

R A Q ' s

Rarely Asked Questions

Strange but true stories from the call logs of Analog Devices

Op-Amp Noise can be Deafening Too

Q. Last month you blamed op amp noise on external resistors. Surely this is not always the case?

A. By no means. Resistor noise is a common problem, and is often overlooked, but op amps themselves can be noisy too.

An op amp has three noise sources: voltage noise (V_n) across its inputs and current noise (I_n) in series with each input.

V_n can be as low as 900 pV/√Hz for op amps with bipolar junction transistor (BJT) inputs; amplifiers with JFET inputs can have around 2 nV/√Hz, but must use large devices with large input capacitance (~20 pF). Digital CMOS is noisy, which is why early CMOS op amps had a poor reputation for noise, but modern analog CMOS processes can make op amps with noise of 6 nV/√Hz.

JFET and CMOS op amps have very low I_n , though. Some electrometer types have I_n as low as 0.1 fA/√Hz, but values in the range 10 to 50 fA/√Hz are more common. Bipolar op amps have much higher current noise — up to several pA/√Hz for wideband types.

In low impedance circuits, I_n does not matter. In high impedance circuits, on the other hand, even a small I_n will produce a large noise voltage. So, for high impedance applications, we must choose op amps with low I_n . If, however, we require very low noise, we must choose op amps with low V_n and use low impedances. In the middle impedance ranges, as we saw last month, the thermal noise of the resistors dominates.

Over most of their frequency range, op amps have white (constant spectral density) noise, but at low frequency the noise rises at 3 dB/octave from the “1/f corner frequency.” So, if low noise at low frequency is required, we must consider the 1/f corner as well as V_n and



I_n . This requires us to choose a value compatible with our operating frequencies.

When op amps were new, “popcorn noise” was a serious issue that resulted in random discrete offset shifts in a timescale of a few tens of milliseconds. This made a noise like cooking popcorn if sent to a loudspeaker. Some devices were so badly affected that, in the words of an engineer affected by the problem, “You could measure it with a frog’s leg and a stopwatch.”¹ Today, although popcorn noise can still occasionally occur during manufacturing, the phenomenon is sufficiently well understood that affected devices are detected and scrapped during test.

This is too complex a topic for a short RAQ; visit the link for a more detailed discussion.

¹ This refers to Alessandro Volta, after whom the volt is named, who in 1791 observed that electrical currents applied to the legs of a recently-killed frog made them twitch and used the phenomenon to detect electricity.

**To learn more
about noise,
Go to: <http://rbi.ims.ca/5696-125>**



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