ANALOG ANGLE

RON MANCINI

Feedback made simple

"Amplifiers oscillate and oscillators amplify!" I wanted to strangle the guy who gleefully told me that. I had been assigned to fix a perennial servo problem, and the guy who had just dumped the problem on me was dispensing cheap advice. The design was weak, and servo problems cropped up every six months. I could have stopped the oscillation with a big capacitor, but at the expense of the transient response. After careful analysis, I realized that the original designer had misapplied basic feedback theory.

In the equation for the feedback diagram, A is the forward gain and β is the feedback gain (**Figure 1**). From this equation, you can quickly come to some dramatic conclusions. When the loop gain $|A\beta|>>1$, the closed loop gain, V_{OUT}/V_{IN}, approaches $1/\beta$. When β is stable and predictable, as is the case with passive components, the gain is stable and predictable. If the phase shift ever exceeds –180° and if $|A\beta|\geq 1$, the circuit oscillates.

When I tried to troubleshoot the circuit, I saw big, ugly sine waves or even uglier square waves on every node I scoped. I broke the loop in an attempt to measure Aβ, but as soon as I did, all the circuits after the transducer (which converts position information to voltage) saturated. Now I knew why I inherited this job; it was not going to be fun.

The transducer had –30° phase shift. The error op amp was saturated, so, to measure the phase shift, I put feedback resistors in the circuit to lower the gain. Was this legal? Who knows? But any linear measurement gives more information than a saturated circuit. The error amp had –135° phase shift at the oscillation frequency, but, even worse, the phase shift increased by another –15°. Then, a large error signal caused the amp to drive a large current into the load. Some filters and stray wiring capacitance added another –20°. No wonder the servo loop oscillated: The accumulated phase shift was –200° with a loop gain greater than one.

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I solved the problem by selecting a high-bandwidth op amp that could drive high-current loads with less than –115° total phase shift. This approach yielded a loop phase shift of –165°, stabilizing the system with about a 20% overshoot. I could have reduced the filter and stray-capacitance phase shift, but that would have required a board change, which management said was a no-no.

So, to design amplifiers (circuits or systems) that do not oscillate, remember the following:

- Believe me, not the data sheet. All op amps have more than –90° phase shift at the unity-gain crossover point.
- Transducers, actuators, and mechanical devices have negative phase shift.
- Driving low-impedance loads increases the amplifier's negative phase shift.
- Input-node capacitance, stray wiring capacitance, long trace lengths, and filters all add negative phase shift.

My next column will continue with feedback circuits by examining oscillators and stability.

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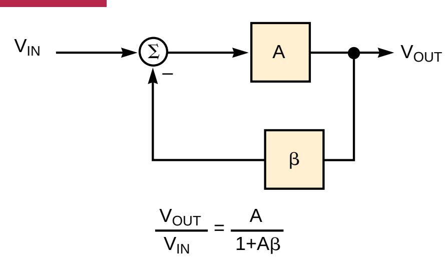
FIGURE 1



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