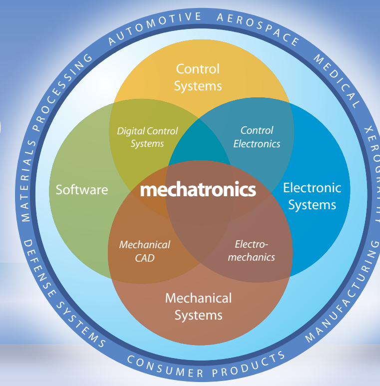
MECHATRONICS IN DESIGN

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



Mechatronic Magnetic Magic

BY KEVIN CRAIG

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The first time I dropped a strong magnet down a copper pipe, I could not believe what I saw. The magnet floating down the pipe without touching the sides, defying gravity, was magical. I just had to understand how this happens. It remains today for me the best demonstration of three of the most important laws of physics — Ampere's Law, Faraday's Law and Lenz's Law. Even though my formal education is in mechanical engineering — and in the 70s and 80s it was purely mechanical — I was drawn to things electromechanical and so I started work in mechatronics in the early 90s while at Rensselaer Polytechnic Institute. Maxwell's equations, usually unknown to ME students, took on an importance for me comparable to Newton's laws and the laws of conservation of mass and energy. The field of electrodynamics is fundamental for the practice of mechatronics and needs to be a part of every mechatronics curriculum — unfortunately, it is not.

For me at that time, the stepper motor was the epitome of mechatronics — an electro-magnetic-mechanical digital actuator energized by turning transistors on and off under open-loop control. Even closed-loop control using back-emf sensing is possible — what more could a mechatronics engineer want? The world today is full of applications for stepper motors, both rotary and linear, where speed, power and accuracy requirements are modest and cost is an issue. Higher torque density, improved step-angle accuracy, drive smoothness and miniaturization are some of the notable stepper-motor trends, along with system integration.

The essential property of the stepping motor is its ability to translate switched excitation changes into precisely defined increments of rotor position (steps). Accurate positioning of the rotor is achieved by magnetic alignment of the iron teeth of the stationary and rotating parts of the motor. The hybrid stepper motor (Figure 1, below left) is the most popular type and is the natural choice for applications requiring a small step length and high torque in a restricted working space. Windings are placed on the stator and a permanent magnet is mounted on the rotor. The rotor teeth of the two sections are completely misaligned, while the stator teeth are completely aligned.

There are typically eight stator poles and each pole has between two and six teeth. There are two windings (phases) and each winding is situated on four of the eight stator poles. The main source of magnetic flux is the rotor permanent magnet; dc currents flowing in one or both stator windings direct the flux along alternative paths.

Most motion-control systems today require high speed, accuracy and resolution, as well as robustness to system changes. Systems have time-varying and position-varying characteristics — inertia, viscous friction, nonlinear dry friction which leads to stick-slip behavior, compliances from flexible belts, couplings and shafts, and backlash from gears (Figure 2, above). Understanding and modeling these effects are essential for the mechatronic design of the system. The challenge is identifying the step-state sequence, usually in half-step operation, for a given motion profile, i.e., the times the phases should be energized to give the desired system motion. The better the model, the better the step-state sequence can be developed that is robust to system changes.

How are step motors used in your applications? How do you generate the step-state sequence for motion quality and robustness? Please let me know at kevin.craig@marquette.edu and I will share the results in a future article.

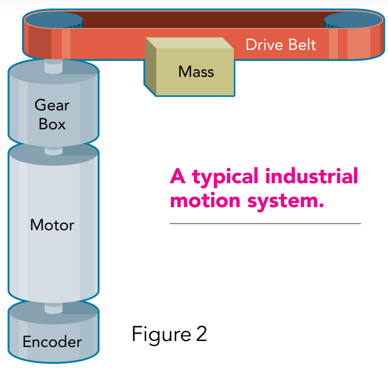
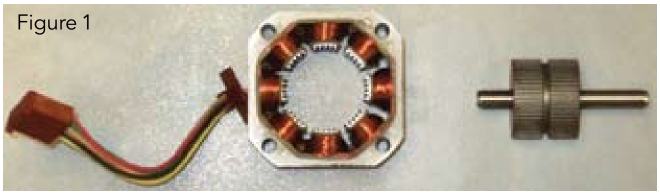


Figure 2

A typical industrial motion system.

Figure 1



A hybrid stepper motor.

The magic doesn't stop here. For more mechatronic marvels go to http://rbi.ims.ca/5721-514.