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Hands-on Engineering: It Works for Newbies, not Just Old-Timers!

Gary Breed
Editorial Director

Experiments are the foundation of all science and technology. Sure, mathematical analysis is always a large part of the process, but it is still derived by observation of real events. When Einstein presented theories of physical principles based on mathematical analysis alone, the scientific community was skeptical for many years, until experiments could verify his hypotheses. Today, the complex concepts of string theory, multiple dimensions and other abstract concepts are considered in the same manner. Ultimately, the math needs to be tested to make sure it works.

OK, once the math is established as correct representation of certain behaviors (or a very good approximation), we can use it as if it were the real thing. This works well for digital logic, DC circuit, and low frequency analog systems. At high frequencies, the accuracy of mathematical representations of circuits and systems are impressive and highly valuable—unfortunately, however, real-world circuits are not always as consistent and predictable as the math that is embodied in design and analysis computer software.

So we spend a lot of time refining manufacturing processes to remove the physical variability, parasitic inductance, capacitance, crosstalk and radiation that cause real circuits to differ from their simulated counterparts. The results of this work are outstanding. We have such things as complex integrated circuits that successfully go directly from simulation to a working device. We're happy that the experiment (the end product) confirmed the accuracy of the math.

But how do we learn to remove those variable parameters that would otherwise limit the accuracy of simulation? It takes an understanding of what they are, how they occur, and what it takes to eliminate them. This requires the accumulation of knowledge gained through experience, which is then applied to each particular problem. The best example I can think of is the collection of component models that are used in the most powerful high frequency simulation and analysis software. These models are not based on abstract concepts; they are the result of extensive study of actual devices—classic experimental science.

Why go through this long-winded exercise? Because too many of today's science and engineering students are skipping the experimental part of learning.

Professors tell me that they are getting the smartest students ever, but they are clueless in the lab. Even worse, there are some engineering schools that are replacing lab work with computer simulation, because computers are cheaper and require less room than lab equipment. C'mon, computer simulation is great, but it needs to be done *in addition to* the lab work!

Do you think I'm wrong or old-fashioned? Just remember those times when younger engineers were unable to determine why a circuit did not work as expected, even after hours of exploring the actual circuit and its simulation. Then one of the experienced "old" engineers hears about it, takes one look and points out the problem. Something like a small capacitor value that is not practical with the parasitic capacitance of the structure. Or maybe a glance at the spectrum analyzer display is all it takes to diagnose the problem as an enclosure resonance.

It happens all the time. This ability comes from the experience of building, testing, measuring and troubleshooting lots of circuits.

On the other hand, those experienced engineers cannot rely on experience alone. The development of products has been accelerated, and their knowledge needs a similar acceleration. Like their younger counterparts, they need a well-rounded understanding of the engineering process—as it is done today. So even the most "intuitive" designers use the powerful software tools we have at our disposal. These tools work very, very well, speeding up the design process in ways that could barely be imagined just 25 years ago.

OK, so this is one of my occasional "down to earth" engineering commentaries! But there is another reason to revisit the relationship between mathematics and reality—over-reliance on analytical methods helped create our present economic woes. Hedge funds, computerized trading and other devices claim to "beat the market" through mathematics, but they forget to balance things with real-world experience.

It doesn't take complex math to tell us that manipulating human behavior usually ends up with unpredictable results. Attitudes and emotions are not easily written into a computer program.

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