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AVHANDLINGENS *Improvements towards Optimal Design of*
TITTEL: *Reliable Subthreshold Digital CMOS with*
applications in Logic and Memory.

Ultra-low voltage circuits promise great improvements to the power efficiency of digital circuits. This could for instance allow longer battery lifetimes, or even operating from energy harvested from the environment. The design of ultra-low voltage circuits is however very challenging, as in current nanometer scale technologies ultra-low voltage circuits may exhibit complex behavior, and excessive variability has severe impact on both performance and reliability.

Through six papers the thesis addresses central and current challenges within the field of ultra-low voltage subthreshold CMOS circuit design. At the device level it is demonstrated how one can exploit the inverse narrow-width device effect to improve operating speed and energy per operation. The dominant source of statistical variation and its effect on the power-efficiency and the performance of subthreshold logic circuits is treated analytically. This allows the development of predictive models that without Monte Carlo simulation can suggest optimal choices for supply voltage and device sizing based on the designer's performance and yield constraints. Due to the complex behavior of subthreshold devices, multi-objective optimization is further explored as a tool to simplify the design process in order to optimize logic and memory cells. This allows a higher-level design space exploration of only the resource-efficient set of trade-offs. Multi-objective optimization is applied to achieve reliable logic operating at 150mV, as well as a 9-transistor SRAM memory cell at 300 mV in a 65nm technology. To enhance performance and reliability the cell features multiple threshold voltages and virtual power rail techniques. Measurements from all samples of a 64 by 32 SRAM module show that all memory cells operate reliably down to 273mV, as well as competitive performance metrics where 17.8 fJ/access/bit and an average speed of 761 kHz is achieved at the minimum-energy supply voltage of 321mV.

