Thermodynamic implications of $^{29}$Si spin impurities on scalability of silicon-based quantum computing$^1$ PAVEL LOUGOVSKI, NICHOLAS A. PETERS, Quantum Information Science Group, Oak Ridge National Lab — It is anticipated that $^{31}$P donors in silicon have the potential for realizing scalable quantum processors in analogue to classical computer chips$^2$. In classical computing, removing excess heat is a challenge that sets practical limits on performance. Here we consider what fundamental thermodynamic limits exist for the P-donor quantum computer in isotopically enriched $^{28}$Si. Specifically, we consider the effect of $^{31}$P nuclear spin rotation on the nuclear spin dynamics of the remaining $^{29}$Si impurity atoms within a single-qubit gate volume. Our simulations show that a $\pi$ rotation of $^{31}$P nuclear spin induces $^{29}$Si nuclear spin flipping resulting in an average energy decrease of the $^{29}$Si nuclear spin bath. For a gate volume of 5 nm$^3$ and $^{29}$Si concentration of 800 PPM at 250\,$\mu$K, the average energy decrease per single qubit rotation is $4.74 \times 10^{-12}$\,eV. This suggests that the scalability of $^{31}$P-donor quantum computer will not be limited by energy dissipation from single qubit control pulses into the $^{29}$Si nuclear spin bath. Moreover, randomized single qubit rotation promises to be useful for cooling the $^{29}$Si nuclear spin bath.

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