From the Editor

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"*Did you get the physics right?*" This is always a good question for our members of the IEEE Circuits and Systems Society.

Josef A. Nossek asked, "Did we, the communication and information engineers, get the physics right in our models?" during his keynote speech given at the IEEE International Symposium on Circuits and Systems in Taipei on May 25, 2009.

When Josef spoke about physically consistent modeling of communication systems in his talk "Do Communication Engineers Need Circuit Theory?", he carefully addressed this question to the audience. In the presentation, he particularly discussed the physical example that power/energy is actually determined by two port variables rather than the squared magnitude of a single variable, contrary to what many of us theoretically assumed in the past.

I think I know what happens. As more advanced mathematics is involved in our analyses and designs of various circuits and systems, the physical meanings behind the mathematical terms are easy to forget. As long as it is mathematically correct, we enjoy publishing a piece of "novel work" but often do not bother to worry about the reality of its physical implementation. Illusion usually comes from the mathematics and simulation plots that we play with on paper. They are supposedly supported by physics that we described at the beginning of the modeling process, but they are gradually lost in a sea of mathematical symbols, formulas, and equations, therefore are forgotten by the immersed researcher in the end. I often made such mistakes myself.

Many clear-minded engineers, scientists, and even mathematicians have noticed this issue already. In his talk, Josef quoted R. Kalman (2005) "First: Get the physics right! Second: The rest is mathematics!" and J. Willems (2007) "Did we, the system theorists, get the physics right? Do our basic model structures adequately translate physical reality? Does the way in which we view interconnections respect the physics?".

Indeed! As a simple example for illustration here, consider the familiar controlled Duffing circuit

$$\begin{cases} \dot{x} = y \\ \dot{y} = -ax - bx^3 - cy + p\cos(\omega t) + u, \end{cases}$$

where a, b, c, p, ω are circuit parameters and u is a controller to be determined. A circuit theorist attempting to force the oscillator state (x, y) to approach the zero equilibrium may easily "design" a controller in the form of

$$u = ax + bx^3 + cy - p\cos(\omega t) + v, \text{ with } v = -\frac{1}{4}x - y.$$

When this controller is applied to the right-hand side of the above system, it works perfectly well, since it results in a simple linear circuit

$$\begin{cases} \dot{x} = y \\ \dot{y} = -\frac{1}{4}x - y, \end{cases}$$

which has two stable eigenvalues $\lambda_1 = \lambda_2 = -1/2$. The argument is that one is allowed to use a nonlinear controller which theoretically can have any well-defined form. Well, while it is absolutely correct mathematically, this theorist has completely forgotten about the underlying physics: when he builds such a control circuit to do the job, he either needs to remove a major part of the given hardware due to the cancellation of some equation terms determined by circuit components, which often is not allowed (for example, if the given circuit is sealed inside a chip), or the control circuit is too expensive in order to cancel some dynamical effects of the given circuit (this controller is even more complicated than the given circuit, therefore as a joke he may end up with designing a Ferrari engine to drive a motorcycle in an industrial project). Of course, there are many other practical controller design methods available in the literature for the above stabilization purpose, which this circuit theorist can learn to use.

After all, circuit theory is supposed to be very practical as it is based on physics. When one proposes a

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new design, such as a communication device or a system controller, it would be wise to think twice about its physical realization, for instance whether or not it could be implemented by a circuit. Josef concluded his speech by saying "Now, after all, do communication engineers need circuit theory?—Yes, they do, if they are aiming at an optimum solution." Hereby, to address my point of discussion, I may paraphrase it as "Now, after all, do circuits and systems theorists need physics?—Yes, they do, if they are aiming at a practical solution."