CASE STUDY

Time Saved in the Race for Controlling Quantum Dot Qubits

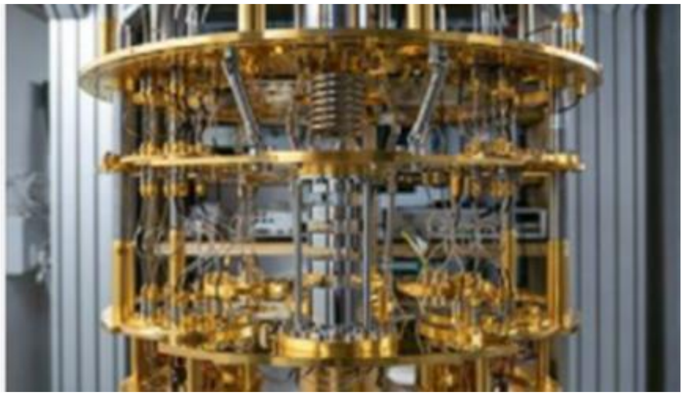
Modular instruments with hardware programmable processing accelerate the quest for Quantum computing

Keysight Expertise Helps a Researcher Stabilize Noise

Quantum technology provides the means to achieve breakthroughs in computing. The team at RIKEN's Quantum Functional System Research Group are focused on technologies to control the quantum state to process information faster with low energy consumption. To make this happen, they focus on establishing one stable qubit then scaling it up to many. In the work of stabilizing a single qubit, noise is a common challenge.

Detecting Small Changes

Researcher, Dr. Takashi Nakajima and his, team are working on ways of detecting a small charge of a single electron in a device known as a quantum dot. Existing charge sensor technologies are vulnerable to noise and need to be stabilized. Their efforts were to stabilize the charge sensor via digital proportional-integral-differential (PID)control to compensate for drift. To accomplish that, the team needed to synchronize PID control with qubit control signals. This was achieved with a Keysight Arbitrary waveform generator (AWG) that controlled the qubit device via high speed pulse signals. The processing involved needed the lowest latency possible and the team wrote their own routines in Verilog and Keysight's FPGA software.



Organization:

Dr. Nakajima, Senior Research Scientist at RIKEN Quantum Functional System Research Group

Challenges:

- Noise sensitivity
- Real-time control
- Ease of use

Solutions:

- Keysight modular AWGs and Digitizers
- PathWave FPGA

Results:

- Saved months of development time

KEYSIGHT TECHNOLOGIES

This code was synthesized down to machine language and programmed into the field programmable gate array (FPGA) running inside the AWG. This is called Hardware in the loop (HIL) where a programmer's code resides in machine hardware, and can run with the lowest latency, and deterministically, without uncertainties intrinsic to running as software in an ancillary CPU.

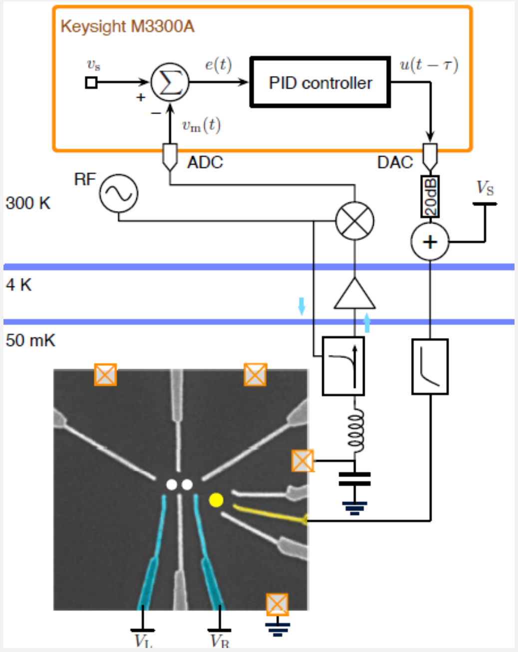


Figure 1. Schematic of the experimental setup including the Si/Si0.7Ge0.3 quantum dot

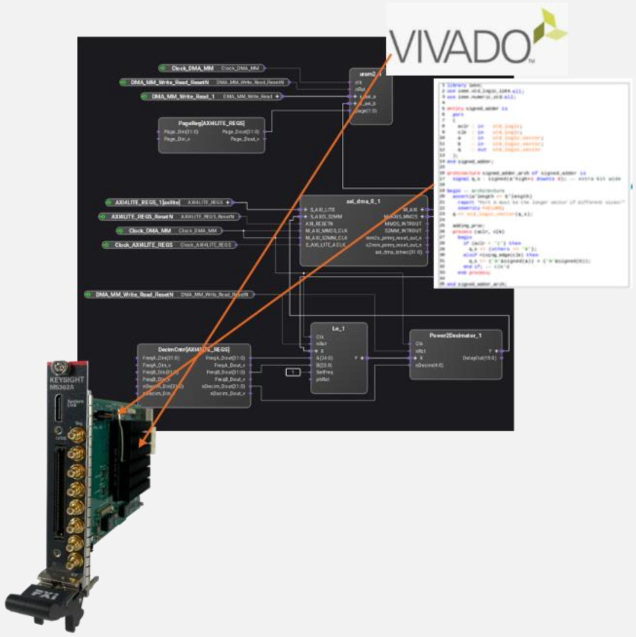


Figure 2. PathWave FPGA Source Keysight

Quick to Deploy Hardware in the Loop

The teams' earlier experiments with HIL involved a development platform from the FPGA manufacturer which they found to be complicated to program, deploy and scale. Keysight's PathWave FPGA software that complements Keysight's AWG, rapidly became the preferred platform, and still enabled them to mix IP from multiple sources, including the device manufacturer. Dr. Nakajima estimates that the team saved months by using this new approach. Dr. Nakajima found the software easy to use and was able to get started quickly and easily. When needed, Dr. Nakajima's local application engineer was able to offer assistance to further speed up the process.

Future Goals

Dr. Nakajima's team concluded that the feedback control of charge sensors is particularly useful in demanding computational tasks requiring a longer calculation time and a larger qubit system.

A next step for the team is to implement a digital down converter (DDC) in the matching Keysight digitizer, using standard blocks available in the PathWave FPGA library. This will help the team realize Quantum error correction with tight control, fast feedback and accurate measurements. From there, they expect to scale up to 10 qubits requiring 40 AWG channels.

Scaling up after proving the concept

Dr. Nakajima and his research team have taken the first step to proving out real-time control for quantum computing. Over time, the research will expand to possibly as many as 10 qubits in the next 5 years. The ability to tightly synchronize multiple channels while continuing to improve error correction is their next challenge. PathWave Test Sync Executive (KS2201A) along with PathWave FPGA can be deployed for these experiments. Test Sync Executive software enables rapid development of high-performance multi-instrument and multi-channel real-time solutions and is often used in quantum physics experiments.

Keysight's role in quantum research

Quantum technology provides the means to achieve breakthroughs in computing. The unique properties of superposition and entanglement enable previously unimagined performance in quantum applications like computing, communications, and sensing. As the quantum ecosystem continues to form, Keysight is committed to providing a full suite of solutions for the overall quantum stack. Modular solutions with PathWave FPGA software enable rapid development of the experiments and research needed to solve previously unsolvable problems.

Learn more at: www.keysight.com/find/pathwave-fpga