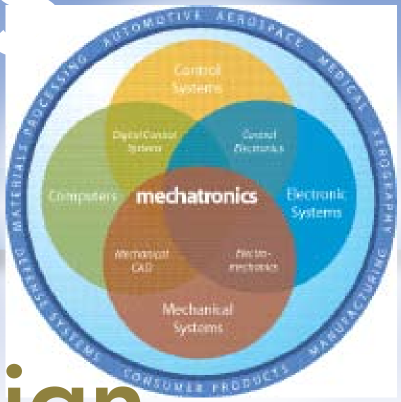
MECHATRONICS IN DESIGN

FRESH IDEAS ON INTEGRATING MECHANICAL SYSTEMS, ELECTRONICS, CONTROL SYSTEMS AND COMPUTERS IN DESIGN



Modeling: Essential Key to Mechatronics Design

BY KEVIN CRAIG

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Ask six engineers what a model is and you may get six different answers. In mechatronics, the word model carries a specific meaning, and modeling is perhaps the single most important activity in mechatronic system design.

There are two models of an actual physical system: a physical model and a mathematical model, and the distinction between them is most important. The physical model resembles an actual physical system in its salient features, but this model is also more ideal, and is thereby more amenable to analytical studies. It is a slice of reality, and in modeling dynamic systems, we use engineering judgment and simplifying assumptions to develop a physical model.

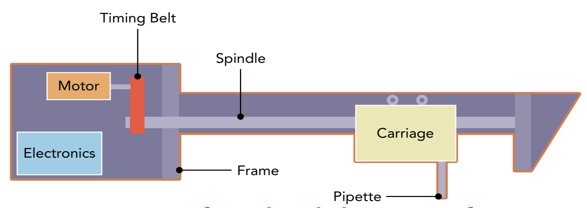

Figure 1. Concept for pick-and-place system for mounting chips on a circuit board.

The challenges of physical modeling are formidable because the dynamic behavior of many physical processes is very complex. You can choose from a hierarchy of physical models, ranging from the less-real, less-complex, more-easily solved design model to the more-real, more-complex, less-easily solved truth model. The degree of complexity depends on the particular need in your design, such as system design iteration, control system design, control design verification and physical understanding.

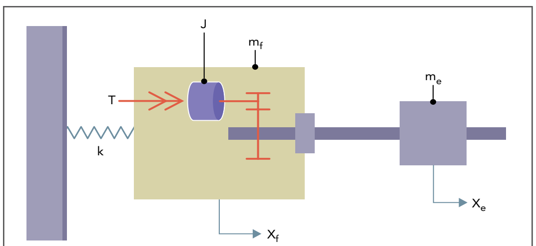

Figure 2. Low-order dynamic model of the same pick-and-place system provides reliable estimates of the dominant dynamic behavior and the attainable closed-loop bandwidth.

Always ask the question: Why am I modeling? The intelligent use of simple physical models requires that we have some understanding of what we are missing when we choose the simpler model over the more complex model. Every successful engineer needs to develop the ability to make shrewd and viable approximations that greatly simplify the system and still lead to a rapid, reasonably accurate prediction of its behavior. Once you have developed a physical model, you can apply the appropriate laws of nature — Newton's Laws, Maxwell's Equations, Conservation of Mass and Energy and the like — to the physical model to generate the mathematical model, the differential equations describing the dynamic behavior of the physical model.

In design, an engineer rarely starts with a blank sheet of paper. Designs are usually the result of the improvement of an existing system, the innovative combination of existing systems, or the application of new technology or new knowledge to an existing system. In all this, understanding what exists is paramount, and modeling is essential to that understanding. Also, once a concept has been developed in the conceptual phase of design, you can evaluate it through modeling — not by building and testing sensors, actuators and controls.

H. J. Coelingh of the University of Twente in the Netherlands gives an excellent example of the use of modeling in his concept for a pick-and-place device for mounting chips on a printed circuit board (Figure 1). To evaluate this concept, we initially neglect the motor dynamics, the compliances of the timing belt and spindle, the friction in the system and any nonlinear and parasitic effects. A low-order dynamic model (Figure 2) takes into account only the rigid-body mode and the lowest mode of vibration, in this case from the frame. With just a few parameters, this model completely describes the performance-limiting factors and provides reliable estimates of the dominant dynamic behavior and the attainable closed-loop bandwidth.

The aim of conceptual design is to obtain a feasible design for the path generator, control system and electromechanical plant with appropriate sensor locations in an integrated way.

Besides providing real understanding of the behavior of physical systems on which to base improved performance and added functionality, modeling enables an engineer to evaluate integrated design concepts early in the design process without having to build and test each one. All engineers need to embrace physical and mathematical modeling.

Learn the tricks of conceptual modeling at *Design News'* Mechatronics Zone: http://rbi.ims.ca/4946-513