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# A Large-Stroke Reluctance-Actuated Nanopositioner: Compliant Compensator for Enhanced Linearity and Precision Motion Control

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***Abstract*— Hybrid reluctance actuators, known for their remarkable motor constant and bidirectional non-contact force, emerge as superior alternatives to piezoelectric stack or voice coil actuators. A key challenge in large-stroke ($> 1$ mm) hybrid reluctance actuators is their inherent nonlinearity characterized by fluctuations in negative stiffness and motor constant. To tackle this problem, we propose a large-stroke reluctance-actuated nanopositioner by leveraging on a compliant stiffness compensator to reduce the adverse impact of the reluctance actuator's nonlinearity. We establish the relationship between the system's equivalent stiffness and the combined effects of the reluctance actuator and compliant compensator. Based on a novel nonlinear decoupling mechanism, the fluctuation in the system's equivalent stiffness is significantly reduced, enabling advanced model-based controls and facilitating high precision motion. A prototype system compatible with atomic force microscopy is established. And the system's performance is validated using a repetitive control with the recently developed optimized passband loss filter, demonstrating nanometric precision in large-range and high-frequency scanning. The experimental results reveal that the proposed system achieves a precision of $17.6$ nm (RMSE) for a $2$ mm triangular wave at $1$ Hz and $8.2$ nm (RMSE) for a $20$ $\mu$m triangular wave at $80$ Hz. Further validation through atomic force microscopy confirms the system's capability in large-range and high-speed characterization. These results suggest that the proposed system could significantly advance the use of large-stroke reluctance-actuated positioners for millimeter-range nano-precision applications.**

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