Bruce Trump   *Jan 22, 2013*

Low noise, low offset voltage, low drift—all the precision low-level signal processing goals get easier when you put voltage gain up front in the signal chain.

It's a simple concept. The error in the second stage is divided by the gain of the first stage, figure 1. For example, with only a modest first-stage gain of ten, the second stage could have a whopping ten-times the error or noise and it would contribute an equal error to that of the first stage. Notice that we commonly refer errors in later stages to the input (referred to input or RTI), as if all errors occur at the first input.

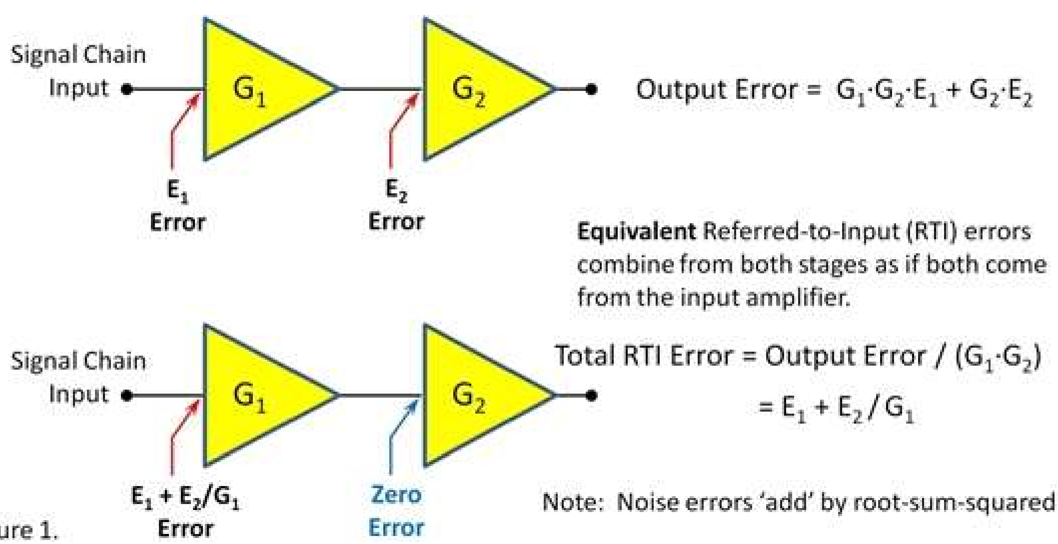

Figure 1.

But let's get philosophical. To improve your whole signal chain, **invest 10x the time and effort in the first stage**. If you acquire a clean, low noise signal in the first gain stage, subsequent stages are so much easier. Life is better!

- Start at the input terminals to your product or system. Carefully execute the path to the first amplifier with quality connectors, good wiring, good grounding and shielding. Contamination on the way to the first stage cannot be undone. Notch filters or DSP cannot fully undo the damage of AC line noise or other interference from a poorly executed path to the first stage.

Input filters may improve your performance. EOS clamps could provide a very robust input circuit. Your competitive advantage may come from an input circuit that survives in a rough environment, free from RF interference and overvoltage damage.

Use a high performance amplifier in the input stage—lower noise, lower offset voltage, lower temperature drift—whatever is important in your application. Put your money here. Use a single-channel, specialized amplifier up front if it can make a difference. You might do better with the high accuracy grade-out. Lower cost duals and quads may be adequate for later stages but don't skimp on the input amp. An instrumentation amplifier or difference amplifier could improve rejection of external noise or reduce common-mode errors.

Some designers create a "spare no expense" design to use as a reference, then value-engineer it to an acceptable performance level. This approach may give you a better awareness of the compromises.

Power supplies can be another pathway for external noise and interference. Maybe low noise LDOs for the input stage can filter external noise and improve power supply rejection. Extra supply R-C decoupling and bypassing may help.

Of course, there are cases when high performance is required in later stages, too. Extra attention to the first stage is no excuse to get sloppy in later circuitry but you get the point. The input stage is crucial. Invest the time and effort to get it right. Peace and harmony… life will be better.

Comments and opinions are welcome.

Bruce email: thesignal@list.ti.com (Email for direct communications. Comments for all, below.)

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Ken Dillinger *over 12 years ago*

I was dinged on this concept during an interview. I only knew that it is beneficial to have a higher gain block in front of a cascaded signal chain, but I did not know the technical reason why and I certainly did not know the math behind it. After the interview I scoured the web and now I know it as Frii's Formula.

MaxO *over 12 years ago*

This all make sense, now, what is the best precision InAmp out there? Let say you don't care about voltage offset since there is filtering circuitry later on, and power consumption is not a problem, so, if you only care about low-noise and high CMRR. I've been using the INA333, does anybody has another favorite?

Bruce Trump *over 12 years ago*

MaxO-- For low noise, consider the INA163 or INA103. For excellent CMRR over frequency consider the INA826. The selection of an instrumentation amp (or an op amp, for that matter) can depend on many factors specific to the application. It's probably best to get into your application details in a forum post. --Bruce