AMPLIFIERS FOR INFRARED DETECTORS

DESCRIPTION

Amplifiers are used to amplify weak signals from low noise detectors and provide optimal conditions for detector operation. Amplifiers protect detectors against overbias and make the detector/amplifier system immune to electromagnetic interference.

VIGO offers a variety of transimpedance amplifiers, AC and DC coupled, with narrow and wide bandwidths, dedicated for integration with detectors in common packages. The transimpedance amplifiers are preferable in most applications due to inherent linearity and good frequency response.

TRANSIMPEDANCE AMPLIFIERS

The current readout of infrared detectors is typically achieved in transimpedance (TI) amplifiers. An important advantage of the TI-amp is the ability to maintain the detector at a constant bias voltage, equal to the voltage applied to the non-inverting input of the op-amp.

A simple description of the detector/TI amplifier system is presented in Figure 1.

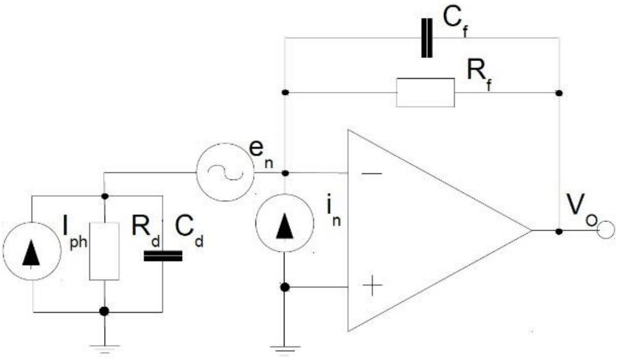

Figure 1. Transimpedance circuit for infrared detector

The detector is modeled by a photocurrent source I_{ph}, shunt resistance R_d and capacitance C_d. The photocurrent is proportional to the input optical power P and detector current responsivity R_i.

$$I_{ph}=R_i\cdot P$$

A transimpedance amplifier is an operational amplifier with feedback resistance R_f. Feedback capacitance C_f is used to set system bandwidth and eliminate gain peaking at high frequencies.

The output voltage of the transimpedance amplifier is:

$$V_0=Z_f\cdot I_{ph}$$

The transimpedance gain Z_f can be approximated by one-pole filter characteristics:

$$Z_f=R_f/(1+2\cdot\pi\cdot f)^2\cdot C_f^2\cdot R_f^2)^{1/2}$$

with cut-off frequency:

$$f_{\infty}=1/(2\pi f\cdot C_f\cdot R_f)$$

It should be noted that the cut-off frequency is typically greater compared with the voltage amplifier when bandwidth is limited by the detector $R_d\cdot C_d$ time constant. For frequencies less than the 3dB cut-off frequency f_{∞}, transimpedance is equal to the R_f. In consequence, the circuit converts linearly optical input power P into output voltage:

$$V_0=R_i\cdot R_f\cdot P$$

with resulting voltage responsivity $R_v=R_i\cdot R_f$ independent of frequency, detector resistance and capacitance.

Unfortunately, the above considerations are limited to the maximal frequencies dependent on detector capacitance and resistance, op-amp gain-bandwidth product and other factors.

NOISE

As follows from the transimpedance circuit (Figure 1) the amplifier noise current can be approximated as:

$$i_{PA}^2=4KT/R_f+i_n^2+e_n^2/Z_d^2$$

Where i_n and e_n are the op-amp open input noise current and short input noise voltage, respectively. Z_d is the detector impedance:

$$Z_d=R_d/(1+2\cdot\pi\cdot f)^2\cdot C_d^2\cdot R_d^2)^{1/2}$$

At low frequencies, amplifier noise (frequently called „floor noise level") is not dependent on frequency:

$$i_{PA}^2=4KT/R_f+i_n^2+e_n^2/R_d^2$$

At high frequencies the noise current increases due to decreasing detector impedance:

$$i_{PA}=2\pi f\cdot C_d\cdot e_n$$

Incorrect frequency compensation of transimpedance amplifier may cause a remarkable increase in the noise level near the top cut-off frequency, as shown in Figure 2.

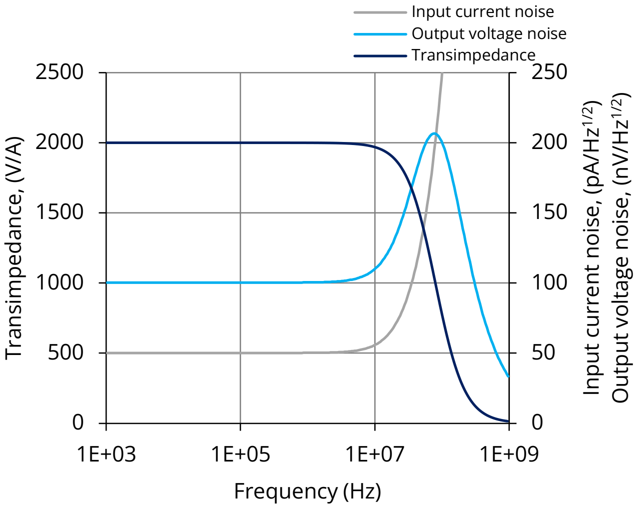

FIGURE 2. Output noise density and frequency response of the transimpedance amplifier

HOW AMPLIFIER AFFECTS THE SYSTEM PERFORMANCE

The total input current noise of a detection module is:

$$i_n^2 = i_{PA}^2 + i_d^2$$

This results in degradation of the overall detectivity of the detector/amplifier system by i_n/i_d factor.

The degradation may be significant for low impedance detectors- having low resistance <50 Ω or, at high frequencies, having large capacitance.

The design of amplifiers is dependent on required bandwidth, gain, detector resistance, capacitance and other factors. The crucial step is the selection of suitable op-amps or discrete transistors. Bipolar op-amps are characterized by large in (~2 pA/$Hz^{1/2}$) and low e_n (~1 nV/$Hz^{1/2}$), in contrast to FET-based amplifiers where in (~1 fA/$Hz^{1/2}$) is low and e_n (~5 nV/$Hz^{1/2}$) is high. Therefore, the low e_n-bipolar op-amps suit well to low Z_d detectors (which means low resistance, high capacitance and high frequencies). FET-based op-amps are useful for high Z_d detectors operating at low frequencies.