BY BONNIE BAKER

Transimpedance-amplifier-noise issues

How much noise is too much noise in a photodiode-preamplifier circuit? You can derive the noise performance of a transimpedance amplifier **(Figure 1a)** with calculations or by using a Spice simulation **(Reference 1)**. When calculating the noise performance of the circuit, consider six regions in the frequency spectrum **(Figure 1b)** and add each region with a root-sum-square equation or the following **equation (Reference 2)**:

$$V_{OUT}(NOISE_{RMS}) = \sqrt{e_1^2 + e_2^2 + e_3^2 + e_4^2 + e_5^2 + e_{RF}^2}.$$

The first five regions are equal to the multiple of the areas under the closed-loop-gain and amplifier-noise-density curves. The area under the noise-density curve in the e_1, flicker-noise (1/f), region is $V_{1/f:fB-fA} = A_N\sqrt{\ln(f_B/f_A)}$, where A_N is the amplifier's input-noise-density at 1 Hz and f_B is the corner frequency where the flicker noise tapers off. For many CMOS or FET amplifiers, the flicker-noise region usually ranges from dc to 100 or 1000 Hz. A calculation proves that the contribution to noise in this low-frequency region is relatively low:

$$e_1 = (1 + R_F / R_{PD}) \times A_N \times \sqrt{\ln(f_B / f_A)},$$

where R_F is the feedback resistor and R_{PD} is the device's parallel resistance.

In the e_2 region, multiply the broadband noise of the amplifier, the closed-loop dc-noise gain $(1+R_F/R_{PD})$, and the square root of the region's bandwidth. Again, the contributed noise in this region is usually relatively low because of its location in the lower frequency range.

$$e_2 = (1 + R_F / R_{PD}) \times e_N \times \sqrt{f_P - f_Z}.$$

Calculate the noise contribution and the e_3 region in the same manner with $f_P=1/[2\pi(R_{PD}||R_F)(C_{PD}+C_{CM}+C_{DIFF}+C_F+C_{RF})]$ and $f_Z=1/[2\pi(R_F)(C_F+C_{RF})]$.

$$e_3 = (1 + R_F / R_{PD}) \times e_N \times (1\ Hz / f_Z) \times \sqrt{f_P/3 - f_Z/3},$$

where C_{PD} is the device's capacitance and C_{DIFF} is the differential amplifier's capacitance.

The noise in regions e_4 and e_5 uses the higher-frequency gain of the closed-loop-gain curve with the value of C_1 being the parallel combination of the input capacitors, or $[C_{P-R1} || 2C_{CM} || C_{DIFF}]$, and C_2 is the parallel combination of C_F and C_{RF}

$$e_4 = (1 + C_1 / C_2) \times e_N \times \sqrt{f_{AOL} - f_P}.$$

$$e_5 = (1 + C_1 / C_2) \times e_N \times \sqrt{\pi \times (f_U - f_{AOL}) / 2}.$$

The sixth part of the noise equation, e_6, represents the noise contribution of the feedback resistor. The amplifier does not gain the contribution of noise from the feedback resistor:

$$e_6 = \sqrt{4 \times K \times T \times R_F \times (BW)},$$

where K is Boltzmann's constant, which is 1.38×10^{-23}; T is temperature in Kelvin; R_F is the feedback resistor in ohms; and BW is the bandwidth of interest.

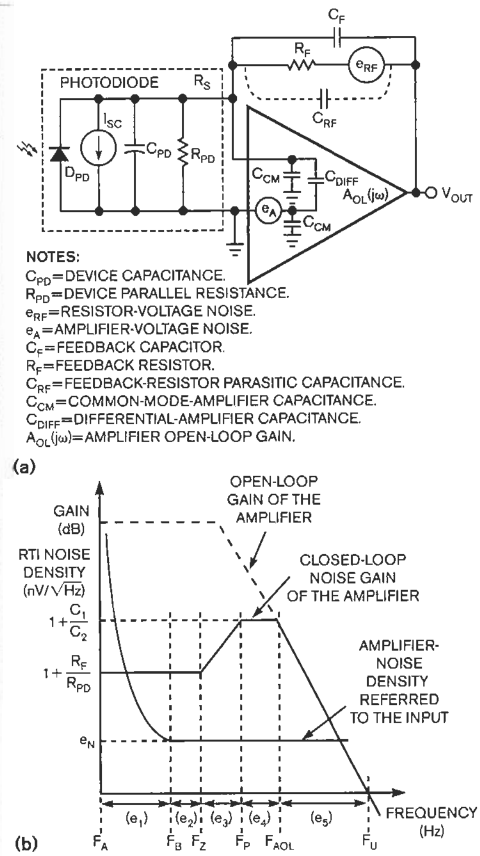

Figure 1 A typical transimpedance photo-sensing circuit (a) has five regions of overall noise response (b).

When asking how much noise is too much noise in this photodiode-preamp circuit, consider that a 12-bit system operating with a 5V input range has an LSB of 1.22 mV. The LSB for a 16-bit system with the same input-voltage range is 76.29 μV. Both LSBs are peak-to-peak numbers, and the values in this column are root-mean-square values **(Reference 3)**. EDN

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