Supplementary Information for

The effects of asymmetry in active noises on the efficiency of single colloidal Stirling engines with active noises

I. THE EFFECT OF CUTOFF ON THE MICROSCOPIC EFFICIENCY

We investigate the dependence of $\langle\varepsilon\rangle$ on the cutoff value of the microscopic efficiency. When the cutoff value is between 3 and 1000, our simulation results for $\langle\varepsilon\rangle$ are almost constant and robust. On the other hand, the values of $\langle\varepsilon\rangle$ are fluctuating when cutoff is larger than 1000. The microscopic efficiency depends on a cutoff because of unconventionally large efficiencies. In this study, we use cutoff of 5 to avoid unconventionally large efficiencies.

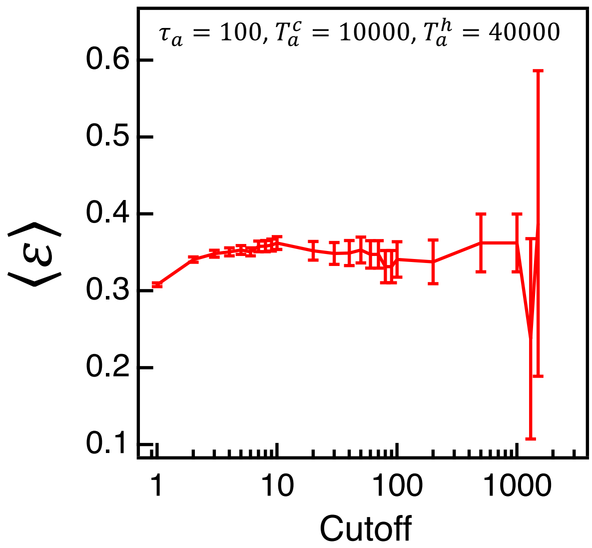

Figure S1. The dependence of $\langle\varepsilon\rangle$ on the cutoff values when $\tau_a = 100$, $T_a^c = 10000$, and $T_a^h = 40000$.

II. THE PERFORMANCE OF ENGINE WITH ACTIVE NOISES AS A FUNCTION OF τ_a PREDICTED FROM THE EFFECTIVE TEMPERATURE

Figures S2 (a), (b), and (c) show the ratios of W_s/W_q, $Q_{h,s}/Q_{h,q}$, and $W_s/Q_{h,s}$ as a function of τ_a, respectively. W_q and $Q_{h,q}$ are the output work and the absorbed heat of passive engines, respectively. As shown in Figures S2 (a) and (b), both W_s and $Q_{h,s}$ increase with increasing τ_a when $T_a^h = 4T_a^c$ and $T_a^h = 10T_a^c$. But, the increase of W_s is much larger than that of $Q_{h,s}$. For example, when $T_a^h = 4T_a^c$, the value of W_s at $\tau_a = 100$ increases about 84 times compared to W_q. On the other hand, the value of $Q_{h,s}$ at $\tau_a = 100$ increases about 26 times compared to $Q_{h,s}$. This difference makes the value of the macroscopic efficiency at $\tau_a = 100$ increase by a factor of about three compared to $-W_q/Q_{h,q}$ (Figure S2 (c)).

Also, Figures S2(a) and (b), W_s and $Q_{h,s}$ converge to constant values as the value of τ_a increases. Therefore, both macroscopic efficiency and microscopic efficiency also converge to constant values when the value of τ_a is sufficiently large.

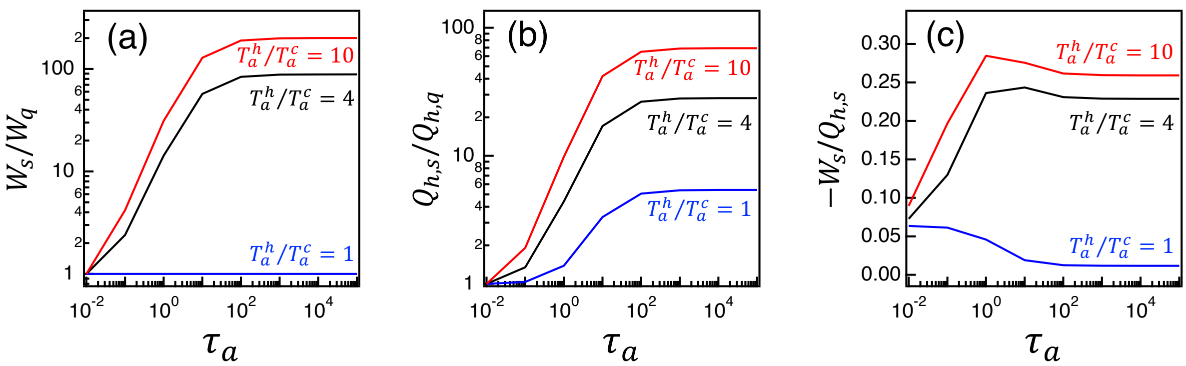

Figure S2. The ratio of (a) W_s/W_q and (b) $Q_{h,s}/Q_{h,q}$ as a function of τ_a when $T_a^h = T_a^c$ (blue), $T_a^h = 4T_a^c$ (black), and $T_a^h = 10T_a^c$ (red). (c) The macroscopic efficiency predicted from W_s and $Q_{h,s}$ as a function of τ_a when $T_a^h = T_a^c$ (blue), $T_a^h = 4T_a^c$ (black), and $T_a^h = 10T_a^c$ (red).