Design of a Modular Platform for Controlling Piezoelectric Ultrasonic Periodontal Scalers

Degree programme: Master of Science in Engineering | Specialisation: Electrical Engineering
Thesis advisors: Prof. Dr. Thomas Niederhauser, Diego Stutzer
Expert: Dr.Giovanni Spiezia (E.M.S. Electro Medical Systems S.A.)
Industrial partner: E.M.S. Electro Medical Systems S.A., Nyon

Piezoelectric periodontal scalers remove dental calculus and plaque during therapeutic sessions through ultrasonic vibration. However, maintaining a consistent vibration intensity during use is challenging due to altering operating conditions. The new modular platform enables the integration of dedicated feedback-control algorithms that improve the overall system performance.

Dominik Wenger
dominik.wenger@protonmail.ch

Background

Caries and periodontal disease count as the most common chronic disorders for humanity that emerge from dental plaque. Disease prevention in clinical settings involves removing plaque and its mineralized form, called calculus, with periodontal scalers. Our group has developed a novel piezoelectric ultrasonic scaler based on a planar transducer, targeting low manufacturing costs. Such devices must operate at resonance to efficiently reach the vibration intensities required for scaling. However, the device‘s characteristics, including the resonance frequency, considerably change during use due to altering operating conditions, such as varying scaling forces.

Methods

A feedback-control system must track the device‘s resonance frequency irrespective of the operating conditions and set the actuator voltage amplitude to maintain a consistent, user-settable vibration intensity, as shown in Figure 1. The system states relevant for the control system can be estimated from impedance measurements. A dedicated modular platform was developed to assist the challenging design and parametrization procedure of control algorithms by enabling tests on actual scalers in realistic settings. This platform‘s electronic hardware and software were designed, implemented, and extensively tested during this MSc thesis and preceding project works.

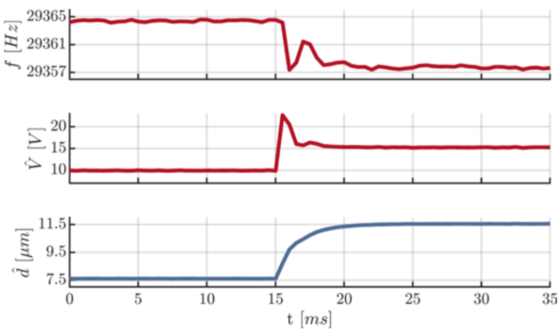

Figure 1: Recorded controller reaction (red) and displacement amplitude (blue) during a target displacement step.

Results

The final hardware setup consists of several modules interconnected by a mainboard, as shown in Figure 2. A signal generation module synthesizes a sinusoidal signal with adjustable amplitude and frequency of up to 10V and 50kHz, respectively, and connects to standard piezo amplifiers for transducer excitation. Two sense modules measure the transducer‘s driving voltage and current of up to ±200V and ±500mA at low RMS noise levels of 9mV and 28μA, respectively. Essential user interaction is enabled by an HMI module. A main processor extracts the amplitudes and phases from measurement data using an LSQ-fit algorithm, estimates the required system states, applies the control law, and updates the excitation waveform accordingly. Closed-loop sampling rates close to 10kHz could be achieved.

Discussion and Outlook

Extensive circuit analysis and careful layout led to high-quality analog front-ends showing exceptional measurement quality. Its modular architecture makes the platform broadly deployable by being highly adaptable and extendable. The written software stack was profiled to identify and resolve bottlenecks using sophisticated optimization techniques, improving the system‘s performance significantly. The new platform is a high-end system that will greatly assist the design and verification procedure of sophisticated control algorithms applied to ultrasonic devices.

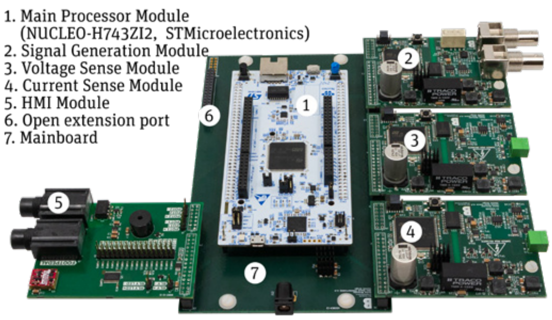

Figure 2: Hardware setup of the new modular control platform.