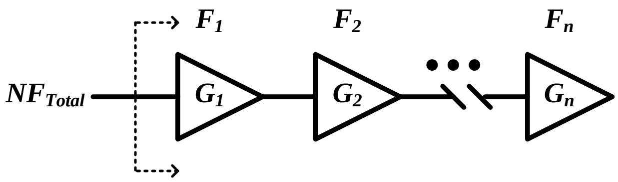
Q: Could you have someone offer me a paragraph justifying an op amp driver with noise figures of 10.5 dB (50 MHz) to 13 dB (200 MHz) for a 16-bit ADC?

A:
Traditionally noise figure (NF) is used in radio receiver link budget analysis as a convenient means to calculate the input sensitivity of a receiver. In the analysis, the noise figure is referred back to the input by dividing the linear noise figure (sometimes called noise factor or F) by the gain seen before it. In equation form:

$$NF_{Total} = 10\log_{10}\left(F_1 + \frac{(F_2 - 1)}{G_1} + \cdots + \frac{(F_n - 1)}{G_1 \times G_2 \times \cdots \times G_{n-1}}\right)$$, Where $F = 10^{\frac{NF}{10}}$

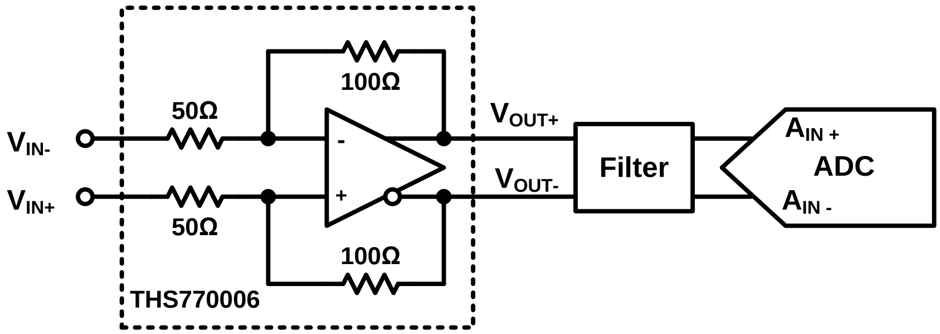


Typically an overall gain of 40dB is seen from antenna to ADC so 10dB or 13dB in the driver stage to the ADC has little effect on the overall noise figure of the radio.

Another less rigorous approach is to simply compare the noise figure of the THS77006 to the noise figure of a 16-bit ADC. The calculation of NF in an ADC varies depending on assumed input impedance, SNR, input full scale, and sampling rate, but if we use 100 ohm differential (like for the THS77006), 75dB SNR, 3Vpp input full scale, and sample rate of 100MSPS, the NF is 33dB. If we change to 200MSPS with everything else the same the NF is 30dB.

More recently designs have become increasingly ADC-centric, in terms of performance, and for noise, ADC SNR is seen as driving the selection of components, in particular the ADC drive amplifier and filter. The design goal is to minimize the impact on the published specification of the ADC.

The way we view a typical application is shown in the block diagram below, with a band limiting filter between the drive amplifier and the ADC to achieve anti-alias filtering and better SNR.



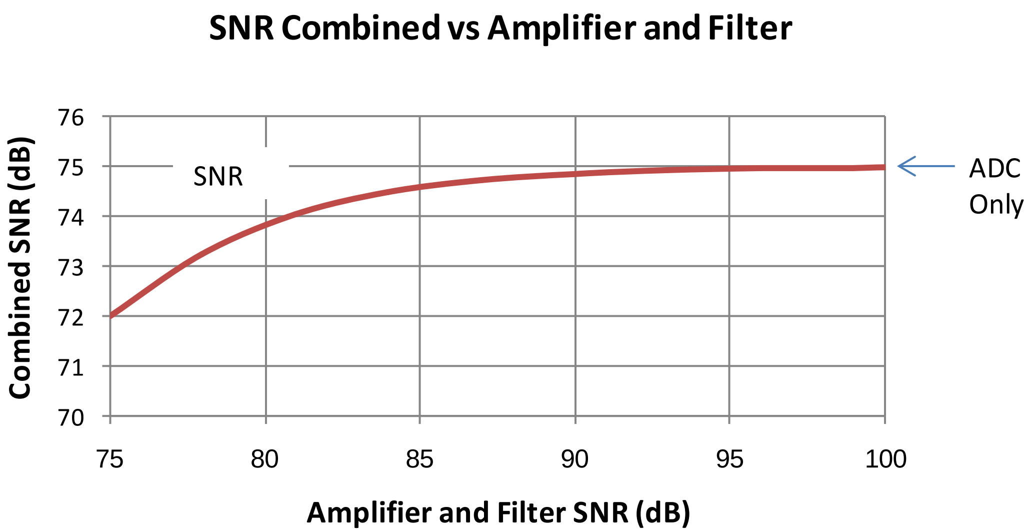
For the particular case of a 16-bit converter, SNR has been improved by not only increasing the number of bits, but also increasing the input full scale voltage of the converter. For example, the ADS5485 (16-bit, 200MSPS) specifies SNR at about 75dBFS from low frequency to over 200MHz with an input full scale of 3Vpp.

Op amps typically specify input referred spectral noise density in nV/rtHz, and to get to an SNR calculation involves first calculating the output noise based on the input noise, the gain of the amplifier, and the value of resistors used. The output spectral noise is then integrated over the bandwidth of the filter and compared to the full scale input of the ADC. In the case of the THS770006, it has internal resistors and fixed gain so we avoid some of the calculation and specify the output noise directly as 3.4nV/rtHz at lower frequency, which increases closer to 4nV/rtHz at 200MHz. The SNR is inversely proportional to the square root of the bandwidth, so higher bandwidth means lower SNR. For example: given FS input to ADC = 3Vpp, the equivalent SNR of the THS770006 is 96.8dB at 20MHz BW, 92.8dB at 50MHz BW, 89.8dB at 100MHz BW, and so on.

Noise or SNR is always added in RMS fashion like power. What this means is you convert the SNR dB values to linear values, square them, add together, take the square root of the sum, and covert back to dB. In equation form:

$$SNR_{System} = -20 \cdot \log \sqrt{\left(10^{\frac{-SNR_{ADC}}{20}}\right)^2 + \left(10^{\frac{-SNR_{Op\ Amp+Filter}}{20}}\right)^2}$$

The practical implication of this formula is that if the ADC and amplifier plus filter SNRs are equal, the overall SNR is 3dB less than the ADC. With higher SNR performance from the amplifier and filter, the SNR asymptotically approaches that of the ADC. 0.1dB degradation is achieved when the amplifier and filter are optimized for 15dB better SNR than the ADC. The graph below shows the combined SNR of an ADC with SNR=75dB versus amplifier with band limiting filter SNR from 75dB to 100dB. Since noise is well behaved from a statistical point of view, the calculation is reasonably accurate, but sample to sample variations will be seen due to the random nature of noise.



So in typical application bandwidths, the THS770006 SNR is good enough that minimal SNR degradation is seen when driving a 16-bit converter. In the applications section of the THS770006 we show interface to the yet to be released ADS5493. In the example, a 30MHz band-pass filter at 100MHz center frequency is used and the SNR result is basically the same as the preliminary specification for the ADC.