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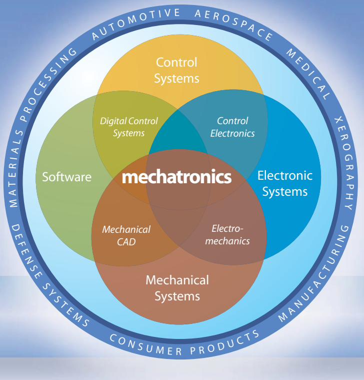
MECHATRONICS IN DESIGN

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



Isn't There Enough Real Inertia Around?

Electronic inertia through acceleration feedback improves performance

BY KEVIN CRAIG

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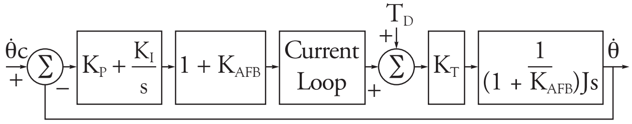
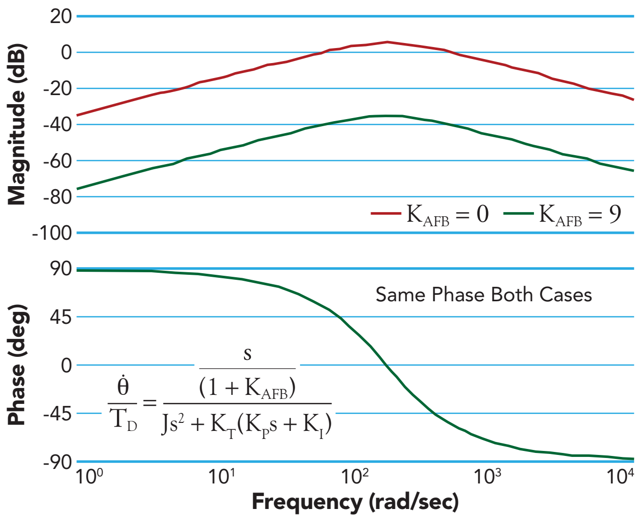
The word inertia in everyday use suggests resistance to change and an unwillingness to act. This is hardly something we need in engineering practice to solve the urgent problems we all face. Even in a motion-system context, the idea of adding inertia to a system, i.e. adding mechanical mass, is not usually desirable as it slows down system response. One familiar exception is adding a flywheel to an engine or machine to smooth out speed fluctuations. Two of the most important benefits of feedback control are command following and disturbance rejection. Usually the focus of attention in a control system is on command following, but in many situations the ability of a system to reject disturbances, i.e., have high dynamic stiffness, is paramount.

For a motor-velocity feedback control system, increasing inertia J reduces the high-frequency disturbance response, i.e. makes the system dynamically stiffer at high frequencies. But the closed-loop command-following is degraded. How do we add inertia without degrading command-following performance?

A common industry motion-control system has three cascaded feedback loops: motor current, velocity and position. Newton's 2nd Law says torque is proportional to angular acceleration, so if we can measure or estimate acceleration, we can scale the acceleration by inertia J to give units of torque, and then by 1/KT, the inverse of the motor torque constant, to give current. This is then multiplied by a gain K_{AFB}, and subtracted from the current command to the current-control loop. K_{AFB} has a similar effect to increasing inertia J; hence the alternate name electronic inertia. To ensure that the command-following performance remains the same, the velocity control gains must be scaled by the same factor $(1 + K_{AFB})$.





$$\frac{\dot{\theta}}{T_D} = \frac{\frac{s}{(1 + K_{AFB})}}{Js^2 + K_T(K_P s + K_I)}$$

The velocity command response is unaffected by the value of K_{AFB} because the loop gain increases in proportion to the inertia, producing no net effect. So why are we adding electronic inertia? The real benefit of acceleration feedback is that the disturbance response is improved by acceleration feedback through the entire frequency range in proportion to the term $(1 + K_{AFB})$, as shown by the block diagram and transfer function and frequency-response plot.

This improvement cannot be realized significantly above the bandwidth of the current loop, as the acceleration feedback signal cannot improve the system at frequencies where the current loop cannot inject current. Of course, a robust acceleration feedback signal is required. This can be accomplished through differentiation of a position sensor signal and filtering or through the use of an observer.

For mechatronics engineers, here is one situation where adding inertia is highly desirable.

In this virtual world we live in, electronic inertia is almost expected. Peter Schmidt, Rockwell Automation, and Robert Lorenz, University of Wisconsin at Madison, have done foundational work in this area and their work should be consulted.

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