Semester project:

Design and deployment of a control board for thermoacoustic experiments

Supervisors: Samuel Balula, Andrea Iannelli
Professor: Roy Smith

Thermoacoustics studies phenomena where the interaction between acoustic wave and heat transfer effects play a crucial role [1]. A broad class of problems that is described within this framework is represented by special types of heat engines and refrigerators, where the conversion heat-work is performed with no moving parts by exploiting pressure waves. These machines have a high potential for the development of sustainable energy systems, and this has stimulated a large body of research on the topic [2]. At the Automatic Control Lab (IfA), several student projects were carried out in the last few years to advance knowledge in this field. Some of them had a great experimental focus [3, 4], and lead to the successful construction of laboratory-scale thermoacoustic machines, e.g. Rijke tube [5], thermoacoustic refrigerators [6].

At the moment, all the operations connected with experimental testing, e.g. data acquisition, system identification, feedback control, are performed through commercial hardware and software. While this has the advantage that standardized solutions and ample documentation for the user are available, there are important drawbacks. These include: high costs; delays in real-time control; compatibility issues (with associated risk of non-repeatability); limited control and authority on the functionalities of the system. For these reasons, this project aims to build up an in-house solution enabling data acquisition and real-time control, with the end goal of deploying it in thermoacoustic experiments.

The main goal is the construction of a control board, featuring an embedded microcontroller and data acquisition functionalities. This board will allow: acquisition of the signals from the sensors; digital signal processing; generation of signals used for control; storage of the data (for post-processing) and web connection for monitoring results during the experiments; robust behavior to incorrect use (e.g. emergency switches). Each of these subsystems and operations will have specified technical requirements, as in real-life applications.

In order to foster this *in-house* approach to experimental testing, an application note with example codes will be released in open source at the end of the project.

The last task of the project consists of testing the functionalities of the microcontroller on one of the existing thermoacoustic machines [5, 6].

A short outline of the project is given below:

- design of a control board with the prescribed functionalities - 1/1.5 month ca.
- testing on the available thermoacoustic machines - 0.5/1 month ca.
- documentation of the in-house apparatus (application note and sample codes) & writing-up dissertation - 0.5/1 month ca.

Experience in the following topics will be beneficial to the prospective applicant: hands-on troubleshooting electrical circuits; basic programming for microcontroller implementations; design of printed circuit boards.

References

[1] Swift, G., *Thermoacoustics*, Springer, 2007.

[2] Garrett, S. and Backhaus, S., "The power of sound," *American Scientist*, Vol. 88, No. 6, 2000, pp. 516–525.

[3] Moghini, M., "Design of a Solar Powered Thermoacoustic Engine-Refrigerator," Tech. rep., MA project - Automatic Control Lab - ETHZ, 2016.

[4] Moser, L., "Design, construction and active control of a travelling wave thermoacoustic machine," Tech. rep., MA project - Automatic Control Lab - ETHZ, 2016.

[5] Schalch, L., "Active Control of Thermoacoustic Instabilities in a Rijke Tube System," Tech. rep., SA project - Automatic Control Lab - ETHZ, 2015.

[6] Giftthaler, M., "Design, Construction and Resonance Tracking of a Laboratory-Scale, Loudspeaker-Driven Thermoacoustic Cooler," Tech. rep., MA project - Automatic Control Lab - ETHZ, 2013.