“Noise is not cool”

By Ton Giesberts (Elektor Labs)

For the last few years we haven’t worried too much about noise in audio any more. In the past, and we mean the pre-CD era, the noise from a cassette player, record player or an FM radio was something we had to learn to live with. You had HiFi and all was well. Now that nearly everything is digital, even the picture and sound on the TV, it appears that noise for most audio designs is no longer a problem. Is noise out of fashion?

In other areas of electronics noise will continue to be a design consideration. Take the accurate conversion of a sensor signal which still requires analogue amplification, conversion and filtering, before it can be digitised.
With microphone signals, hum, noise and other interference signals are the criteria that will receive the most attention in studios or live performances. Once the recording is in a digital format the greatest problems are overcome. The problem of noise is then moved to sample frequency, the number of bits, digital operations and mixing.
With the arrival of the CD and the digital age the problems have become more complex and are harder to understand. For example, take the perennial discussion as to whether an LP sounds more faithful than a CD. The specifications of the noise in an analogue system are more informative to most people than the specifications of a digital linear phase filter. The noise of the latter is generally so low that most people will have difficulty comprehending it. The dynamic range of most modern codecs is greater than that of human hearing. Reproducing the sound pressure of a Saturn rocket at take-off (about 195 dB) is not required in our living room.

You would think that the boundary of what is necessary and useful has now been reached. In Elektor magazine, audio circuits have acquired a different position in recent years. The world of electronics these days revolves around microprocessors, FPGAs and so forth. With the exception of the revival of the LP and of valve amplifiers there seems to be little merit to be had from the familiar discrete stereo power- and pre-amplifiers from the good old days. Surround sound systems cost almost nothing nowadays and have more bells and whistles than you could ever need. In addition, most people are happy listening through cheap headphones (at levels that are much too loud) to the heavily compromised MP3 files.
But nevertheless there appears to be a revival of the ordinary stereo and so the story of noise reappears.

Noise of the oldies..

The vintage Elektor projects where a special effort was made to control the noise were mainly high end MD and MC amplifiers for record players. We also published discrete radio receivers where the noise characteristics are very important. But here too there are changes happening. Recently we published a small FM receiver (Mini FM receiver, January 2009) where the entire receiver is integrated into a single IC. With RF designs it is sometimes difficult to justify a discrete design, certainly since everything can be made so small now. The advantage of a discrete design is that there is no need to compromise on any part of the circuit — at most the total cost will be more of a determinant of the final design. An example of the latter is the MC amplifier from March 1992. Here a dual PNP transistor was used for the input stage (lower LF noise than a NPN version) to obtain as low an input noise as was possible. We now use an ordinary opamp for that (for example the TL071). To avoid any other compromises, the small capacitors that were used for the correction network were not standard polyester devices but expensive ‘styroflex’ types with polystyrene as the dielectric. For the larger values ‘MKP’ types with a polypropylene dielectric were used. The larger value polystyrene capacitors were also made by Siemens, but production has been stopped since.

Or take the symmetrical microphone amplifier from November 1997. For optimal quality the phantom voltage has to be free of ripple and the amplifier has to have low noise. At the heart of the circuit was a symmetrical audio amplifier in an 8-pin DIP package from Analog Devices (there are now pin-compatible successors such as the SSM2019 and INA217). With 1 nV/√Hz input noise (at 1000×) this is difficult to equal with a discrete design taking up the same amount of space. In the meantime even better versions have appeared. In the datasheet for the SSM2019 you can find a nice application where the noise of the microphone amplifier is calculated based on the individual noise sources: source impedance of the microphone, current noise and voltage noise of the inputs. The influence of the current noise is frequently overlooked, because it is not often found in the datasheets. Because the individual noise sources are not correlated they cannot be simply summed together but you need to take the square root of the sum of the squares. If you would like to know more about different types of noise we can recommend the article by Hameg at www.hameg.com: “What is noise?”.

The real work

From the well-known formula for noise √(4kTBR) — Boltzmann’s constant, temperature in Kelvin, bandwidth and the resistance — the noise of a resistor can be calculated. You can use this, for example, to determine how low the noise of an opamp needs to be so that the effect on the signal processing is minimal compared to the impedance of the network around the opamp. And the other way around as well, of course. Once we have selected a certain application for an opamp then we can calculate the equivalent resistance of, for example, the feedback network so that it contributes to the noise as little as possible. The noise voltage is normally expressed at a bandwidth of 1 Hz. At T = 290 K noise is then equal to

$$\sqrt{4 \times 1.38 \times 10^{-23} \times 290 \times 1 \times R} = 127 \times 10^{-12} \times \sqrt{R} \ \text{(per } \sqrt{\text{Hz}}\text{)}.$$

So a resistance of 10 kΩ theoretically produces a noise voltage of nearly 13 nV/√Hz. If we take the entire audio bandwidth then the total noise voltage becomes 1.8 µV! Depending on the output current capability of an opamp and the signal level, the resistor values in a design cannot be smaller than a certain value. Whether

The influence of current noise is frequently forgotten and is often not even shown in the datasheet.

an expensive low-noise opamp will make a difference is then easily calculated. Other specifications can be more important, such as bandwidth, slew rate or distortion. We can also quickly calculate the effect of a resistor or network on the signal-to-noise ratio of a circuit: the noise of a resistor at a temperature of 290 K and a bandwidth of 20 kHz is then 18 nV×√R.

If we wanted to design a microphone amplifier with a signal-to-noise ratio of 100 dB (with respect to 2 mV, B = 20 kHz), the total input noise would have to be less than 20 nV. This corresponds to the noise of a resistor of 1.2 Ω. In practice 20 dB less of signal-to-noise ratio will be more realistic (resistance of 120 Ω). The source impedance of the microphone is often the limiting factor.

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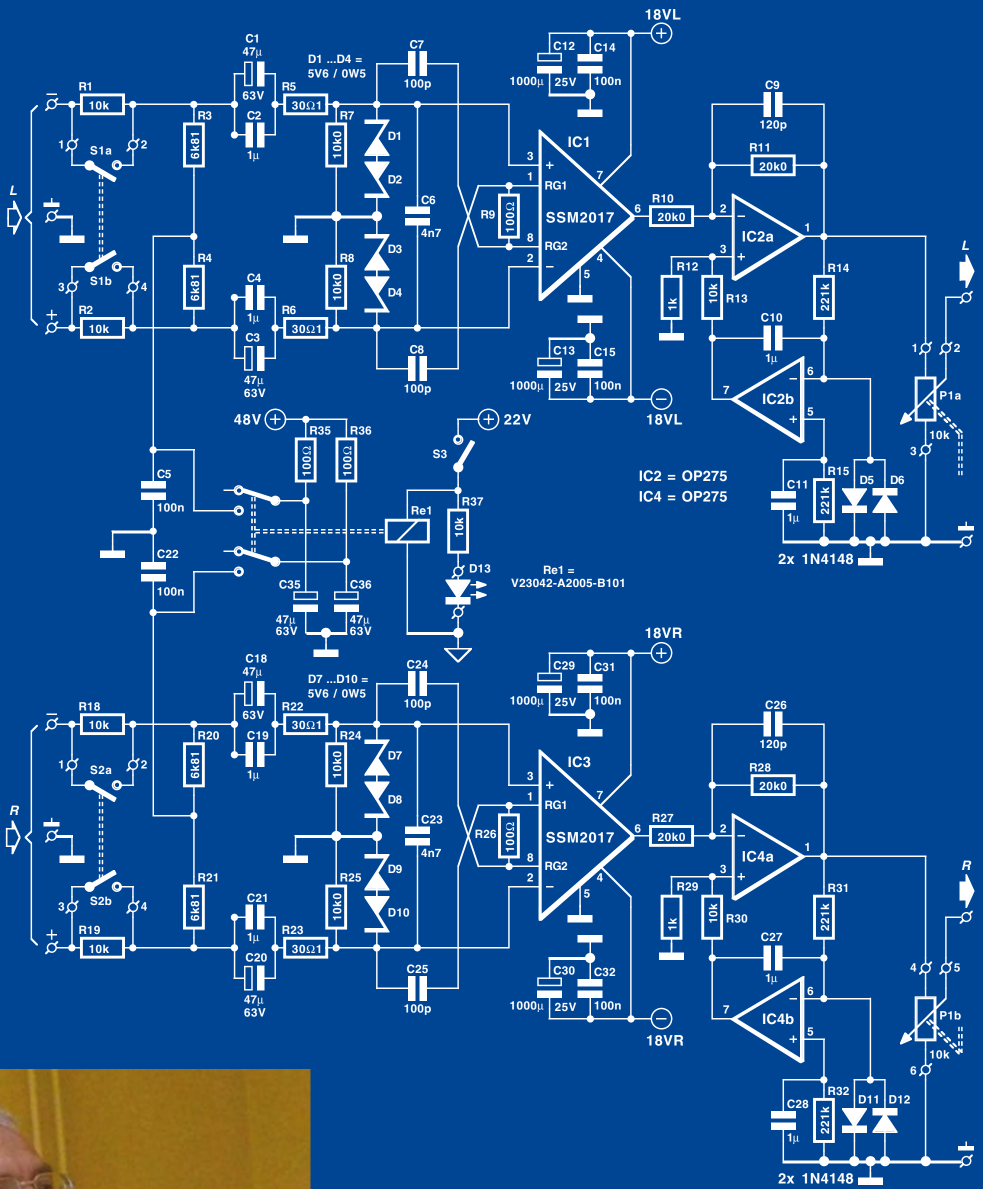

Ton Giesberts studied Electrotechnical Engineering at Heerlen Polytechnic in the Netherlands and has worked in the Elektor Labs since 1987. As a designer and a technical editor Ton's mainstay is the analogue project area. Ton's help is also called for occasionally when there's a niggling problem to solve with an RF circuit ...