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actuators MDPI

Tracking Control for Piezoelectric Actuators with Advanced Feed-forward Compensation Combined with PI Control

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Piezoelectric Actuators : State of art

- Active Vibration Systems.
- Sensing.
- Energy Recovery.
- Stick-slip motors.

Nonlinearities

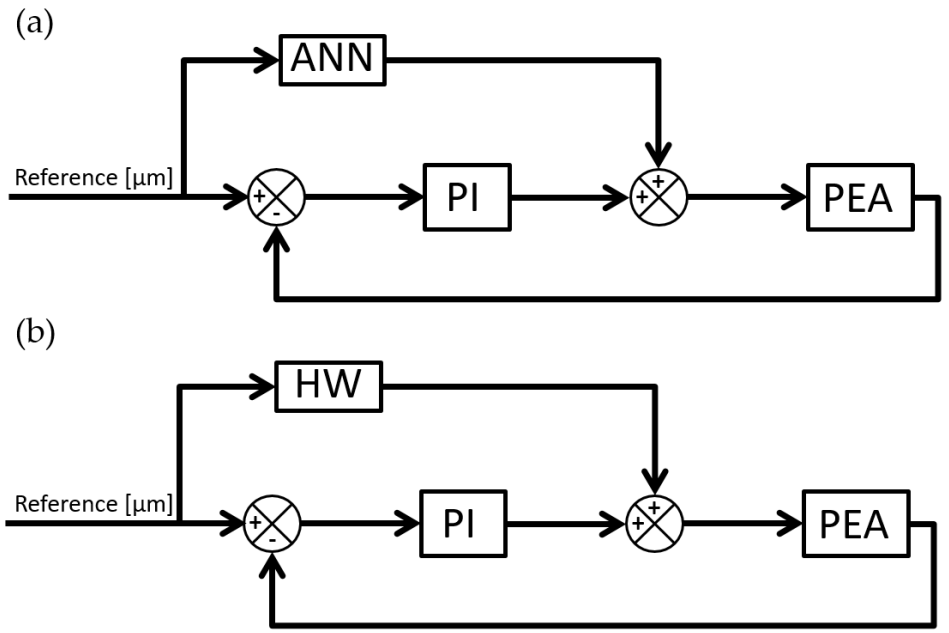
- Hysteresis
- Creep.
- Vibration dynamics.

Common controllers

- SMC.
- SMC w/ PID.

In this research:

- Feedback-Feedforward control architecture for PEA tracking.
- FF compared: Artificial Neural Networks (ANN) & Hammerstein Wiener (HW).
- Feedback controller: Proportional-Integral (PI).
- Performance metrics: error analysis, control signal and integral of absolute error (IAE).



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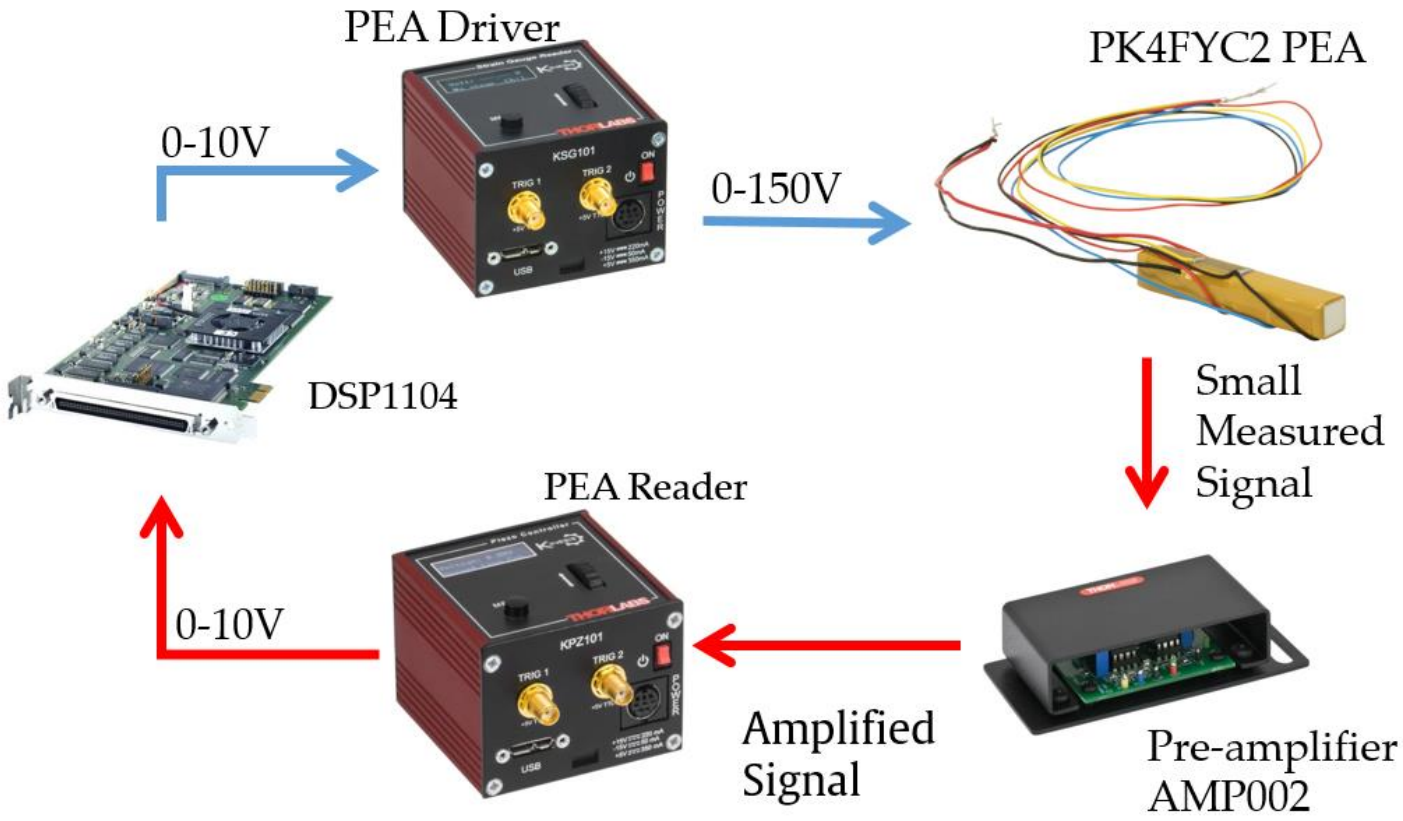
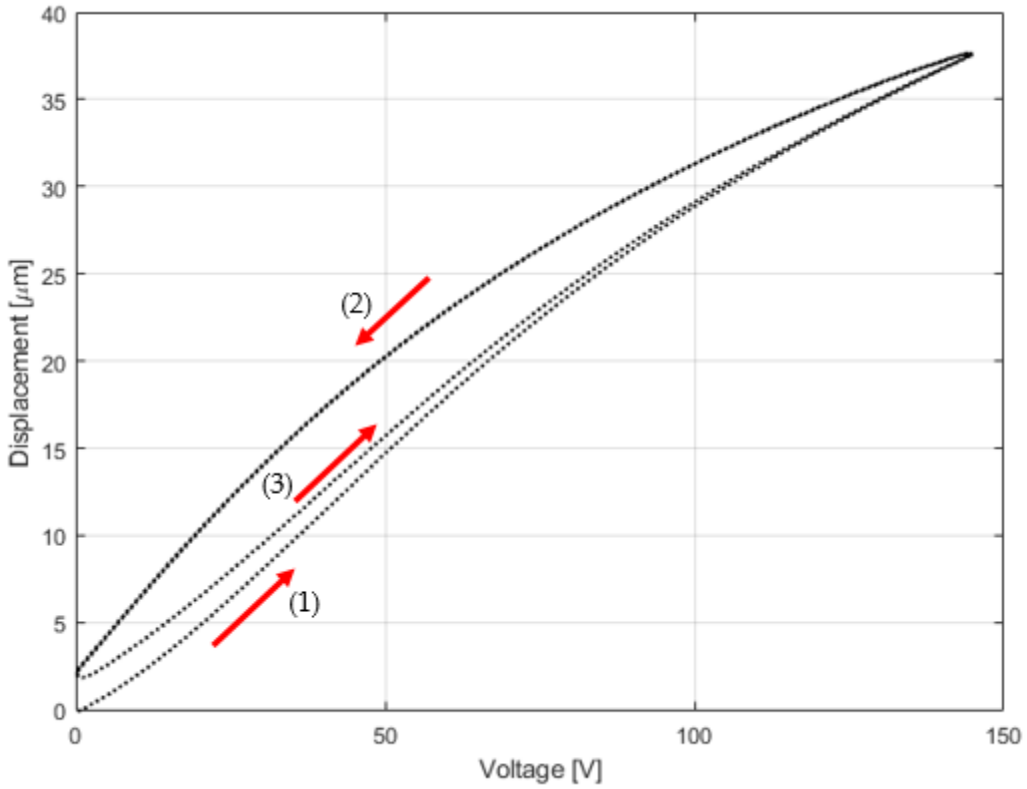
Hardware involved



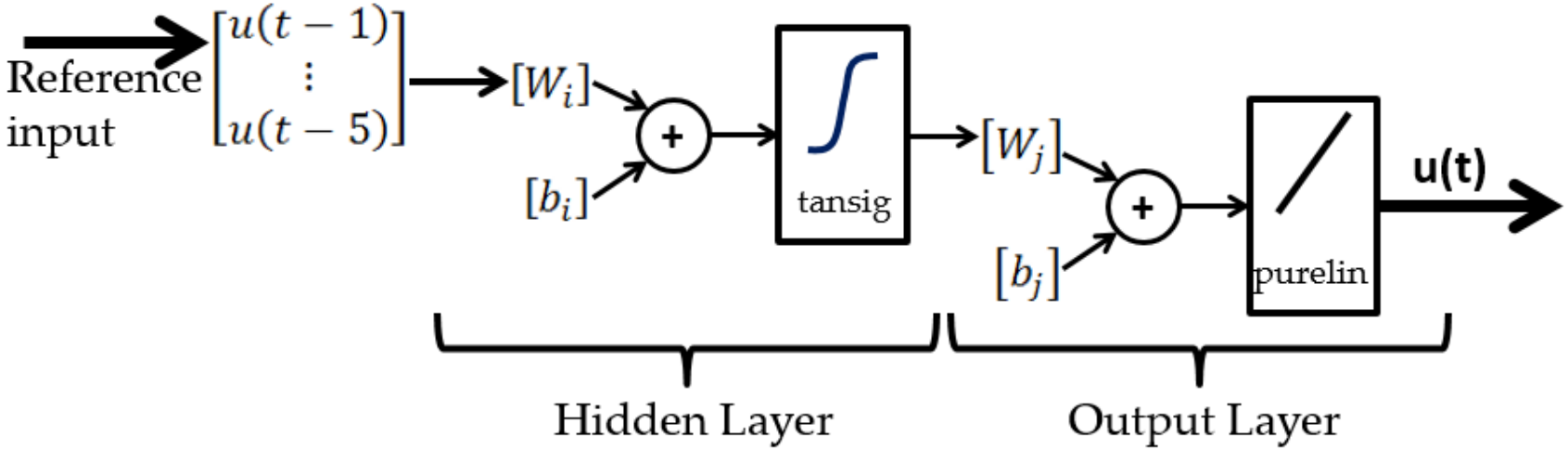
Properties	Values	Units
Physical Dimensions	7.3x7.3x36	mm
Max displacement	38.5	µm
Max force	1000	N
Drive voltage range	0-150	V
Error due to hysteresis	15	%

Hysteresis description



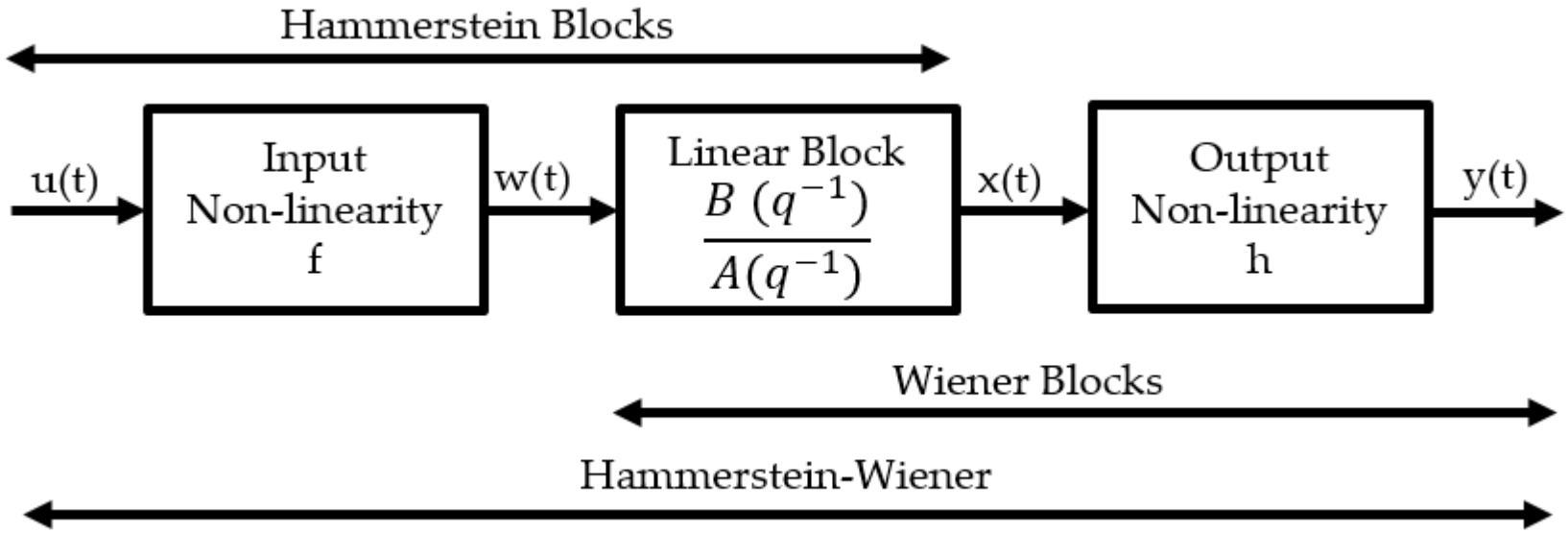
- Triangular input signal.
- Amplitude: 145V.
- Period: 1s.
- Sampling time: 1kHz.

ANN Settings



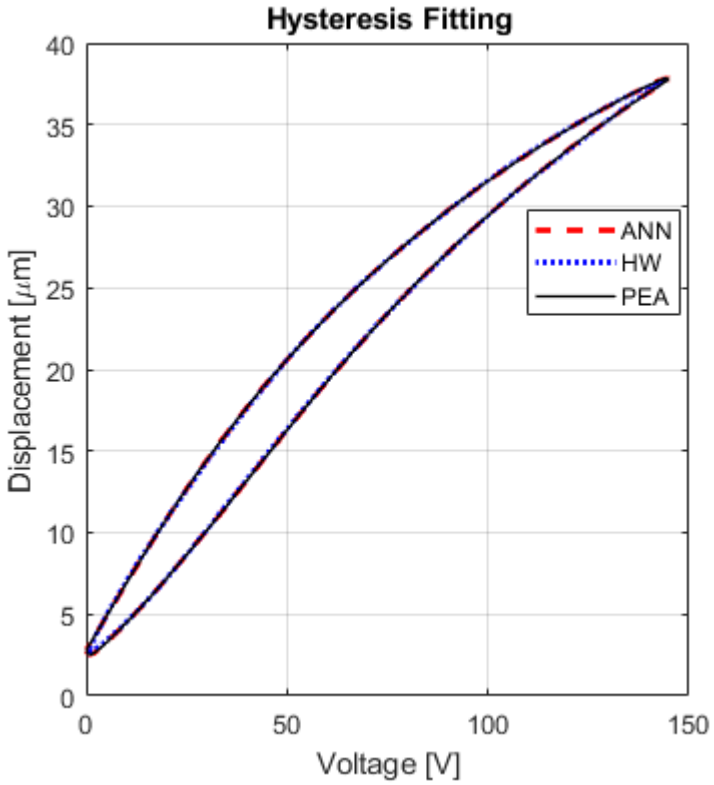
- TDNN
- Training set: Input voltage & displacement along 10s.
- 70/15/15 data split.
- Levenberg-Marquardt training algorithm.
- 22 neurons.
- 5 delays.
- Metric: mean squared error (MSE).

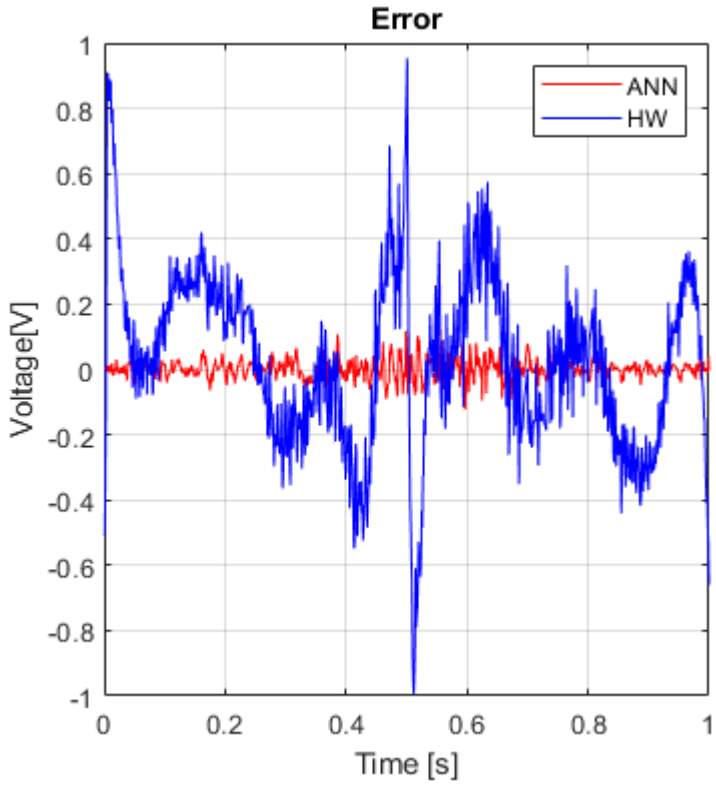
HW settings



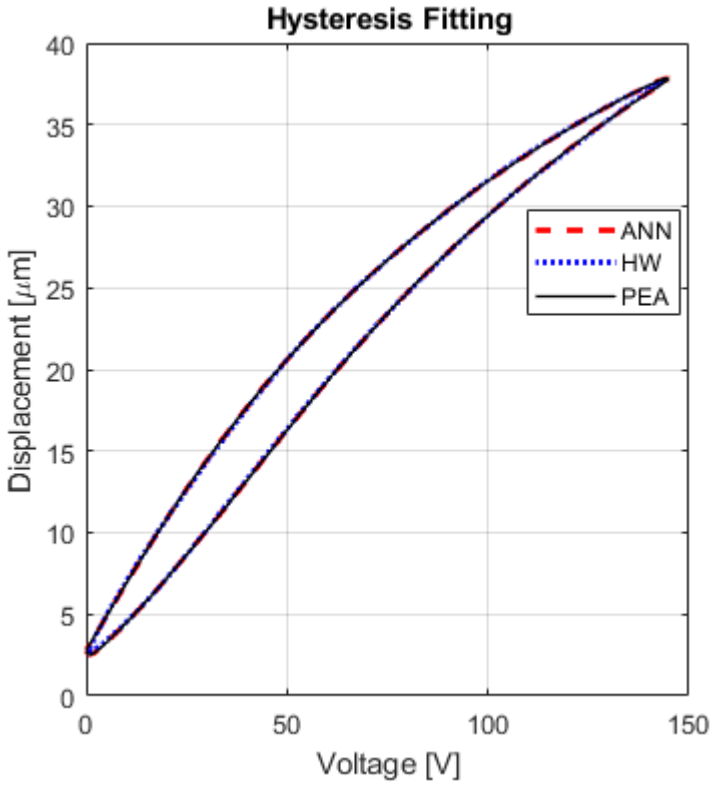
- Input/ Output Polynomial.
- Training set: Input voltage & displacement along 10s.
- Metric: fit percent.

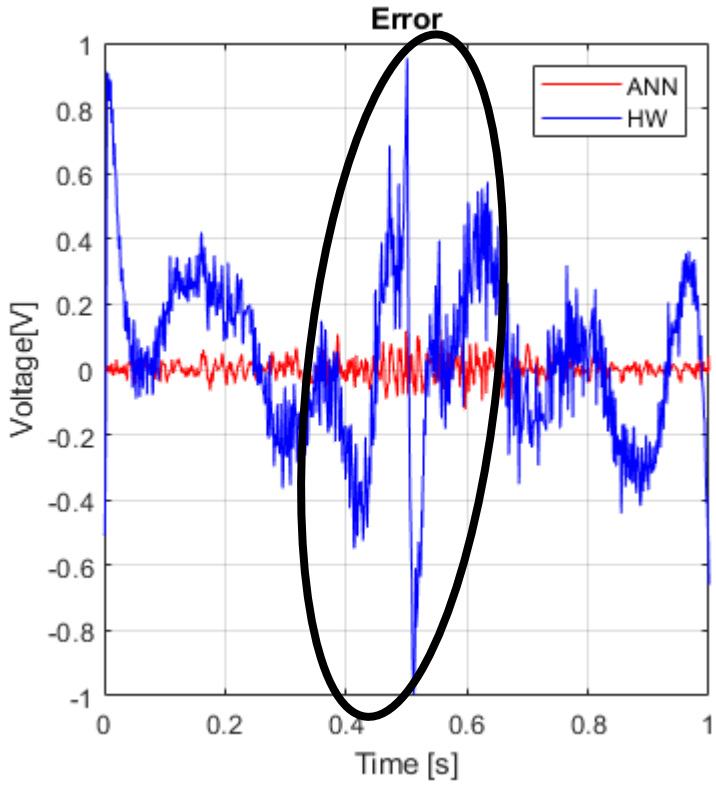
Results: Hysteresis fitting



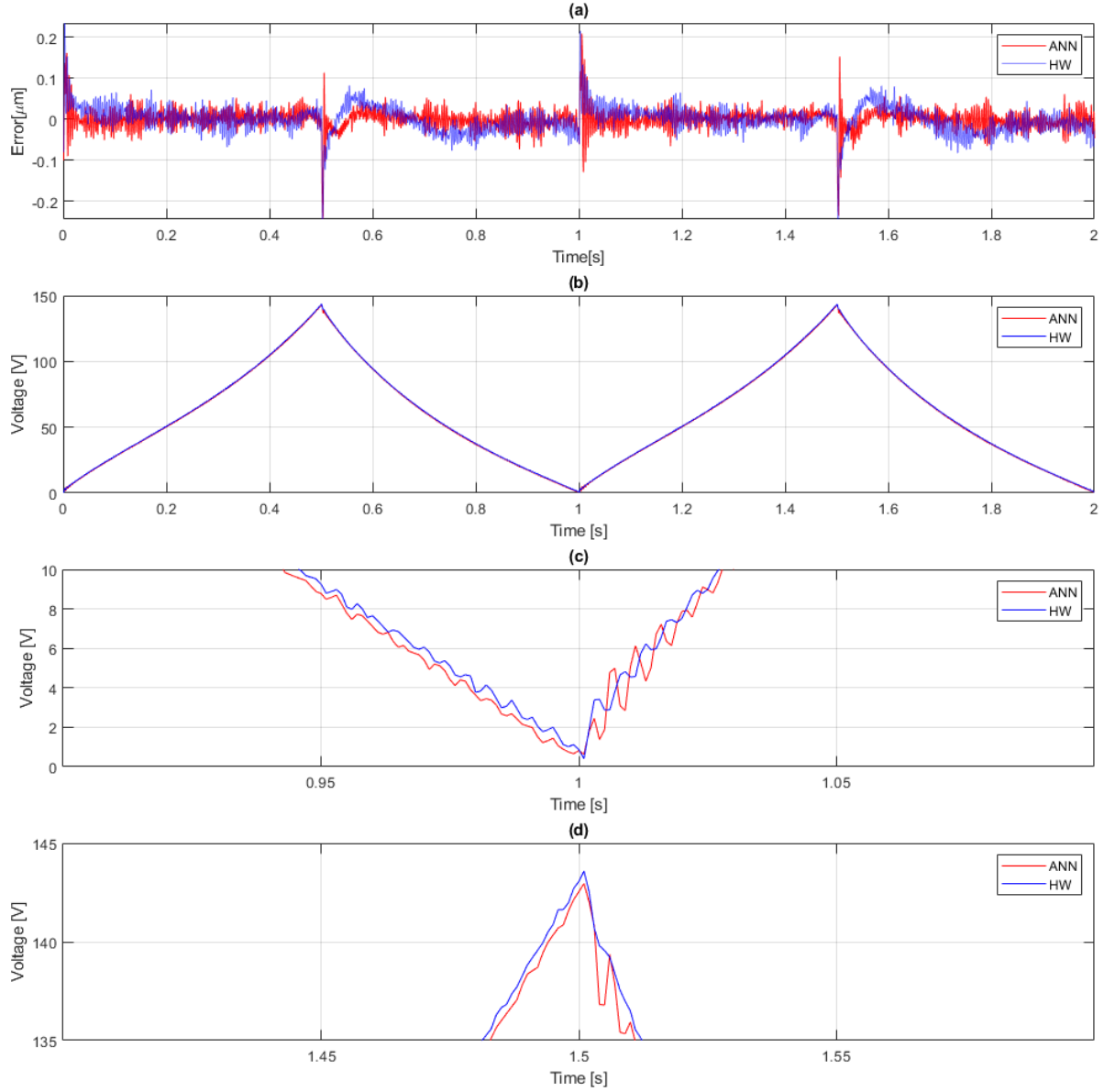


Results: Hysteresis fitting



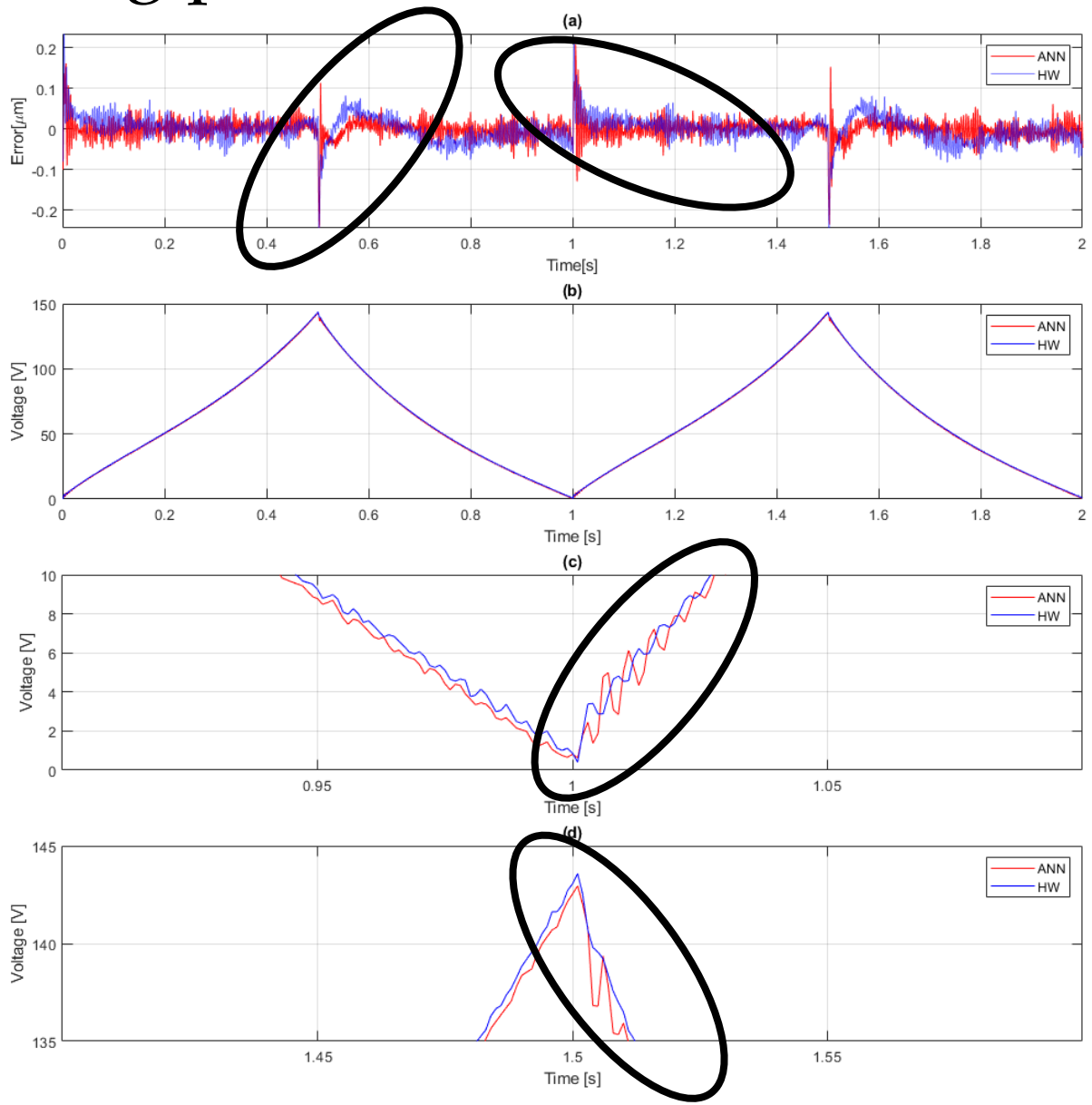


Results: Tracking performance



- Kp = 10.
- Ki = 1000.

Results: Tracking performance



- IAE_ANN = 0.0384.
- IAE_HW = 0.0486

Conclusions

- Experiments with a commercial PEA were carried.
- The hysteresis plot was obtained.
- ANN & HW was used for mapping and feed-forward.
- A PI controller was implemented in the feedback loop.
- HW has a good performance in terms of control action.
- ANN behaves better in terms of tracking (Lowest IAE).
- Future research: Comparison with advance PI controllers (FPID, neural), other ANNs configurations (LSTM), different HW configuration or optimisation, etc.

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