Analysis and Optimization of Sleep Modes in Subthreshold Circuit Design

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Subthreshold operation is a promising method to reduce power consumption in ultra-low-power applications, such as active RFIDs and sensor networks. It was shown in previous works that operating at the $V_{min}$ supply voltage results in optimal energy operation, where $V_{min}$ typically falls below the threshold voltage. However, all previous subthreshold analyses ignore the leakage current in standby mode. Hence, for applications where operation at $V_{min}$ results in completion of the task well ahead of the required deadline, the energy consumption can be significantly underestimated. In this work, we investigate the effect of the non-zero standby energy on the optimal energy consumption in subthreshold operation. We first analyze energy consumption both with and without a cutoff technique in standby mode. Two parameters are proposed to capture the cutoff structure’s effect on the energy consumption and delivered for the generic power gating switch (PGS) case. Second, a methodology to minimize the total energy consumption is addressed. The selection of the PGS is examined by comparing three different PGS. Then, a co-optimization method to optimize the size of the PGS concurrently with the supply voltage is proposed. In case of long duty cycle operation where most of sensor applications fall, this approach provides extremely small PGS size together with slightly higher supply voltage than the conventional $V_{min}$ as an optimum operation and results in total energy reduction by 99.2% compared to standby-energy-unaware optimization. This project is supported by the Engineering Research Centers Program of the National Science Foundation under award number EEC-9986866.

Energy saving by the proposed co-optimization.