Course audit

Motion control made easy

Day 5

Advanced compensation tools

Topics of discussion:
- Integrator freeze
- Low-pass filter
- Notch filter

PID filters are common in motion control. But there are additional tools, beyond PID filters, that can improve the performance of some motion systems.

Integrator freeze

Consider a system where the motor must move rapidly between two points, and the design objective is to complete the move (which includes settling time) in a minimum amount of time. Assume that you are using an ordinary PID filter.

During the deceleration phase, the motor develops a large following error. This error is, of course, integrated. As a result, once the motion is complete, the integrator output continues to produce a voltage, forcing the motor to overshoot, which prolongs the time it takes to settle the move.

The best solution here is to "freeze" the operation of the integrator whenever the motor is commanded to move. In other words, the integral would be active only during time intervals where the motor is required to stop. This provides the needed accuracy, without the unnecessary overshoot.

Low-pass filter

The behavior of a PID filter can be characterized in terms of its frequency response. A typical curve, as shown in Figure 1, reveals distinct segments, each correlating to a different PID term.

Note that the segment associated with the D term is a place where the gain increases with frequency. This is due to the nature of the derivative function, and it's likely to cause a problem in any noisy system. In fact, all high-frequency noise gets amplified by the D filter, further intensifying its damaging effect.

You can solve this problem by modifying the PID filter such that the gain curve levels off beyond a given frequency, as shown in Figure 2. Here, all you do is limit the frequency, thereby limiting the amplification of the noise. The modified compensation technique essentially amounts to a PID filter followed by a low-pass filter.

Notch filter

In many systems, the mechanical couplings between the motor, load, and sensor are not perfectly rigid, but instead act

PID filter

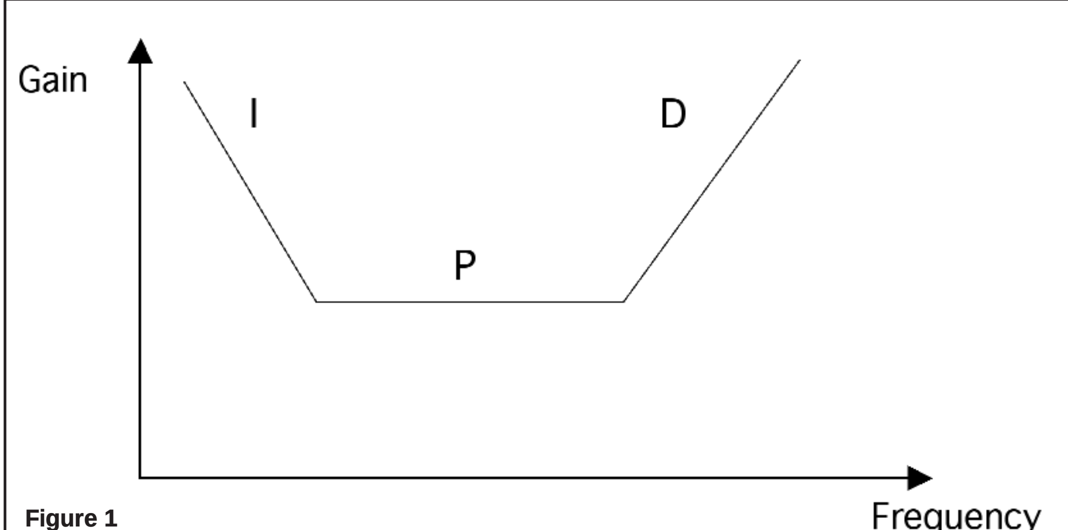

Figure 1

The frequency response of a PID filter reveals the effect of the PID elements.

Low-pass filter

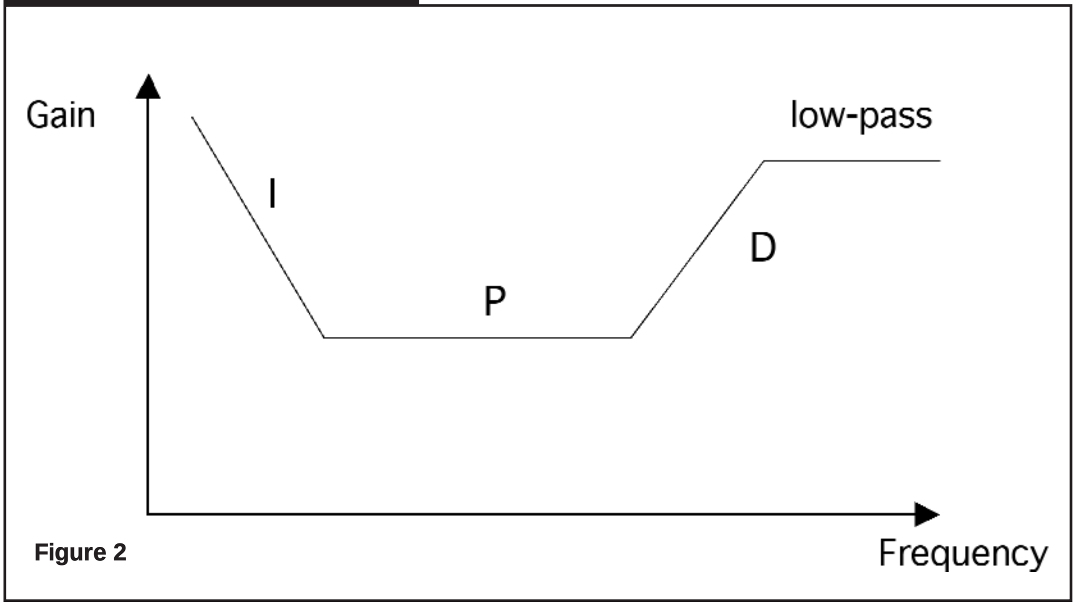

Figure 2

Adding a low-pass filter to a PID loop limits the high-frequency gain, and hence, the amplification of undesired high-frequency components.

Notch filter effect

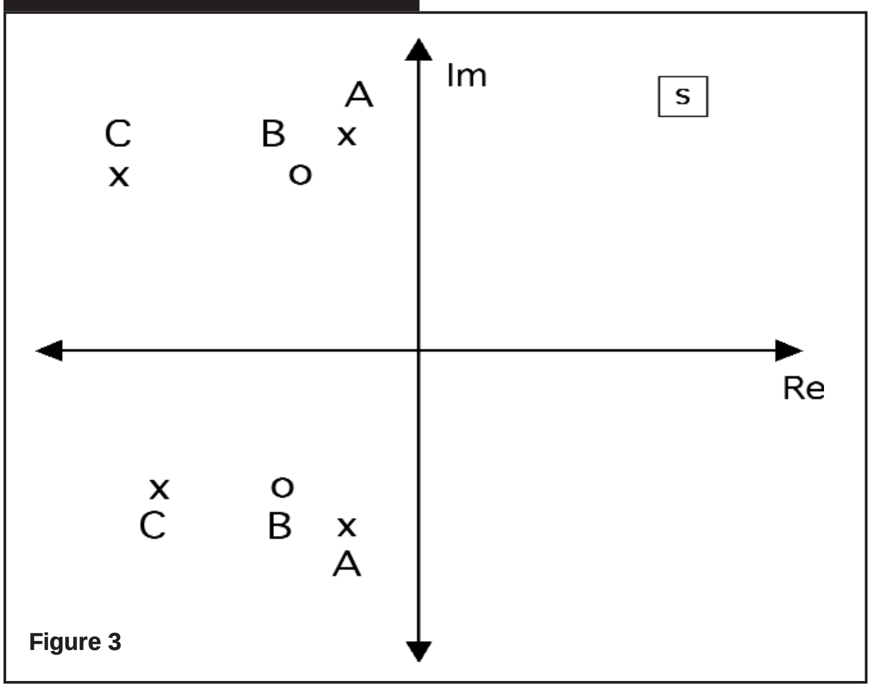

Figure 3

A notch filter compensates for torsional resonance in an electromechanical motion control system by canceling the resonance poles (A) with complex zeros (B). The poles marked "C" are the new equivalent resonance.

like springs. Here, the motor response may overshoot or even oscillate at the resonance frequency resulting in longer settling time. The most effective way to deal with this torsional resonance is by using an anti-resonance notch filter.

According to standard frequency analysis, resonance is characterized by a pair of poles in the complex frequency plane. The imaginary component indicates the resonant frequency, while the real component determines the damping level. The larger the magnitude of the real part, the greater the damping.

A notch filter consists of a pair of complex zeros and a pair of complex poles. The purpose of the complex zeros is to cancel the resonance poles. The complex poles, on the other hand, create an additional resonance. If the magnitude of the real value of the poles is large enough, it will result in a well-damped response.

A model showing what the addition of a notch filter means to the dynamic response of an electromechanical motion control system can be found in Figure 3. The diagram shows where the poles and zeros of the system are located on the s-plane. The poles marked "A" are the ones due to the mechanical resonance. These are cancelled by the complex zeros marked by "B." The poles marked "C" are the new equivalent resonance introduced by the notch filter.

Although it is assumed that the notch filter completely cancels the resonance poles, perfect cancellation is not required. As long as the notch zeros are close enough to the original poles, they can adequately reduce their effect, thereby improving system response.

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