Developing a New Product Line

CSM: *Thank you for speaking with CSM. I understand you've had a diverse background beginning in physics and astronomy. Could you describe your career path leading up to your present position?*

Matt: I became interested in physics in high school in New Jersey, which led me to MIT, where my undergraduate major was physics. Looking back, it was during this time, surrounded by really good engineering students, that I began to appreciate design work. I continued studying physics at the University of California at Berkeley, working on high-energy particle physics experiments at SLAC (Stanford Linear Accelerator Center, Menlo Park, California) and Fermilab (Fermi National Accelerator Laboratory, Batavia, Illinois). I cut my teeth in electronics at Fermilab, and I've been heavily involved in electronics design ever since. After receiving my Ph.D. in 1992, I switched to astrophysics, joining a group based at NASA's Goddard Space Flight Center (Greenbelt, Maryland) making measurements of the cosmic microwave background radiation. Our group built instruments that flew on high-altitude balloons, and the group had a tradition of building most of its own equipment.

After five years and four balloon campaigns, I was interested in doing something different. In basic research, a truly optimized experiment should fall apart shortly after the final measurements are taken. If it doesn't, then you might have spent too much time building a "gold-plated" apparatus, and you run the risk of your competition beating you to publication! I was much more interested in designing instruments that were built to last, which led me to my current position at SRS. Our research group at NASA had several of the company's products, and we were always impressed with the technical support we received. After joining the R&D department at SRS, I discovered that my path here was not at all unique since a majority of the staff were former research scientists in physics or physical chemistry.

CSM: *Did any of the projects you worked on involve control technology, and, if so, what was your role in developing the designs and implementing the systems?*

Matt: My first exposure to control systems was when I was working at SLAC. Our experiment involved sending short laser pulses out of a trailer, down a ventilation shaft into the accelerator tunnel, and into the main beam pipe, where the pulses would scatter off the high-energy electron beam. Each mirror in the laser path was instrumented with tilt actuators and optical sensors, and a slow control system kept the beam centered all the way down. A professional staff engineer from Lawrence Berkeley Lab was responsible for building that system, but as a graduate student I was involved in determining some of its performance requirements.

The first control problem I really had to tackle myself was while I was at NASA, where I was upgrading a home-built Fourier-transform infrared spectrometer. The problem was to move a somewhat massive linear stage at a uniform programmed velocity for a scan. We replaced a finicky optical interferometer with a linear encoder,

Matt Kowitt and his son Quinn, age five. Matt is employed by SRS in Sunnyvale, California, where he is project lead for SRS's new Small Instrumentation Modules product family, which includes the SIM960 Analog PID Controller.

The SIM960 Analog PID Controller is a broad-bandwidth, all-analog controller with front-panel adjustable gains and built-in anti-windup and bumpless transfer features.

along with a linear velocity transducer (LVT). My original design ran entirely in software using an early version of LabVIEW on a 1990-vintage Macintosh computer, and the results were very poor! I didn't know any control theory at the time, and so there was a lot of trial and error. I finally built an analog loop to control velocity using the LVT and left the computer to supervise this loop with slow setpoint updates to keep the velocity true to the linear encoder. That was when I learned that a few well-placed op-amps can save weeks of software headaches.

CSM: *SRS has introduced a unique product, namely, the SIM960 Analog PID Controller. How did this product originate, and what is the market?*

Matt: The original focus area for the SIM product line was instrumentation for researchers in low-temperature physics. A key element in that line was a temperature controller. We were targeting a very demanding customer group, one where noise concerns are paramount. We wanted to avoid the prospect of quantization and discretization artifacts upsetting a sensitive measurement or damaging a sample. Working together with Brian Mason, a physicist at SRS who is the design engineer directly responsible for the SIM960, we decided on an all-analog signal path. We also felt that computer control, as well as local (front-panel) control, was important in a modern instrument. The architecture that emerged uses all analog op-amps in the signal path, with parameter adjustments implemented using resistive D/A converters as programmable resistors.

We soon realized that this instrument would also have significant bandwidth and probably have interesting uses outside of temperature control. Applications that immediately came to mind include vibration control and position servos for scanning probe microscopy. As it has turned out, a popular use for the SIM960 has been stabilizing the wavelength of external cavity diode lasers. Our goal was to build an instrument that users could pick up and start using immediately without having to study a programming interface. We even put the transfer function equation on the front-panel artwork, so users can quickly understand the exact form of the control law.

CSM: *The SIM960 is advertised as having antiwindup and bumpless transfer features. Can you tell us a little about how these features were designed and implemented?*

Matt: Well, the antiwindup feature involves preventing the integral term from marching off into deep saturation whenever the loop saturates. We were sensitive to the problems of windup, including delayed recovery from saturation and potential limit oscillations, and wanted to find an approach that would work well on an analog controller. Brian had a copy of Astrom & Hagglund's book *PID Controllers: Theory, Design, and Tuning*, (1995), which has a very nice discussion of integrator windup. It was here that he found a description of the conditional integration scheme we eventually settled on. Basically, the input to the integrator is switched off whenever the output is in saturation and the sign of the error signal is "in the same direction" as the output saturation. This approach prevents the integrator from being pushed further into saturation, and was straight-forward to implement with CMOS logic and some analog comparators.

The bumpless transfer feature allows a user to switch from a manually controlled output level to the controller output without a step discontinuity. The key to making this work is the integrator stage, which has an undetermined initial value in the control equation. We take advantage of this free parameter to pre-charge the integrator to just the right value, so that the PID output starts at the manual output voltage when the switchover occurs. This way, a user can "manually fly" a plant to about where they want it, and then switch over to control without suffering a big "bump."

CSM: *Do you see future products for control applications? I was thinking, for example, of analog filters for noise reduction and antialiasing, which are needed for control experiments and prototyping, but few commercial products are available.*

Matt: Funny you should ask about filters! Our newest release of products in this line includes a programmable analog filter module, the SIM965. Briefly, this unit can be set to low-pass or high-pass as either a Bessel or Butterworth filter, with the cutoff frequency programmable from near 1 Hz to several hundred kHz, and the filter order selectable from 2-pole to 8-pole. Like the PID controller, the filter implementation is entirely analog, with continuous-time op-amp signal paths throughout. Additional modules that should be of interest to the control community are a four-input summing amplifier (where each input can be selected as inverted, noninverted, or off), a "vernier" scaling amplifier with continuously adjustable gain and input offset, and an analog limiter module with programmable upper and lower limits.

CSM: *These control-related products from SRS should be of interest to the control community for experiments and prototyping. I'm sure we'll hear about successful applications in the future. Meanwhile, thanks for talking to IEEE CSM, and we wish you and SRS the best of luck in your traditional markets as well as in control technology.*