Active Noise Reduction

- Developing active noise reduction for turboprop airplanes
- Department of Mechatronics relies on dSPACE ACE Kits in research and teaching
- Parallel DS1005 PPC Boards provide the necessary computing power

The Department of Mechatronics at Helmut Schmidt University (HSU) / University of the Federal Armed Forces Hamburg, Germany, is developing systems for active noise reduction. Research is currently focusing on active systems for turboprop airplanes, whose powerful engines cause high sound pressure inside the plane, experienced by passengers and crew as loud noise. To develop noise reduction systems, the department is using several dSPACE ACE Kits with the DS1103 PPC Controller Board in both research and teaching, and a multiprocessor systems based on two DS1005 PPC Boards for particularly high performance requirements.

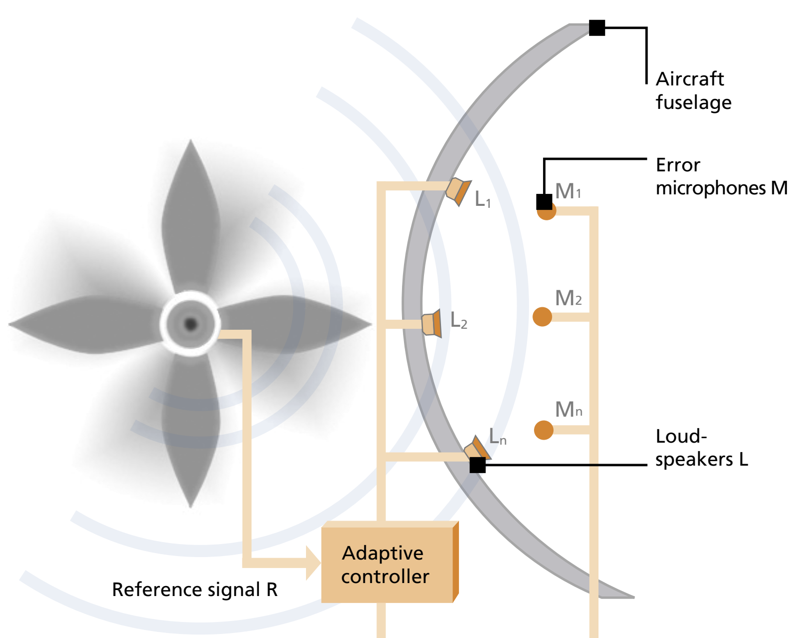
The passive noise insulation currently in widespread use employs heavy noise-damping material in the airplane's outer skin. Active noise control (ANC) has the decisive advantage over this of saving weight. No heavy material is used; instead, a counterwave cancels out the disturbance sound wave.

Active Noise Control

An ANC system basically consists of reference sensors (R), loudspeakers (L), error microphones (M) and a digital controller. Reference sensors record the reference signal, which depends on the engine speed and corresponds to the primary sound field. The controller processes this reference signal by means of adaptive filters, and returns it via the loudspeaker as a 180° phase-shifted counterwave of the same amplitude (secondary sound wave), so that the two sound waves cancel each other out. However, the counterwave is affected by various factors such as variations in air pressure and temperature. The error microphone returns these variations or "errors" to the controller as disturbance variables, and the controller recalculates the secondary sound wave. The controller has to combine robustness and adaptivity in order to react to the wide variety of effects working on the sound field. Our research work is currently concentrating on developing these control strategies, and on skillful placement of loudspeakers and error microphones.

> *"The dSPACE multiprocessor system gives us a way of developing fast controllers at a high abstraction level."*
> ***Prof. Dr. Delf Sachau***
> ***Helmut-Schmidt-University / University of the Federal Armed Forces Hamburg***

The basic structure of the control system for active noise control (ANC).



Local and Global Noise Reduction

We already ran several projects implementing experimental setups for local noise reduction, for example, as part of the aviation research program of the City of Hamburg and in a program sponsored by the Deutsche Bundesstiftung Umwelt (German Federal Environment Foundation). These projects were concerned with noise reduction in a restricted space of around one cubic meter. A current focus of our scientific work is on designing an ANC system for global noise reduction. Depending on the application, global noise reduction means preventing sound propagation to the outside or quieting a very large space, such as the entire interior of an airplane. However, global noise reduction requires a considerably greater number

▲ *Experimental setup of a loudspeaker-error microphone system for active noise reduction.*

of error microphones and loudspeakers than local noise reduction. The photo shows what an experimental concept for global active noise reduction, with relatively few error microphones and loudspeakers, could look like. By means of the loudspeaker-error microphone array, the ANC system prevents the noise from passing from the first to the second laboratory room via a sound transmission opening. No noise is perceived in the second room. As an example, the graphic shows the controller success at one of the error microphones. The frequency spectrum comprises three dominant frequencies: 1st bpf, 2nd bpf, 3rd bpf. "bpf" is the blade passing frequency, i.e., the frequency of the disturbance noise emanating from the rotor blades. The 1st bpf is the frequency at which the rotor blade tips pass the plane's fuselage.

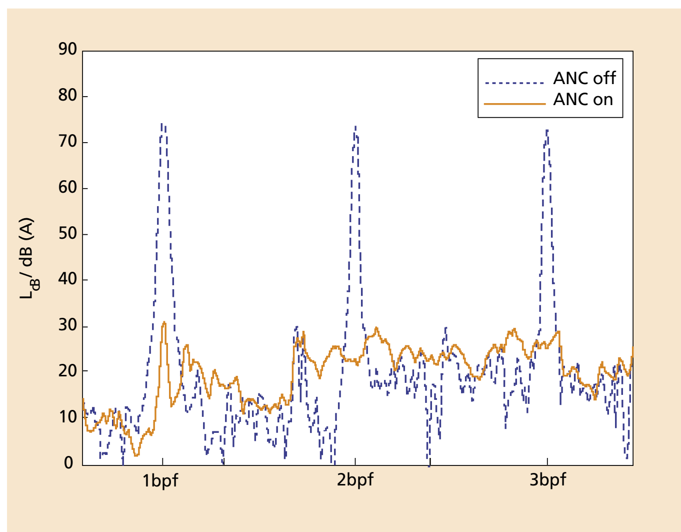
The 2nd and 3rd bpf's are both multiples of the first bpf. It can clearly be seen that the 1st, 2nd, and 3rd bpf's have almost completely disappeared from the frequency spectrum when the ANC system is switched on.

"With the modular hardware concept from dSPACE, we can tap into computing performance with virtually unrestricted scalability, and use it to develop ANC systems that can be executed in real time despite high sampling rates."

Dipl.-Ing. Kay Kochan
Helmut-Schmidt-University / University of the Federal Armed Forces Hamburg

Controller Development with the Multiprocessor System

The controller development for this ANC system is performed in the graphical development environment of MATLAB®/Simulink®. In accordance with the model-based approach to controller development, this especially shortens the time between the idea for the controller and its implementation on the processor. At the same time, this procedure guarantees transparent teamwork on controller development, even where students are involved in current research. Above all, however, errors in the algorithm can be detected very early on by means of simulation. As the number of loudspeakers and error microphones rises rapidly, so too do the requirements for computing power. dSPACE's modular hardware concept provides the necessary performance by allowing processors to run in parallel. At the moment we are implementing controllers with up to 40 error microphones, 20 loudspeakers, and one reference sensor. For error-free calculation of the secondary sound signals, we implemented 60 adaptive filters and 2400 secondary plant models in the controller. This would not have been possible without a multiprocessor system consisting of two parallel DS1005 PPC Boards and various I/O boards. With the DS1005 multiprocessor system, we are able to implement active noise reduction projects that are extremely complex in terms of control technology.



▲ *With the ANC switched on, the three blade passing frequencies (bpf) manifest noise reduction by 45 dB, 51 dB, and 47 dB to the level of background noise.*

Captain Dipl.-Ing. Kay Kochan
Prof. Dr. Delf Sachau
Helmut-Schmidt University / University of the Federal Armed Forces Hamburg
Germany