Stochastic Differential Algebraic Equations in Circuit Simulation

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The increasing scale of integration, high tact frequencies and low supply voltages cause smaller signal-to-noise-ratios. In several applications linear noise analysis is no longer satisfactory and thus transient noise analysis becomes necessary.
We deal with the thermal noise of resistors as well as the shot noise of semiconductors modeled by additional sources of additive or multiplicative white noise currents. The resulting system is described by a stochastic differential algebraic equation (SDAE) of the form

$$A(x(t) - x(t_0)) + \int_{t_0}^{t} f(x(s), s)ds + \int_{t_0}^{t} \Sigma(x(s), s)dw(s) = 0 \quad ,$$

where A is a constant singular matrix which is determined by the topology of the electrical network and w is a k-dimensional Wiener process. One has to deal with a large number of equations as well as of noise sources. We assume that the noise sources do not disturb the constraints of the DAE and express this in terms of the network topology.
Using techniques from the theory of DAEs as well as of the theory of SDEs we derive existence and uniqueness for the solutions as well as convergence results for certain implicit methods for systems with DAE-index 1 or 2.