold, 7

I

IDDDQ, 182
 In situ monitors methodology
 ageing-aware gate characterization,
 168–170
 conventional monitor insertion, 165–168

L

Lifetime abstraction
 analytic models, 23
 CET map bins, 23
 Logic gates
 ageing-aware gate library, 43–45
 BTI-induced degradation, 43
 and circuits, 39
 CMOS, 48
 delay degradation, 43–45
 logic-level BTI mitigation, 132
 stress condition, 68
 stress probabilities calculation, 40–43
 Logic synthesis
 basic flow, 114–115
 optimization process, 115–116

M

Masked fault, 5
 Memories
 ageing mitigation techniques (*see* Ageing mitigation)
 bit flipping, 98–103
 SRAM (*see* Static random-access memory)
 Metal oxide semiconductor field effect transistors (MOSFET)
 reliability issue, 91
 threshold voltage shift, 36
 transistor basics, 4, 10–12

N

Netlist, 5, 28–30, 80, 114, 162, 165, 166

O

Oxide defects
 device's threshold voltage, 8
 trap
 activation, 15–17
 degradation, 17–19
 formation, 12–15
 Oxide layer, 10, 18

P

Performance
 integrated circuits (*see* Ageing effects)
 memory cell, 186
 and power consumption effects, 207
 power-speed, 176
 and reliability monitors (*see* Reliability)
 SNM degradation, 92
 SRAM memory cell, 181
 transistors, 28
 PUF
 instruction cache-based, 103–109
 SRAM, 92, 96

R

Razor FF, 212–213
 Reliability
 ageing effects (*see* Ageing effects)
 commercial synthesis tools, 116
 delay measurement monitors, 161–162
 detecting performance violations
 embedded monitors, 159–161
 external-design monitors, 157–158
 discussions, 162–164

- Reliability (*cont.*)
- dual-function SRAM, 109
 - MOSFET, 91
 - SRAM, 95
 - synthesis, 116–118
 - ageing-aware (*see* Ageing-aware transformation)
 - BTI-aware optimization techniques, 117
 - guard-banding method, 118–121
 - library re-characterization, 121–126
- S**
- Sense amplifier (SA), 187–188
- process, voltage and temperature dependencies, 204–206
 - and repair options, 201–204
- Sensors
- cost-efficient aging (*see* Cost-efficient aging)
 - critical path, 158
 - dedicated, 182
 - operating conditions, 170
 - periodic aging, 208
- Signal probability (SP)
- critical paths of the processor, 71–72
 - duty cycle, 68
 - gate-level simulations, 28
 - j*-th clock cycle, 42
 - normalised propagation delay, 44
 - OpenRISC processor, 72–77
 - path delay degradation, 79
 - signal node, 68
 - stress table, 41
- Single event transient, 46–48
- Soft error rate (SER)
- CMOS circuits (*see* CMOS circuits)
 - combinational logic (*see* Combinational logic)
 - single-event transients, 46–48
 - in storage (*see* Storage elements)
- Static random-access memory (SRAM)
- ageing impact
 - as memories, 93–95
 - PUFs, 95–97
 - memory cells
 - operation, 185–186
 - and repair options, 196–199
 - process, voltage and temperature dependencies, 199–201
 - SA operation, 186–187
 - testing procedure, 207–208
- Stochastic trap models, 20–24, 26, 27
- Storage elements
- BTI ageing, 56, 60–61
 - latch critical charge, 58–59
 - latch SER, 60–61
 - SER, 56
 - SET, 56
 - set-up time, 58–59
 - WOV, 57, 58
- Stress analysis
- BTI-critical path selection, 70–71
 - instruction/program-level workload, 72, 76–77
 - SP(0) distribution, 71–72
- T**
- Transistors
- architecture-based solution, 3
 - CET map-based ageing, 22
 - HCI, 18
 - MOSFET (*see* Metal oxide semiconductor field effect transistors)
 - pMOS, 36, 49
 - threshold voltage variation, 38
- Trap activation, 15–18, 20, 27–29
- Trap centric modelling, 27–29
- Trap formation, 12–15, 17