Analog and Mixed-Signal Circuit Design

When State of the Art Is Not Quite Enough

Purpose: When ORNL researchers, industrial partners, or colleagues from government or military agencies have a unique measurement requirement, EESG has the expertise and the experience to move the requirement from a concept to a design to implementation in a laboratory or in the field.

EESG's analog and mixed-signal circuit design capabilities effectively bridge the gap between unusual (often one-of-a-kind) sensors and the latest data acquisition and control systems in an impressive variety of R&D applications.

Complementary Capabilities: EESG analog and mixed-circuit design expertise meshes well with other EESG and MSSE strengths in the following:

- RF circuit and antenna design.
- Sensor development.
- Real-time computation.
- Programmable device applications.
- Embedded intelligence.
- Power electronics.
- Optics and image processing.
- Electronic signature analysis.
- Radiation detection and characterization.
- Nanotechnology.

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Oak Ridge National Laboratory (ORNL) researchers, because of the unique and leading-edge nature of their investigations, often encounter situations in which no commercially available instrumentation meets their measurement needs. In other cases, researchers' goals are to advance the state of the art by increasing the range, resolution, or accuracy of scientific measurements in their fields of expertise. Sometimes the sheer number of measurements required to collect all required data or to properly control an experiment precludes the use of off-the-shelf instruments.

The Electronic and Embedded Systems Group (EESG) stands ready to partner with these scientists and provide electronics development and other measurements-related capabilities that will enable their research to move forward.

Capabilities

EESG has established expertise in the following areas critical to scientific measurement, data acquisition, and control:

- Sensor-electronics integration.
- High-precision data conversion.
- Data multiplexing and telemetry.
- Low-noise signal conditioning of high-speed and low-level signals.
- High-voltage biasing and pulsing.
- Board- and system-level design.
- Electromagnetic emissions and susceptibility control.
- Efficient power conversion and distribution.
- Interfacing disparate systems.
- Built-in test and calibration.
- Wireless sensor networks.

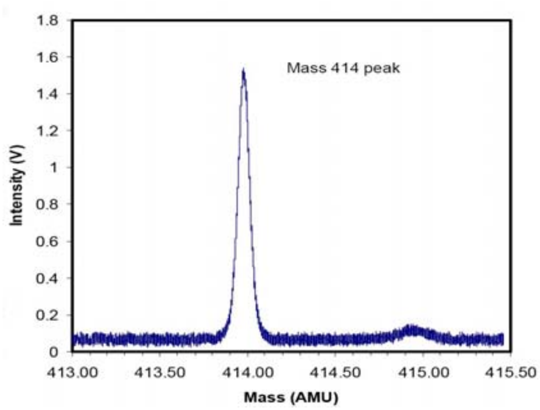
When possible, EESG engineers perform board- and system-level design using commercially available sensors, integrated circuits, modules, and subsystems to reduce cost. Other MSSE and Laboratory resources are tapped when the use of custom sensors, materials, or integrated circuits is beneficial.

Development of "front-end" circuitry such as sensor excitation and signal conditioning is accelerated by modeling with PSPICE and similar simulation packages. Modeled designs import easily into printed-circuit layout software for rapid production of prototype boards. Small quantities of circuit boards and instruments are usually built in-house. Larger quantities are usually outsourced to trusted fabrication houses.

Success Story: DDS Mass Spectrometer

Spectrometrists in the Chemical Sciences Division had a great idea: use Direct Digital Synthesis (DDS) to generate the frequencies used for exciting the electrodes in a digital ion-trap mass spectrometer. DDS would allow the frequencies to be varied in arbitrarily small steps, greatly increasing the resolution of the measurement.

The catch? To capitalize on the frequency selectivity and stability offered by the DDS approach, extremely stable high-voltage supplies, extremely fast high-voltage pulsing, and extremely low-jitter generation and distribution of the clock and switching signals were required. In addition to implementing the DDS and clock-generation algorithms in a field-programmable gate array (FPGA), EESG developed the power conditioning and high-voltage switching circuitry that completed the package. When the EESG prototype circuit board was used to replace the electronics in a modern laboratory-grade mass spec, an immediate 5× resolution improvement was realized.



Separation of the isotope peak in this segment of a DDS mass spectrum for perfluorotributylamine is clearly evident.

Another 5× increase in resolution is expected in the next generation of the DDS timing circuitry.

Success Story: Acoustic Measurements Facilities Improvement Program, Phase II (AMFIP II)

The U.S. Navy faced a dilemma: The new Seawolf class of fast-attack submarines being planned was going to be so stealthy that no existing noise-measurement sonar system would be able even to verify that the new boats met their unprecedented noise-generation specifications.

The Navy turned to ORNL for assistance, and EESG personnel, members of the Real-Time Systems Group, and industrial partner Planning Systems, Incorporated, worked together to develop the most sensitive sonar system ever deployed. Considering that the acoustic noise levels emitted by the Seawolf are considerably lower than the background noise levels even in the quietest seas on the planet, the challenge of not only detecting these emissions but of accurately measuring them over a wide bandwidth was daunting.

MSSE's Real-Time Systems Group led the effort to develop the data acquisition and analysis system based on two Cray SuperServer highly paralleled processors. EESG members took responsibility for conditioning and digitizing signals from the three 10-meter-tall, 1,000-hydrophone high-gain arrays (HGAs) and delivering them from a depth of 100 meters and over distances of up to a kilometer to the USNS Hayes, the Navy's noise analysis laboratory ship.

Every link of the signal processing chain had to be ultra-accurate to maintain the precise gain and phase relationships between hydrophone signals that allow the topside computers to form the arrays' sensitivity patterns into the narrow beams required to attenuate the ocean's background noise and to focus on specific portions of the submarine being tested.

Powering thousands of channels of electronics through kilometers of cables presented another set of challenges. The use of 300-VDC power transmission through the umbilical cables minimizes power loss in the cables but requires conversion to much lower voltages inside the underwater pressure vessels. The EESG-developed power conversion and conditioning subsystem delivers the low-noise power required for precise amplification, filtering, and digitization. It also achieves the high efficiency required for keeping the signal conditioning and data telemetry electronics cool, ensuring high reliability and long life.

For over a decade now, the AMFIP II system has been used by the Navy to ensure that our nation's submarine fleet keeps its edge by maintaining its silence.

Nighttime deployment of an HGA from the USNS Hayes.

Contact Information

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