

# Nonlinear Data-driven Identification of a Thermo-electric System

***Citation for published version (APA):***

Noël, J.-P., Evers, E., & Oomen, T. A. E. (2020). Nonlinear Data-driven Identification of a Thermo-electric System. In R. Carloni, B. Jayawardhana, & E. Lefeber (Eds.), *39th Benelux Meeting on Systems and Control: Book of Abstracts* (pp. 100). University of Groningen. <https://www.beneluxmeeting.nl/2020/program/book-of-abstracts>

***Document status and date:***

Published: 01/03/2020

***Document Version:***

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

***General rights***

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

***Take down policy***

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# Nonlinear Data-driven Identification of a Thermo-electric System

Jean-Philippe Noël, Enzo Evers, Tom Oomen

Control Systems Technology Group, Eindhoven University of Technology

j.m.m.g.noel, e.evers, t.a.e.oomen @tue.nl

## 1 Introduction and motivation

Thermo-electric coolers based on the Peltier effect are a popular actuation option in high-precision systems where active heat exchanges are required [1]. State-of-the-art modelling in the field is largely performed by relying on first principles. This contribution presents a data-driven approach to modelling the nonlinear dynamics of Peltier elements.

## 2 Identification procedure

The adopted identification methodology proceeds in two steps. Firstly, a nonparametric analysis is achieved in the frequency domain, with the objective of quantifying the amount of nonlinear distortions affecting the system output spectrum at a given excitation amplitude. A discrimination between distortions originating from odd (symmetric) and even (asymmetric) nonlinearities is also made possible by the use of special multisine excitation signals [2]. Secondly, a nonlinear state-space model is identified from data. The identification is carried out in the frequency domain again, by minimising an unweighted least-squares cost function. The nonlinear model terms are function of the measured current at the system input side, following the prior knowledge that a Joule effect, which is related to dissipation in heat conduction, is the dominant source of nonlinearity in a Peltier element dynamics when excited over a reasonably small temperature range.

## 3 Identification results

Fig. 1 depicts the nonparametric analysis of an input-output data set measured under a multisine excitation signal with a root-mean-squared amplitude of 0.64 A. In the frequency domain, this signal contains no power at the even lines to detect asymmetric nonlinearities, and randomly leaves odd lines unexcited to detect symmetric nonlinearities. Fig. 1 reveals that a substantial even nonlinearity (blue) distorts the system output spectrum (grey), as opposed to the marginal amplitudes of the odd distortions (yellow) and noise disturbances (black). The result of the nonlinear state-space modelling step is provided in Fig. 2. The identified model incorporates a quadratic input term in the state equation, reflecting the outcome of the nonparametric analysis in Fig. 1. This model features 5 state variables and overall comprises 41 parameters. The associated residual in Fig. 2 (green) is seen to be 10 to 20 dB below the corresponding linear modelling error level (blue) over the frequency range from DC to 0.1 Hz.

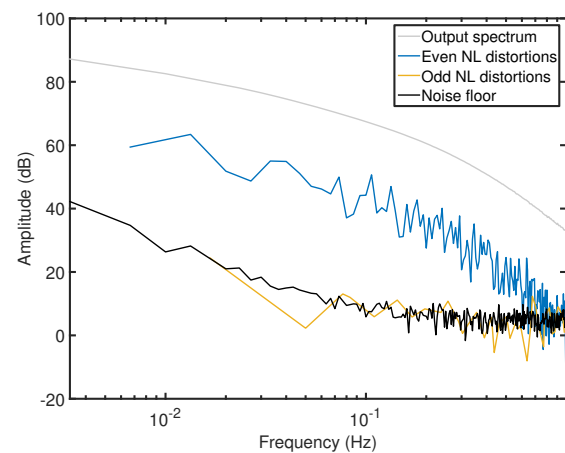


Figure 1: Nonparametric analysis of test data.

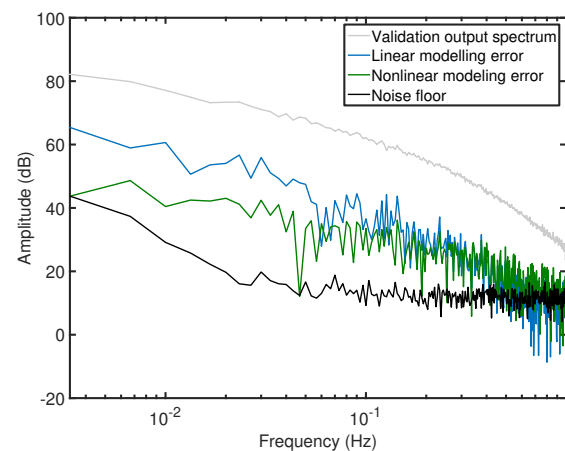


Figure 2: Parametric nonlinear modelling in state space.

## 4 Conclusion and outlook

On-going investigations focus on identifying the Peltier dynamics over larger temperature ranges, and on exploiting the resulting data-driven models for designing feedback linearisation controllers.

## References

- [1] R. van Gils, *Peltier for precision actuation*, *Mikroelektronik* 59(2), 5-10, 2019.
- [2] J. Schoukens, L. Ljung, *Nonlinear system identification: a user-oriented road map*, *IEEE Control Systems Magazine* 39(6), 28-99, 2019.