Resolution, Bits, SNR and Linearity

Mike Story, Duncan McLeod and Martin Reynolds[1]

Background

The issue of resolution in a DAC, and how this ties up with SNR and linearity, sometimes causes discussion. *dCS* uses the following definitions.

Resolution and Bits

A DAC is a 24 bit device – that is, it has 24 bit resolution – if it responds to the lsb (only) changing in a 24 bit input word, for any value of the word. It is a functional specification, and is either true or false. There are no half measures.

SNR (Signal to Noise Ratio)

The signal to noise ratio of a DAC is the ratio of a rms value of a full scale sinewave input to the rms value of the output noise in the specified bandwidth. It is a performance specification, and has a value, usually expressed in dB's.

Linearity

The linearity of a device is a measure of how the output signal level varies with input signal level. For an ideal device, the output should reduce 1 dB for a 1 dB drop in input, but DACs (and ADCs) can potentially show a problem where below some level, the output does not track the input with the expected law. Care has to be taken with linearity measurements to adequately account for output noise in the output signal. There is no widely accepted way of reducing linearity to a single figure – *dCS* uses the point where the output level is 1dB different from the level expected. Linearity is a performance specification, and has a value.

Compression

Associated with linearity, but not often stated, is a Compression specification. As the signal gets larger, the output may not rise 1 dB per 1 dB increase in signal level. The points at which the output is 1dB lower than one might expect is the 1dB compression point. Generally, if compression is occurring, distortion is occurring – but this may be in an acceptable form, such as second or third order only. Loudspeakers are of this form. Compression is a performance specification and has a value.

Comments on the Terms

There is a relationship between the resolution and the SNR. If the resolution is n bits, and the input signal is a normal sinewave type signal, then the SNR ratio cannot be greater than:

$$\{n.20.\log_{10}(2)+10.\log_{10}(12/8)\}\ \text{dB}$$

This is the same as the normal rule of thumb that the SNR cannot be better in dBs than "6 times the number of bits". The second term is a correction to do with the distribution of a sinewave and Q noise distribution.

The linearity measurement is related to the noise bandwidth that the measurement is carried out in. If the SNR is less than the linearity (in dBs) then the noise bandwidth has to be reduced so that noise power does not dominate the linearity measurement. Figure 1 shows how the measurement bandwidth affects the result from an ideal device with 115 dB SNR.

[1] with *dCS* Ltd, Mull House, Great Chesterford Court, Great Chesterford, Saffron Walden, UK

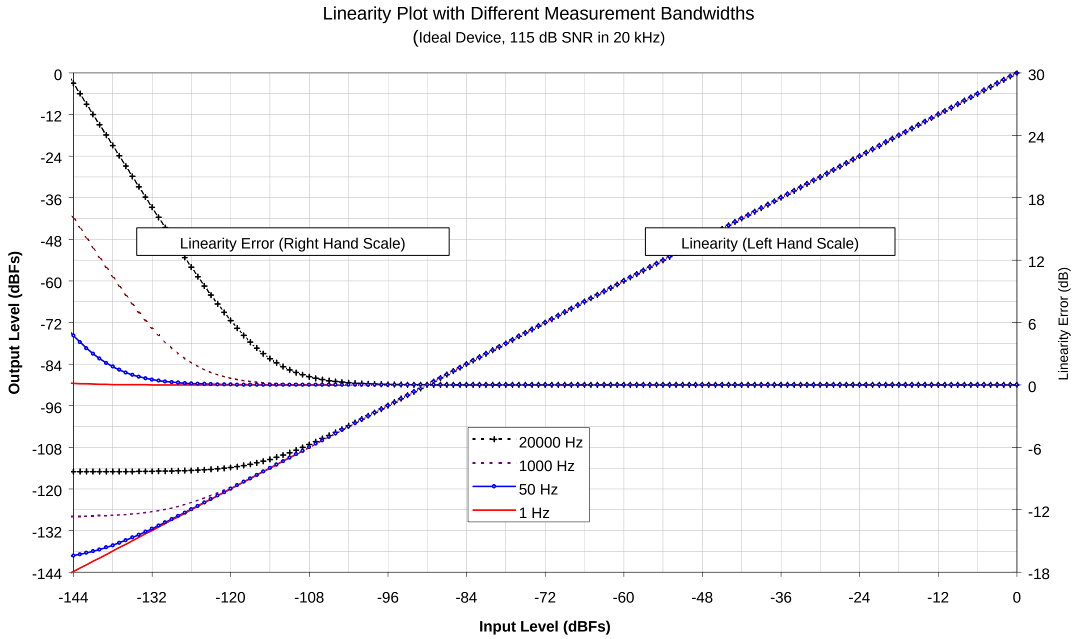

Figure 1

Figure 2 shows the lower level end of the range for the *dCS* Elgar. These measurements are not easy to make because we are dealing with very small signal levels. The test set up was a *dCS* 972 used as a (digital) signal source, feeding a *dCS* Elgar DAC. The output was then fed into a *dCS* 902D ADC operating at 48 KS/s, and an FFT used to examine the output spectrum and (effectively) obtain a very narrow band measurement. A 16384 point FFT, using a cosine^6 (H6) window function was used.

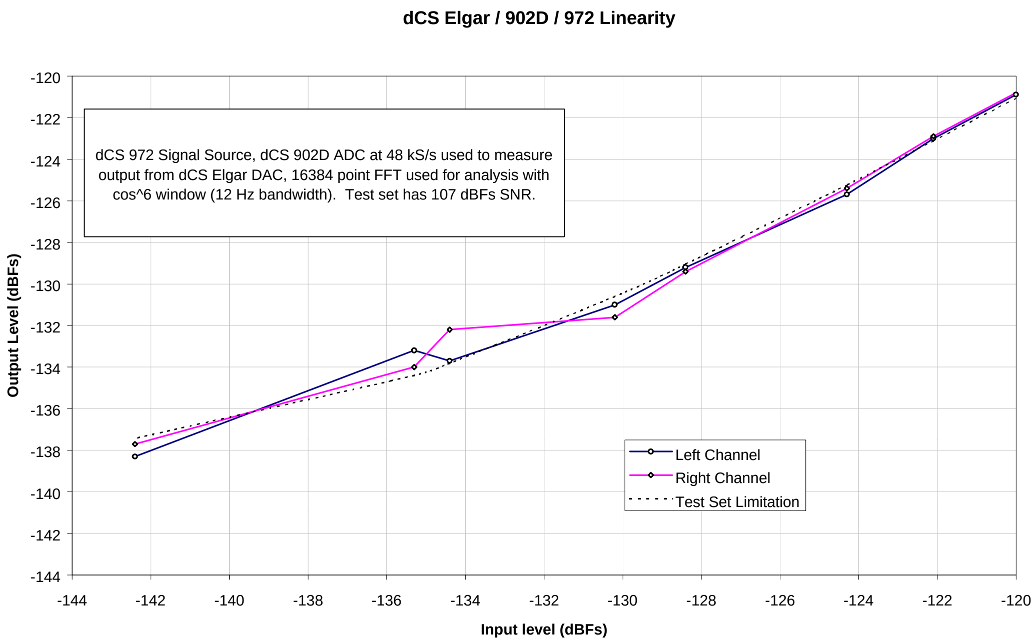

Figure 2

The window function and FFT length give a noise bandwidth of about 14 Hz, and the overall test system used had a noise floor of about –107 dB, mainly due to ADC noise and gain range mismatches. Measurements were automated (on a *dCS* 250 test system) and measurement repeatability in the area of interest was about 0.5 dB

The measured data fits well to the theoretical curve, with the possibility of one or more of the devices in the chain showing some sort of artefact at about –130 dBFs and –135 dBFs. At present we are cautious about assigning this to the Elgar – there are a number of other possibilities. These include bugs in the DSP instructions used (we have found that some DSP instructions have bugs at about the –130 dB level) and other artefacts.

What the results do show is that at the 24 bit level, the response of the overall system (including the Elgar) is still very close to the ideal expected. We are happy to refer to the Elgar as having 24 bit resolution.