HOT BOX

Simulation helps cool the calibration head for the world's fastest real-time oscilloscope.

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O scilloscopes are digital instruments that display and measure the wave shape of an electrical signal. High-performance oscilloscopes, which are capable of measuring signals at very high frequencies, are used primarily in high-speed serial communications, radio frequency/radar/aerospace and high-speed physics applications.

Keysight Technologies (formerly Agilent Technologies), which bills itself as the world's premier test and measurement company, develops equipment with breakthrough capabilities that help solve tough measurement challenges. For example, the Infiniium 90000 Q-Series oscilloscope is the first to reach the 60 GHz barrier, enabling engineers to make measurements on a new generation of fiber-optic transponders and systems that provide higher levels of data communications speeds than previously possible.

As part of the design of the world's highest-bandwidth real-time oscilloscope, Keysight Technologies determined that it needed to develop a new electrical calibration source to ensure
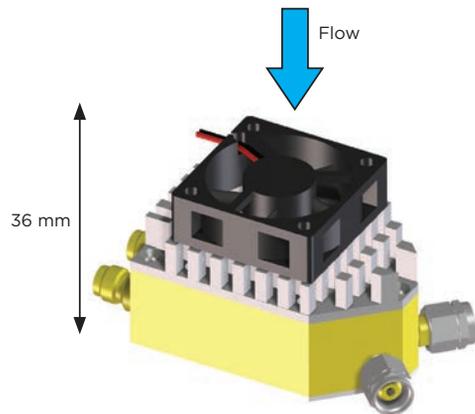
▲ Typical fan/heat exchanger configuration
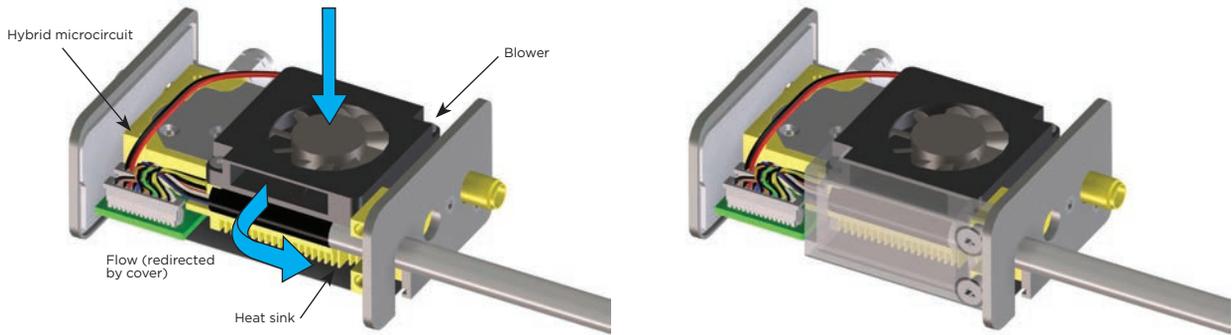
▲ **Final head design using cross flow. Image on left is without a cover; image on right shows transparent cover.**

that the oscilloscope could set a new standard for measurement accuracy. This design of the calibration source (Agilent N2806A) involved challenging electrical, mechanical and thermal requirements. Keysight utilized ANSYS CFX computational fluid dynamics (CFD) software to model the environment and produce a design that could exceed all of the requirements. Keysight delivered a first-pass success on the design and is now shipping the world's highest-bandwidth real-time oscilloscope based on this calibration technology.

The major challenge in designing the package for the calibration head was cooling. The head contains two integrated circuits (ICs) that dissipate a total of 3.2 watts within a 35-mm-wide by 42-mm-long by 15-mm-high box with 5,250 mm^2 surface area. Because of the limited size of this box, the energy released by the circuits produces a considerable temperature increase, which can adversely affect handling comfort. The packaging is built around a machined-aluminum base incorporating the heat sink and cavities for mounting the ICs. To address this cooling challenge, the engineers decided to try a cross-flow heat exchanger approach even though they had no experience with this configuration. Building physical prototypes would normally take up to eight weeks and require first-pass success with the prototypes to ensure on-time project completion. Instead, Keysight engineers turned to ANSYS CFX computational fluid dynamics (CFD) software to model and simulate the cross-flow configuration. They first performed an airflow-only analysis to determine pressure drop, then followed up with a heat-transfer analysis to determine temperature rise. The

design created with the aid of simulation worked perfectly when production parts were built.

EVALUATING ALTERNATIVE COOLING DESIGNS

Before employing simulation, Keysight engineers made a quick calculation to determine if the unit could be cooled with free convection using a formula to determine temperature rise in a package. In this case, the rise was predicted to be 86 C, much higher than the design specification of 15 C — the limit at which the device can be comfortably handled. Forced air was needed to cool the head, but what type of forced-air cooling would provide the best results? The fan/exchanger configuration that Keysight normally uses positions the fan on top of the head blowing air downward onto the heat sink and exiting around the sides of the unit. This approach requires a relatively large package height, and the connectors need to be positioned toward the edge of the unit, which was not compatible with the connector placement on the front of the instrument that the head was used to calibrate.

Keysight engineers then looked at the alternative of a blower/cross-flow heat exchanger design in which the airflow is perpendicular to the face of the heat sink. In this application, the inner walls of the case form a curved channel that directs the air around the top of the heat sink. This approach offered the advantage of reduced height requirements and enabled the connectors to be centered on one side of the calibration head. Since the wrapped flow configuration was previously

unproven, access to simulation was critical in optimizing the design. It would have taken six to eight weeks to build the physical prototype parts, and the cost of computer numerical control (CNC) programming for manufacturing would have been about 20 percent of the overall first-run cost. Consequently, a failed initial prototype design would have led to budget and schedule overruns.

Keysight engineers used simulation to evaluate design alternatives and prove out the cross-flow configuration. The team had been using ANSYS structural and thermal tools, and decided to use this project to evaluate ANSYS CFX software. CFX works within the ANSYS Workbench environment, so it shares the same interface as the structural and thermal tools that Keysight uses. Workbench also integrates well with PTC® Creo® Elements/Direct™ CAD software, which is part of the Keysight toolkit. The CFD technology also offers sophisticated meshing tools, a flexible solver and a variety of physical models, so it handles all of Keysight's fluid-flow simulation requirements.

> 🖥 **ANSYS COMPUTATIONAL FLUID DYNAMICS SOFTWARE**
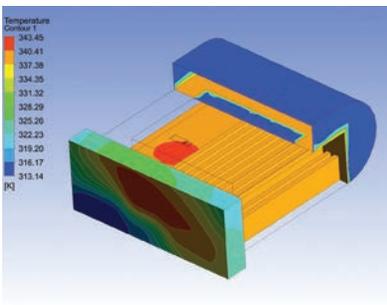> ansys.com/83CFD

SIMULATING AIRFLOW AND HEAT TRANSFER

The primary concern of the cross-flow design was that the flow rate of the blower would be reduced due to the pressure drop associated with redirecting the airflow over the heat sink. The blower manufacturer provided a fan curve showing the flow generated at any
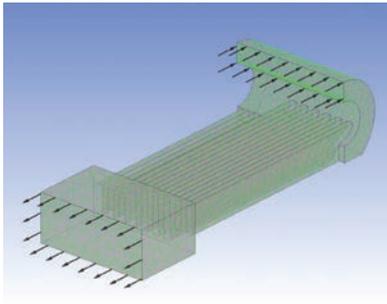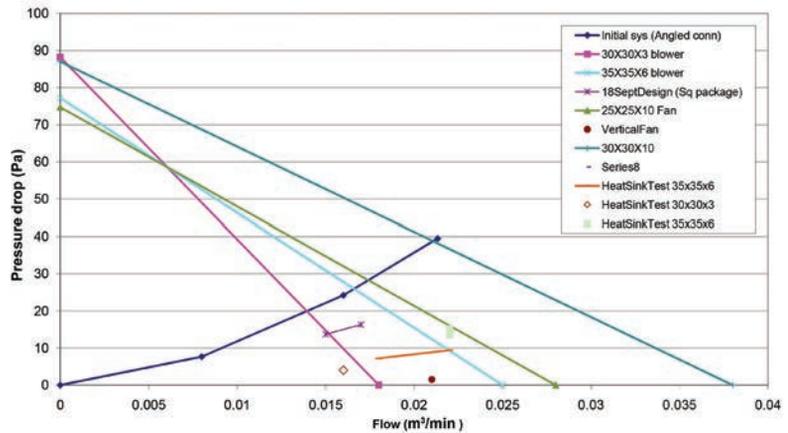
▲ Airflow-only model
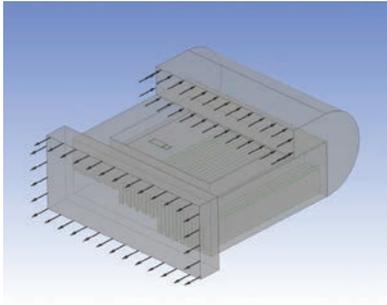
▲ Heat transfer model

▲ Heat transfer results

▲ Airflow-only model results

particular pressure drop, but the pressure drop through the calibration head was initially unknown. The team created a proposed design and used CFD to predict the pressure drop at various flow rates. They reasoned that the pressure drop could be reduced by increasing the heat exchanger channel area, so they created a second simulation model.

The team successfully produced a highly robust solution that exceeded requirements for thermal stability, signal integrity and usability.

Simulation results showed that the second configuration did indeed create less pressure drop, resulting in a higher flow rate sufficient to cool the calibration head.

To ensure that this cooling airflow would be sufficient, engineers then built a heat transfer model with 1.5 million tetrahedral elements. The ICs were configured as heat generators, and the conductivity of the housing was based on aluminum. The airflow predicted by the first simulation was used as a mass-flow input. The heat transfer simulation took about 15 minutes to solve on a personal computer; it showed that the case temperature rise was well within the 15 C design specification.

SIMULATION RESULTS MATCH EXPERIMENT

Keysight engineers went one step further by constructing a cross-flow prototype using on-hand parts. Included were a similar heat sink from another project, a blower and a plastic duct. The prototype was constructed to match the latest design configuration as closely as possible. Physical measurements showed that the heat sink rose in temperature by 9.5 C. Keysight engineers modeled the prototype

in CFX and ran a simulation to validate the simulation method. The simulation predicted a temperature rise of 9.5 C, a perfect match with the physical measurements. Minor differences in pressure drop and flow between the simulation and physical measurements were within the margin of error of the measurements. These results helped to build confidence in the simulation methodology.

The simulation results helped Keysight engineers to convince management that the cross-flow design would deliver the desired results. Brad Doerr, R&D project manager for Keysight's high-performance oscilloscopes, summarizes Keysight's experience using ANSYS CFX: "Keysight oscilloscope customers demand world-class measurement accuracy to enable emerging technologies. In producing the 90000Q family of oscilloscopes, the Keysight design team needed to develop a superior calibration source to ensure that the product could deliver the industry's highest real-time bandwidth, lowest noise and best jitter performance. In designing the N2806A calibration source, the Keysight R&D team utilized ANSYS CFX software to simulate the environment and optimize the design. As a result, the team successfully produced a highly robust solution that exceeded the requirements for thermal stability, signal integrity and usability. Success was achieved on the first prototype, and this helped Keysight become the first oscilloscope manufacturer to break the 60 GHz real-time bandwidth barrier and enable a new class of ultra-accurate high-bandwidth measurements." ∧