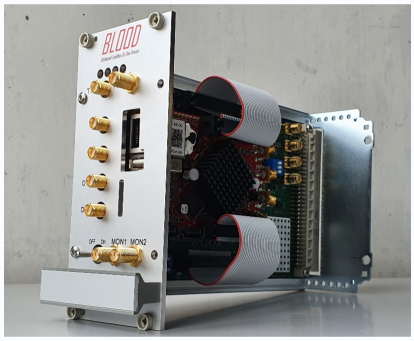
Lab Integration of Multi-Client Digital Laser Lock Box for Trapped Ion Experiments

Semester Thesis **Spring 2024**

Background

In 2022, our students developed a novel digital lock box, named BLOOD (Bichannel Lockbox On One Device), the successor to the decade-old EVIL. At its core, BLOOD is a PID controller designed to stabilize laser frequency by 'locking' it to a set value. Featuring a Red Pitaya FPGA board and a custom-designed PCB, BLOOD maintains backward compatibility with existing EVIL setups and our DEVIL client/server software. A major improvement compared to its predecessor is the capability to digitally control analog gain and offset parameters. The first prototype of BLOOD has shown promising results, successfully locking lasers in the lab. Nonetheless, further development is necessary to fully unlock its potential.



Proposal

We propose a semester project with the following main goals and expected outcomes:

- Continued development of BLOOD to ensure its readiness for regular lab use.
- Adding software support for the second channel of the device.
- Resolving existing issues to improve reliability and optimize performance.

The project will contribute significantly to our group's research and give you a great learning experience.

Recommended Skills

Desirable (but not mandatory) skills are:

- Proficiency in **C/C++** and **Python** for software development.
- Some experience with hardware design, **FPGA** development, and embedded systems.
- Familiarity with version control systems, particularly **git**.
- Basic understanding of **Linux** operating systems.

Learning Opportunities

Self-development opportunities include:

- Gaining hands-on experience in collaborative, team-based software development.
- Improving your hardware design skills, with a focus on PID implementation in FPGA.
- Learning how to find and fix bugs, and make systems work better.
- Getting familiar with Linux operating systems, including command line usage.

Timeline

The project aims for completion in one semester, starting February 2024:

Kick-off
Weeks 1-2

Initial meeting. Get familiar with BLOOD and Python-based DEVIL Client software (GUI and API). Use the example Jupyter Notebooks as tutorial. Fix minor bugs and resolve issues on GitLab. Document changes and release the updated version of DEVIL Client.

Linux OS
Week 3

Upgrade Buildroot to latest version and implement auto-generated unique hostnames for Red Pitaya. Compile and boot the new OS. Test with remote access using Linux commands (ssh, systemctl). Document changes and release the updated version of Red Pitaya OS.

Server
Weeks 4-8

Begin development on C++-based Server code to enable second channel of BLOOD. Use the server code for EVIL as example. Build the software, upload it to FPGA and debug using VS Code. Document changes and release the updated version of DEVIL Server.

Hardware
Weeks 9-12

Upgrade PyRPL FPGA project to Vivado 2023.2, resolve any timing violations. Implement a configurable PID output limiter for preventing integrator wind-up. Generate the bitstream, upload it to FPGA and test it. Document changes and release the updated version of PyRPL FPGA bitstream.

Finish
Weeks 13-14

Test the new features of BLOOD in the lab and try to lock a laser with it. Prepare the final project report, detailing the development process, challenges, solutions and future work. Update example Jupyter Notebooks if necessary.

The project's duration, estimated at 300-400 hours, is subject to variation based on the specific departmental requirements (Electrical Engineering, Physics, etc.). This timeline presents an extensive list of tasks, serving as a best-case scenario. It's understood that, given the project's scope, completing every task may not be feasible, and prioritizing key components is acceptable.

Contact

Lab:
Trapped Ion Quantum Information Group
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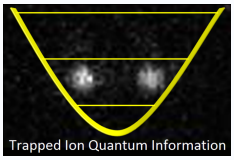

Location:
Hönggerberg Campus, HPF (E Floor)

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