Hysteresis Characterization Using Charge-Feedback Control for a LIPCA Device

James Beck[a], Maciej Noras[b], Jerzy Kieres[b], John E. Speich[a], Karla M. Mossi[a] and Kam K. Leang[a]

Virginia Commonwealth University

Objective

To characterize the no-load hysteresis of a lightweight carbon composite piezoelectric actuator device (LIPCA) under voltage and charge-feedback control. The results show charge-feedback control reduces hysteresis up to 80%.

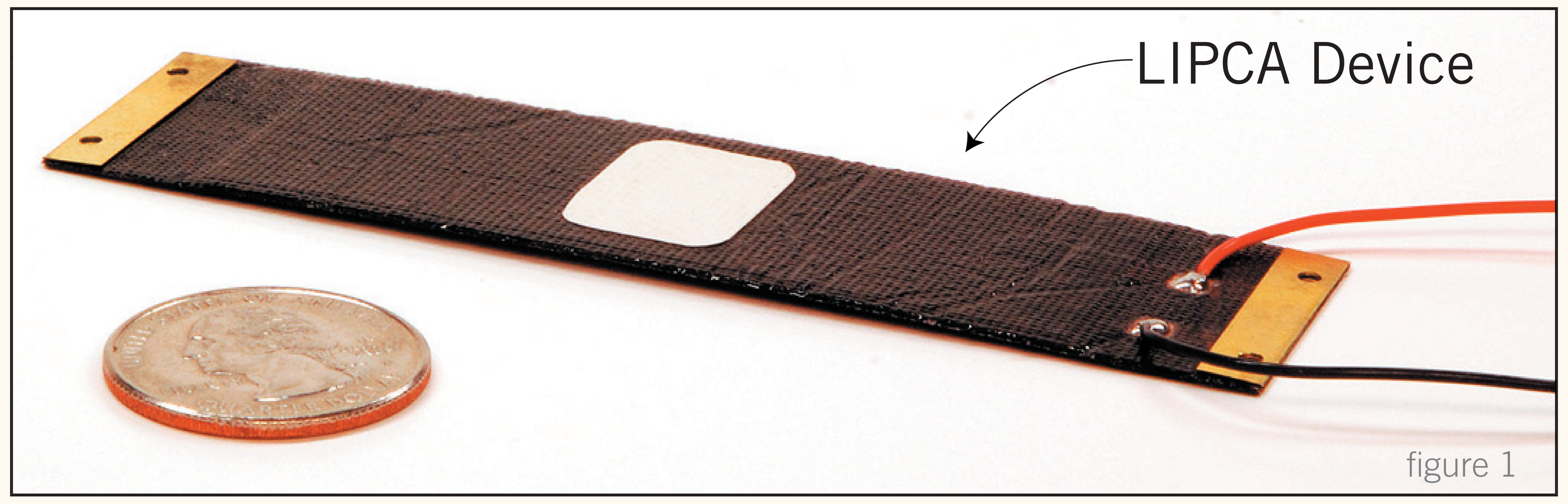


figure 1

The subject LIPCA device compared to a US $0.25 coin.

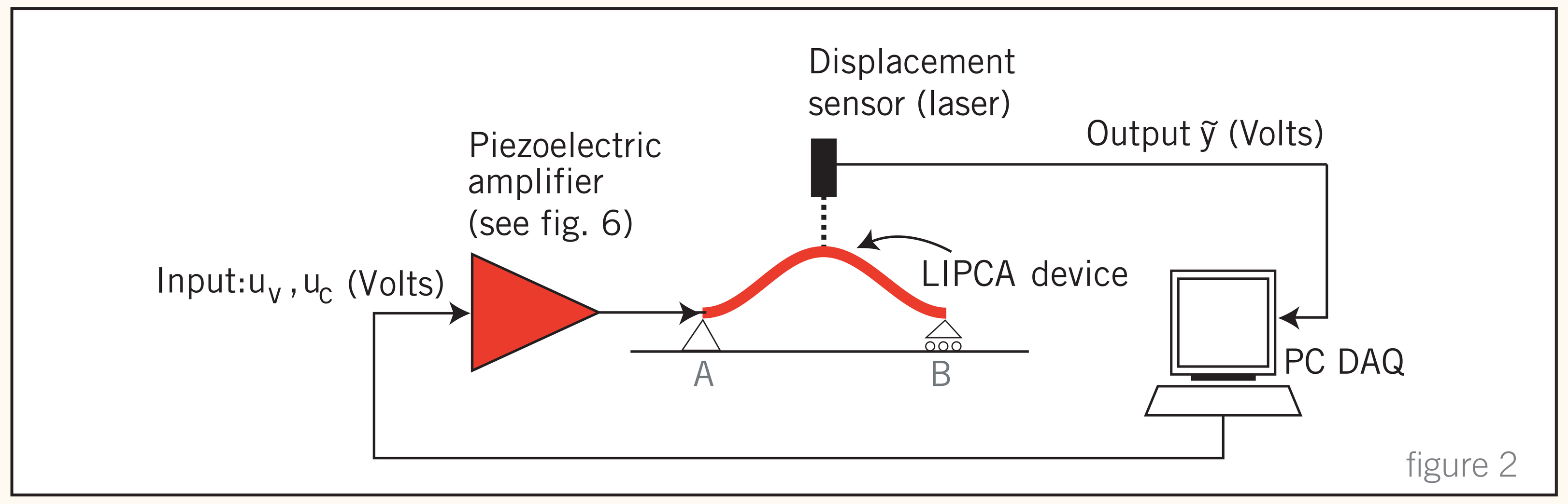


figure 2

The experimental setup: A reference input (voltage or charge) generated by a PC/DAQ and applied to the piezoelectric amplifier. The displacement of the LIPCA is measured by a laser (2.0106 mm/V).

Methods

figure 3

Output of LIPCA contains creep, hysteresis and vibration. This study focuses on the hysteresis effect.

Minimize Vibration Effect

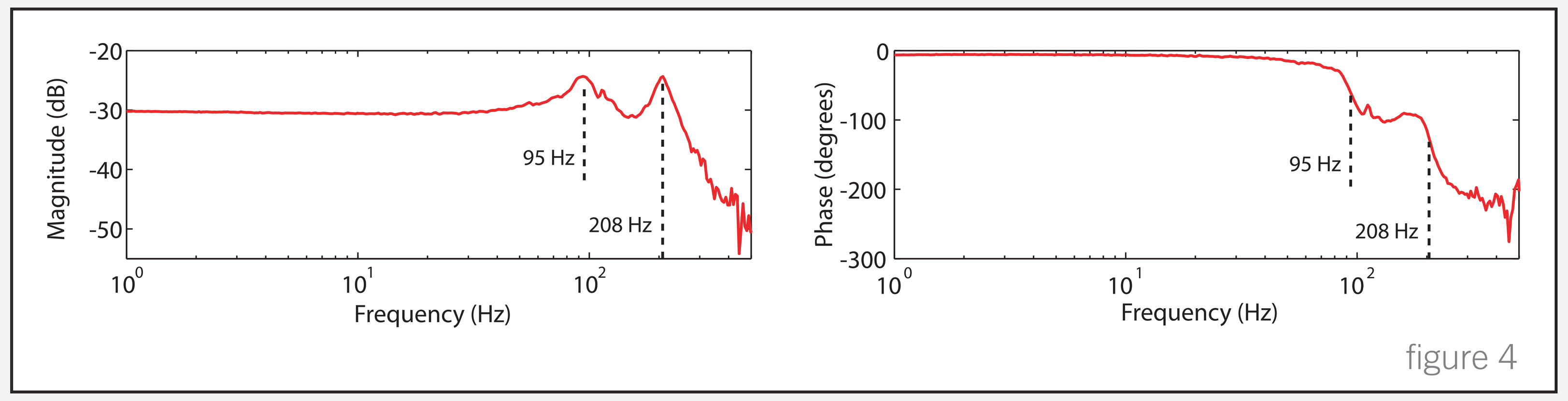


figure 4

Bode plot of LIPCA device showing magnitude and phase response vs. frequency.

Sinusoidal inputs (<5Hz) were applied to minimize vibration.

Compensate for Creep Effect

A linear creep model (G_C) was found, then inverted to find an input to account for the creep effect.

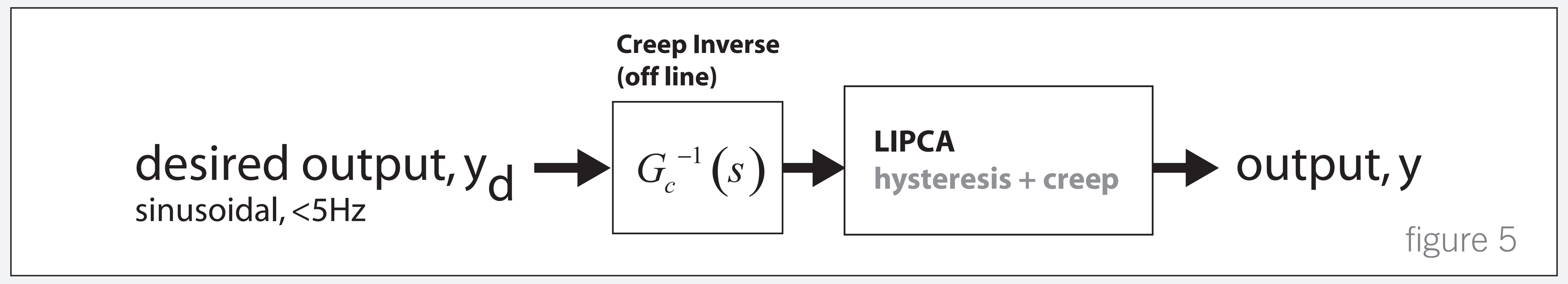


figure 5

An inversion-based feedforward approach was used to account for creep effect.

Amplifiers

Two different piezoelectric amplifiers were used:

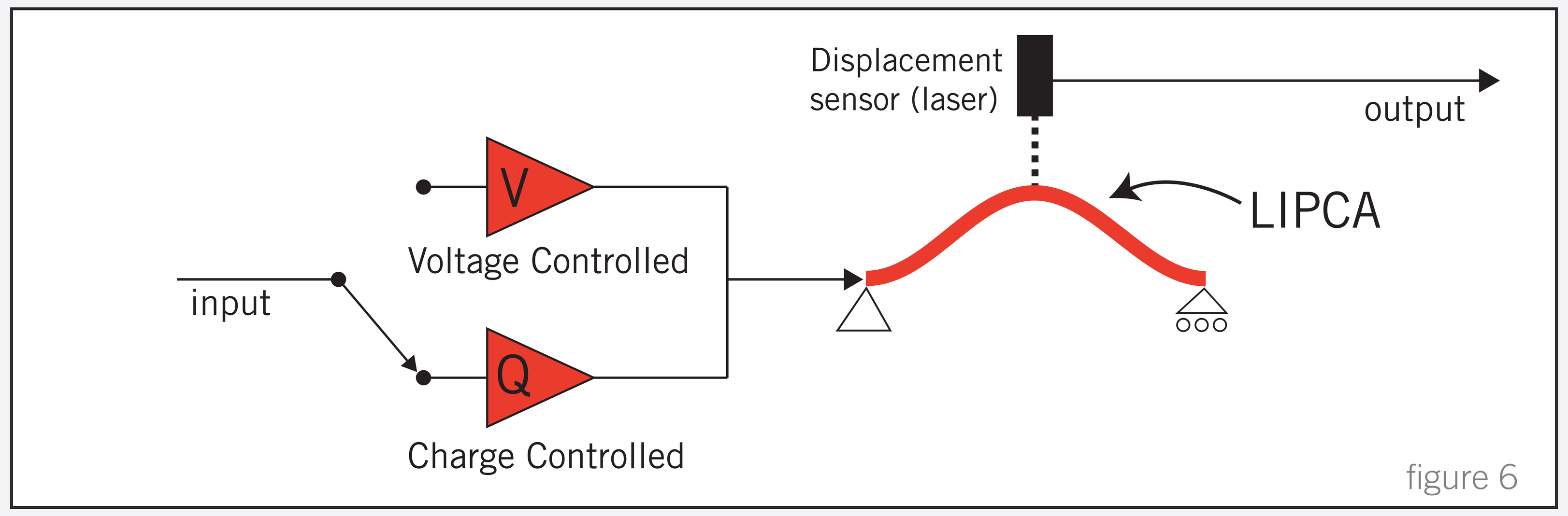


figure 6

1. Voltage Control Amplifier

- Applies a specified *voltage*
- Trek Model PZD-2000 high voltage piezoelectric amplifier

2. Charge-Feedback Amplifier

- Applies a specified *charge*
- Based on the Trek Model PZD-700. Circuit shown below

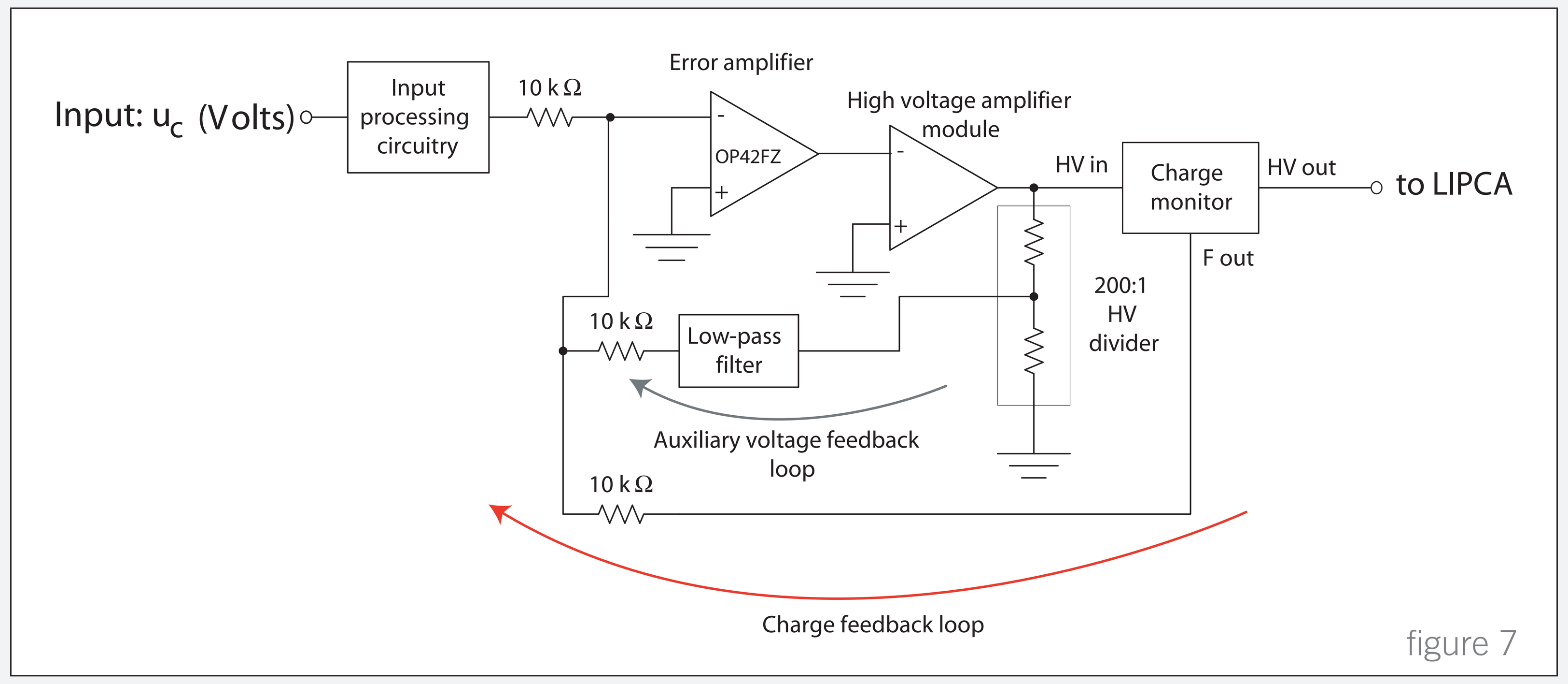
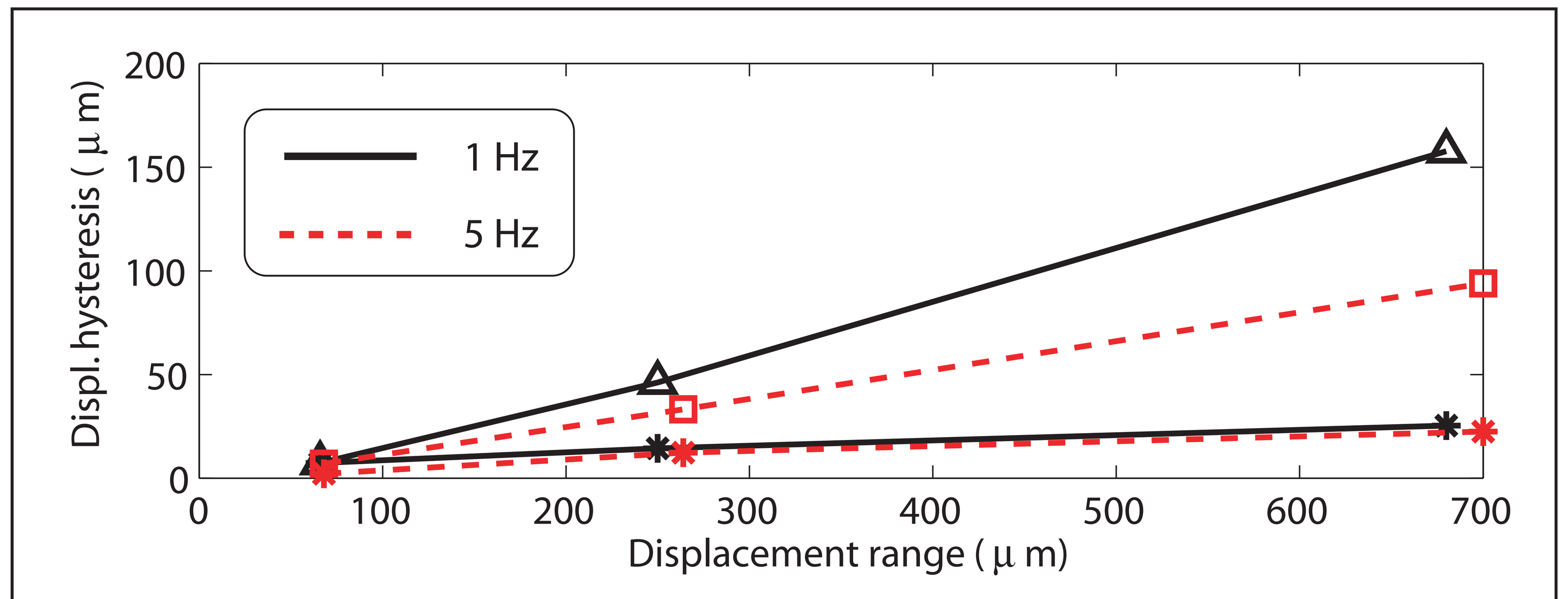


figure 7

Charge-feedback amplifier design
The output follows a reference input charge by measuring the charge on the LIPCA and feeding it into an error amplifier.

Results



Frequency	Voltage Control	Charge Control
1 Hz	23.7 um hysteresis per 100 um of range	3.4 um hysteresis per 100 um of range
5 Hz	13.6 um hysteresis per 100 um of range	3.2 um hysteresis per 100 um of range

figure 8

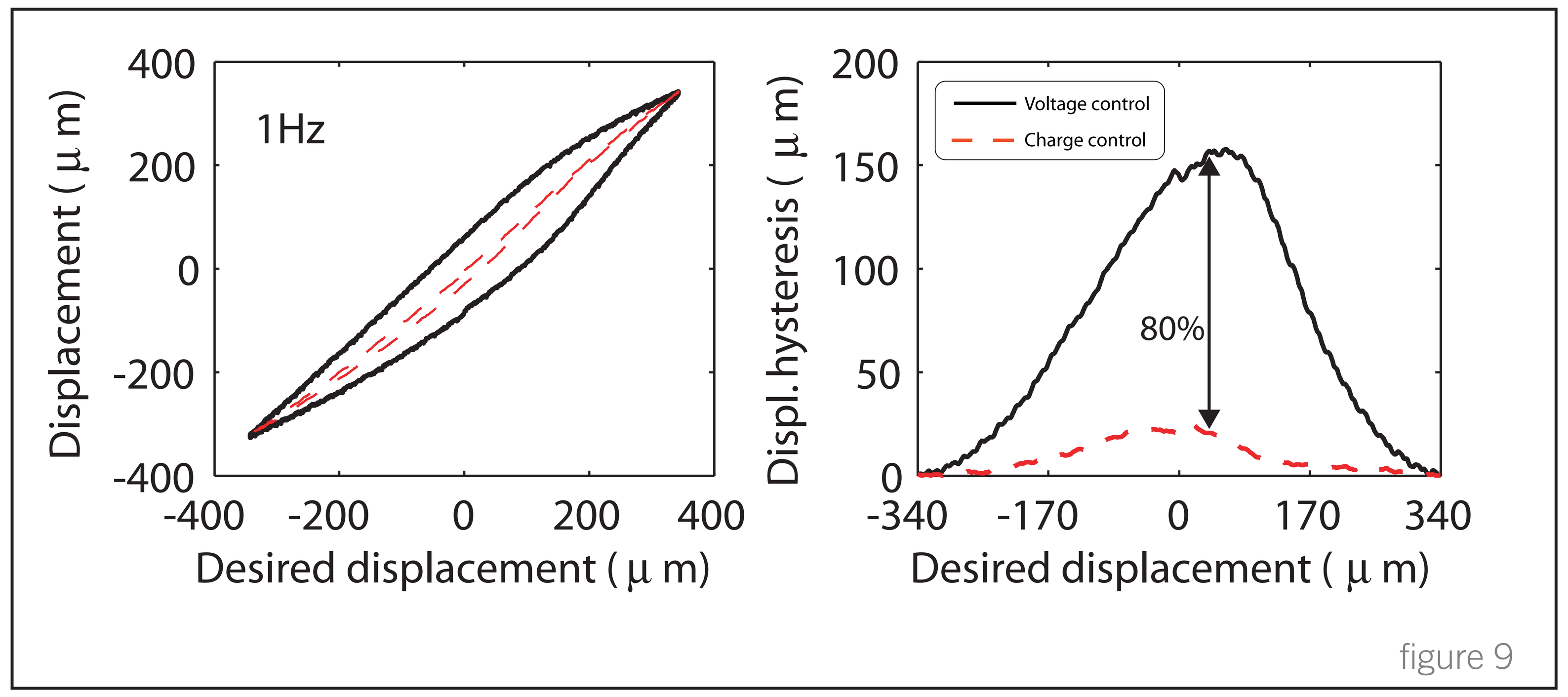


figure 9

Conclusion

- Inversion-based feedforward input compensates for creep effect
- Charge-feedback control reduces hysteresis by 80%

[a] Virginia Commonwealth University, Dept. of Mechanical Engineering, 601 W. Main Street, PO BOX 843015, Richmond, VA, 23284-3015, USA [b] Trek Inc., 11601 Maple Ridge Road, Medina, NY 14104, USA