PIN'S PARAMETERS DETERMINATION

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ABSTRACT

This article deals with problems of PIN photodiode parameters measurement. The possibilities of measurement of the most important parameters are shown. An example of determination of parameters such as responsivity and NEP is shown as well. Sometimes we need to use a photodiode in a different mode, than it is written in datasheet. We can use presented method for finding parameters in required mode.

1 INTRODUCTION

The parameters of receiver are very significant for an optical link budget. The basic element of optical receiver is a photodiode (PIN or APD). The most important photodiode's parameters are noise equivalent power (*NEP*) and responsibility (R_u).

The first mentioned parameter *NEP* describes how much of noise it is introduced into the system. Voltage responsivity determines the level of electric signal at constant received optical power. We can calculate minimal level of received optical power, when the parameters mentioned above and the signal bandwidth are known.

It is possible to determine maximal received optical power, when the optical dynamic range of receiver is known. The optical and the electrical dynamic receiver's range are not the same. The relation between optical and electrical dynamic range will be shown at the end of this paper.

2 RESPONSIVITY DETERMINATIONS

The responsivity R_u can be expressed as

$$R_u = \frac{dU}{dP_r} [\mathrm{V.W^{-1}}]. \tag{1}$$

The relation between R_u and R_0 is following:

$$R_u = R_0 . R , \tag{2}$$

where R_u is voltage responsivity [V.W^{-1}], P_r is received power [W], R_0 is current responsivity [A.W^{-1}] and R denotes load resistor [Ω].

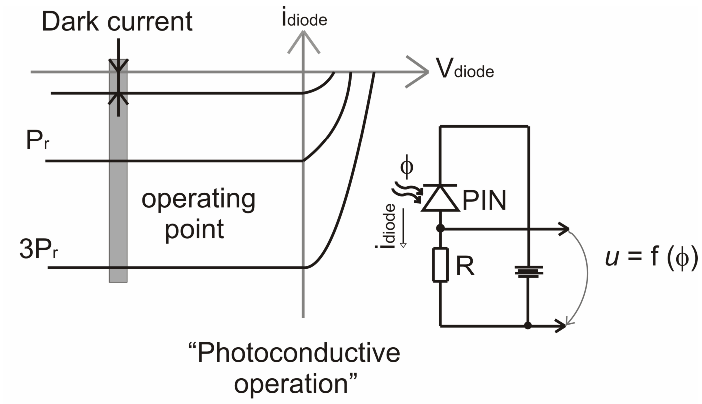

Fig. 1: *Operating region for a photodiode.*

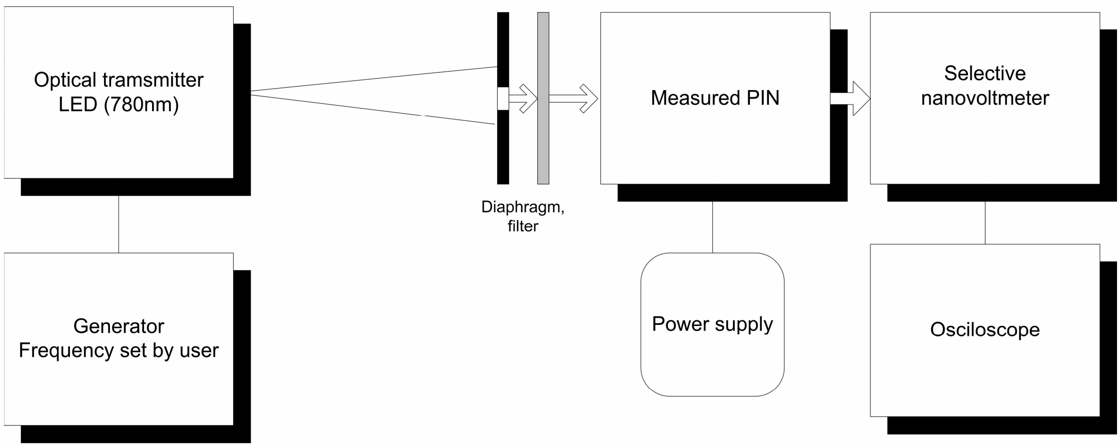

Fig. 2: *Block schema of R_u and NEP measurement.*

3 NEP DETERMINATIONS

S/N is given by equation [3] with respect to shot noise, dark current and thermal noise

$$\frac{S}{N} = \frac{R_0^2 P_r^2}{2e(R_0 P_r + I_{dark})B + 4k_B T_0 B F_t / R_1}, \tag{3}$$

where e is electric charge [C], I_{dark} dark current [A], B bandwidth [Hz], k_B Boltzmann constant [J.K^{-1}], T_0 absolute temperature [K], R_1 load resistance [Ω], F_t noise figure of the following preamplifier.

For an optical receiver, threshold sensitivity (TS) is defined by following Eq.4. For shot noise limited case (Fig.3), other sources of noise are small as compared to shot noise.

$$\frac{S}{N} = \frac{I_p^2}{2e(I_p + I_{dark})B}, \tag{4}$$

where $I_p = P_r\, R_0$.

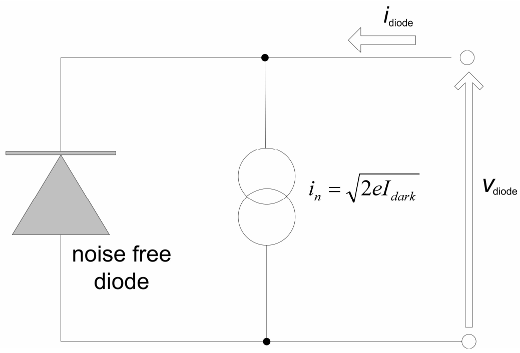

Fig. 3: *Noise equivalent model.*

When $I_p << I_{dark}$ (the terms are complied with filter attenuation)

$$TS = \frac{\sqrt{2eI_{dark}}}{R_0}\sqrt{B} = NEP.\sqrt{B}, \tag{5}$$

where

$$NEP = \frac{\sqrt{2eI_{dark}}}{R_0} \tag{6}$$

Here, *NEP* stands for *noise-equivalent power*. The *NEP* depends on frequency of the modulated signal, the bandwidth over which the noise is measured, the area of the detector and operating temperature.

Further it is possible to express *NEP* (received power respected $I_p << I_{dark}$)

$$NEP = \frac{\sqrt{2eI_{dark}}}{R_0} = \frac{\sqrt{2eI_{dark}B}}{R_0\sqrt{B}} = \frac{\sqrt{\langle i^2\rangle}}{R_0\sqrt{B}} = \frac{\sqrt{\langle u^2\rangle}}{R_0 R\sqrt{B}} = \frac{\sqrt{\langle u^2\rangle}}{R_u\sqrt{B}}[\mathrm{W.Hz}^{-1/2}] \tag{7}$$

where $\langle i^2 \rangle$ is the mean square value of signal – effect of dark current, $\sqrt{\langle u^2 \rangle}$ is the mean square value of measured signal – voltmeter (unipan 233) provides this data.

We can calculate *threshold sensitivity* (*TS*), when *NEP* and signal bandwidth *B* are known. Consecutively, it is possible to define power relations and to outline an easy power diagram. In Fig.4 there is an example of power diagram with notes. Operating area expresses power level which is required for the correct function of optical link. Margin ρ denotes power reserve. This reserve respects the quality demand of received power level.

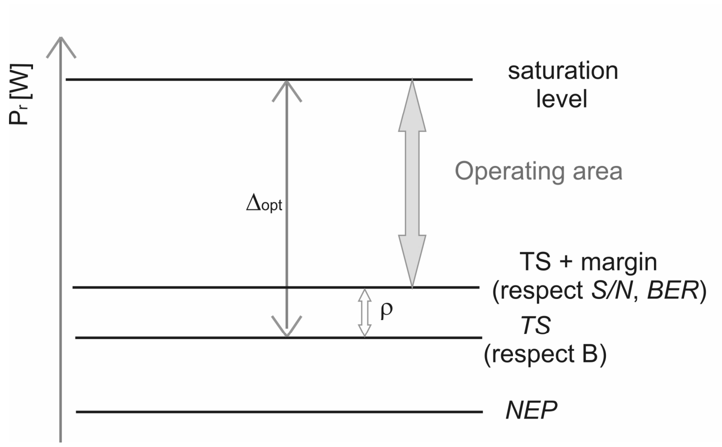

Fig. 4: *Power diagram.*

4 MEASURED DATA

Responsivity R_0 (A/W)	Active area (mm^2)	See datasheet (780 nm)	R_0(A/W)	R_U (V/W)
FDS100	13	0,5	0,5	5.10^3
FDS010	0,8	0,5	0,45	$4{,}52.10^3$
1PP75	30	NA	0,17	$1{,}68.10^3$

Tab. 1: *Responsivity of measured PIN's*

Measured with 10 kΩ load and 12 V Bias at 780 nm

NEP $\left(W/\sqrt{Hz}\right)$	See datasheet	1 kHz $(\Delta f = 20Hz)$	10 kHz $(\Delta f = 200Hz)$	100 kHz $(\Delta f = 2kHz)$
FDS100	$1{,}2.10^{-14}$	$4{,}9.\ 10^{-12}$	$2{,}8.\ 10^{-12}$	$4{,}9.\ 10^{-12}$
FDS010	$5.\ 10^{-14}$	$4{,}9.\ 10^{-12}$	$3{,}9.\ 10^{-12}$	$6{,}4.\ 10^{-12}$
1PP75	NA	$7{,}9.\ 10^{-9}$	$2{,}1.\ 10^{-12}$	$0{,}4.\ 10^{-9}$

Tab. 2: *NEP of measured PIN's*

Some PIN's parameters are not available today (e.g. 1PP75). So it is possible to measure the characteristic data. The NEP value may be distorted by the condition of measurement (the thermal noise of input circuit of voltmeter and the load resistor). We can see the NEP dependency on the mean frequency.

5 DYNAMIC RANGE DETEMINATIONS

The optical and the electrical dynamic receiver's range are not the same. This is not respected always. It is the reason for explanation.

$$\Delta_{opt} = 10\log\frac{P_{r\max}}{P_{r\min}} = 10\log P_{r\max} - 10\log P_{r\min} \quad (8)$$

$$\Delta_{el} = 20\log\frac{U_{\max}}{U_{\min}} = 20\log\frac{P_{r\max}/R_u}{P_{r\min}/R_u} = 20\log\frac{P_{r\max}}{P_{r\min}} = 2.(10\log P_{r\max} - 10\log P_{r\min}) \qquad (9)$$

Using Eq. (8) and (9) we can calculate

$$\Delta_{opt} = \frac{1}{2}\Delta_{el}\,. \qquad (10)$$

6 CONCLUSIONS

In this article, we have reviewed the parameters that are needed to design optical receiver. This paper deals with problems of measurement of PIN photodiodes' main parameters. The possibility of measurement of the most important PIN's parameters was shown. The reason is very simple. Sometimes it is needed to know NEP level at other frequency than it is written in datasheet. The difference between optical and electrical dynamic range was explained. Graphic resume of established parameters was shown at the end.

ACKNOWLEDGEMENT

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