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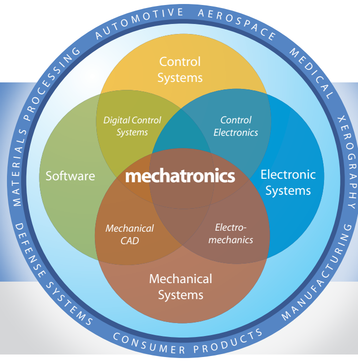
MECHATRONICS IN DESIGN

FRESH IDEAS ON INTEGRATING MECHANICAL SYSTEMS, ELECTRONICS, CONTROL SYSTEMS AND SOFTWARE



Engineering Education in Context

Engineers practice engineering in context, so why is it taught out of context?

IF A YOUNG PERSON WANTS to be a complete baseball player, he must be able to field, throw, run the bases, hit with power, and all these skills must be applied in an actual baseball game. To achieve this goal, he learns all these skills at the same time, improving gradually in each one while playing actual games and, over time, develops into a complete baseball player. The result is more than just the sum of the skills learned, but a sense of confidence and savvy that makes him a winner.

In the area of mechatronics, the necessary skill set includes modeling and analysis of multidisciplinary dynamic systems, analog and digital control systems, and sensors and actuators with the necessary electronics. Theory and practice must be in balance when mastering these skills. If "playing a game" means putting these together to create a system to solve a problem, then that rarely happens in engineering education, and if it does, it happens for only a few students who aggressively seek out that integrated, total experience. We devote separate courses to each skill and somehow think that learning each skill very well will somehow magically enable the student to graduate and critically think, integrate it all, and solve a real-world problem. In the baseball analogy, this would be utter madness, yet in engineering education, it is routine.

I am speaking from first-hand experience, as I am presently teaching a course to 60 second-year engineers called Electromechanical Engineering Systems, with 16 personal contact hours each week — 10 in studios and six in classes. There are no teaching assistants, just graders. Everything is done in the context of real-world engineering practice and problem solving.

The process works as follows, with mathematics and physics learned and applied as needed: A physical engineering system (electrical, mechanical or electromechanical) is chosen that must behave dynamically in a specified way. The system is first physically modeled with simplifying assumptions and then mathematically modeled by applying the laws of nature and appropriate component constitutive equations to the physical model. We start with a system whose model is first-order and study it from both time-domain and frequency-domain perspectives. Putting the mathematical model in a standard form (i.e., time constant, steady-state gain) allows an engineer to relate performance (e.g., speed of response, steady-state error, relative stability) to the hardware parameters in the physical model. As is often the case, the system cannot meet performance specifications operating open loop. A feedback control system is then designed and implemented. Closed-loop PI control of a first-order model results in a closed-loop differential equation that is second-order with a numerator zero. Second-order dynamic systems are introduced naturally, as part of the process, along with the effect that a real zero has on ideal second-order behavior. Again, time-domain and frequency-domain perspectives are emphasized.

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Once PI control gains are selected by a combination of pole-placement and simulation iteration, it is time to build the system. First an analog op-amp system is built with a difference amplifier and PI controller. Loading effects must be addressed, as must the limit on the control effort due to op-amp implementation. Measurements are compared to model predictions and model adjustments are made. Digital control with the Arduino microcontroller, inexpensive and open-source, is then used with the MatLab/Simulink Real-Time Workshop providing automatic code generation. Issues such as pulse-width modulation and low-pass filtering (which introduces a real pole), saturation, and A/D and D/A resolution all can be addressed in simulation and then easily in hardware implementation. Loading issues are again addressed with buffer op-amps.

In this scenario, the students are "playing the game" from the start. In past columns, I have decried engineering silos and engineer comfort zones, both in industry and academia, as the two biggest obstacles to innovation. Add this educational deficiency to that list. Let's get our heads out of the sand! **DN**

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