Rational Rate

This column is the first installment of a new department in which readers are invited to submit technical questions, which will be directed to experts in the field. Please write to us about any topic, problem, or question relating to control-system technology.

The expert we called upon to inaugurate this column is Gene Franklin. Gene is the recipient of the 2005 AACC Richard E. Bellman Control Heritage Award. His acceptance speech can be found in the December 2005 issue of *IEEE Control Systems Magazine*. Gene is a faculty member in the Electrical Engineering Department of Stanford University.

Q. As my first assignment as a control engineer, my supervisor has tasked me with developing specifications for a digital control system. Do you have any advice on how I should select the sampling frequency?

Gene: In general, overall system performance and budgets press to push control engineers to set as low a sampling rate as possible. Within this environment, the following three rules guide sample rate selection:

1) Sample as fast as project managers, technology, and money permit.
2) Follow the guidelines given in standard textbooks, such as Chapter 11 of [1].
3) Select a "reasonable" rate and explore other choices by simulation.

Three major factors influenced by sample rate are aliasing, dynamic response, and disturbance rejection. Aliasing is the name given to the fact that samples from a sinusoid whose frequency is higher than half the sampling frequency are identical with samples taken from an aliased sinusoid at a frequency inside that range. As a result, the sampling rate must be sufficiently high that all frequencies of interest in the closed loop can get by a lowpass filter designed to prevent aliasing. If dynamic response is measured by the step response, a good rule is to sample at least five to ten times per rise time. This rule may be translated to conclude that the sample frequency should be at least 20 times the system bandwidth.

For disturbance rejection and stability margins, one can sketch out a design as if the system is to be continuous time and then set the sample frequency at 20 times the resulting system bandwidth. Afterwards, the design should be recomputed in the discrete domain to be sure the closed-loop poles are properly mapped. Finally, go back to step three and simulate the result since, as the saying goes, "The proof of the pudding is in the eating."

REFERENCE

[1] G.F. Franklin, J.D. Powell, and M.L. Workman, *Digital Control of Dynamic Systems*, 3rd ed. Ellis-Kagle Press, 2006. http://www.digitalcontroldynsys.com/

Hidden Meaning

It is, of course, natural for birds to surrender individual autonomy to the flock; according to the Roman ornithologist Clausio Carere, who has identified 12 basic flock patterns, the starlings are primarily trying to evade falcons. But we project onto the natural world a large measure of ourselves. In ancient Rome, augurs studied the flight patterns of birds to divine the will of the gods; part of the fascination of the starlings is the way they seem to be inscribing some sort of language in the air, if only we could read it.

A consortium of ornithologists, physicists and biologists in Italy and other European countries has in fact begun studying the birds with the aim of learning not only about the relationship of individual birds to the surrounding flock but about human behavior as well. The project, named StarFLAG, entertains hopes of using the birds to illuminate herding responses in human beings with a particular eye on stock-market panics.

— From "Flight Patterns," by Jonathan Rosen,
New York Times Magazine, pp. 61–62, April 22, 2007.