A Method for Modeling Decoherence on a Quantum Information Processor G. Teklemariam†, E. M. Fortunato‡, C. C. López§, J. Emerson‡, J. P. Paz§, T. F. Havel‡ and D. G. Cory‡

†Department of Physics, MIT

abstract We develop and implement a method for modeling decoherence processes on an N-dimensional quantum system that requires only an $N^2$-dimensional quantum environment and random classical fields. This model offers the advantage that it may be implemented on small quantum information processors in order to explore the intermediate regime between semiclassical and fully quantum models. We consider in particular $\sigma_z \sigma_z$ system-environment couplings which induce coherence (phase) damping, though the model is directly extendable to other coupling Hamiltonians. Effective, irreversible phase-damping of the system is obtained by applying an additional stochastic Hamiltonian on the environment alone, periodically redressing it and thereby irreversibly randomizing the system phase information that has leaked into the environment as a result of the coupling. This model is exactly solvable in the case of phase-damping, and we use this solution to describe the model’s behavior in some limiting cases. In the limit of small stochastic phase kicks the system’s coherence decays exponentially at a rate which increases linearly with the kick frequency. In the case of strong kicks we observe an effective decoupling of the system from the environment. We present a detailed implementation of the method on an nuclear magnetic resonance quantum information processor.