Polaroid Optocouplers LED-phototransistor

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The applications field of the optocouplers, in the case when the user has access to the optical path of the light beam, becomes larger and larger. Polaroid optocoupler LED–phototransistor is a device in which it is introduced a system of polaroid filters, on the path of the light beam that performs the optical coupling between the transmitter and receiver modules. By introducing this system of polaroid filters, one can modify the intensity of the output current as a consequence of an axial rotation movement, of the receiver module towards the emitter module. Such a device can be used both as a mechanic-electrical transducer and as a mechanic-electrical modulator. The device is designed for applications both in the field of robotics and of mechatronix.

Keywords: Optocoupler, Phototransistor, Polaroid filters, Polaroid optocoupler, Transducer

1. Introduction

Optocouplers are optoelectronics devices whose main trait is the galvanic separation of two optically coupled electrical systems, which have different voltage.

This trait determined the use of optocouplers in different fields: in communication or data transmission [1], in medical electronics [2], in power electronics for the separation of the law power circuits from the high power circuits or for the separation of the control or signalization part from that of force [3, 4], in the nuclear spectroscopy [5].

If the user has access to the optical path of the light beam, optocouplers can accomplish different functions: some circuits' optical switching, optical filtering of the electrical signals, optical multiplexing/ demultiplexing of the electrical signals and optical detection of the electrical signals [6].

By introducing a system of polaroid filters on the path of the light beam, the output signal of the optocoupler can be modulated as a result of some relative axial rotation movements of the transmitter module (T_x) towards the receiver modules (R_x).

Such an optocoupler is named *Polaroid optocoupler*.

In this paper is presented the way in which the output current intensity of a polaroid optocoupler LED-phototransistor can be modulated, as a result of the relative rotation and the axial translation movements of the transmitter module towards the receiver module.

2. Description of the device

The Polaroid Optocoupler LED–phototransistor is an optoelectronic device of compound circuit: the transmitter, the receiver and the mechanical system, which could permit the axial assemblage of these modules' compounds, as well as their setting into action.

The transmitter module is composed of a light source and a polaroid filter P-polarizer, and the receiver module is composed of a polaroid filter A–analyzer and a phototransistor.

Polaroid optocoupler can be designed in two types: polaroid optocoupler with/without distance adjustment, (figure 1).

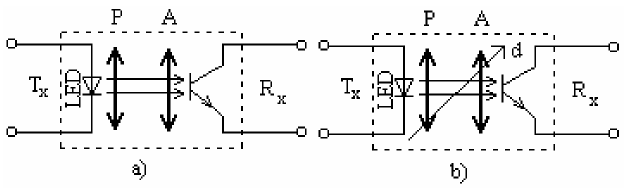

Fig.1 Polaroid optocoupler LED–phototransistor (a)without distance adjustment, (b) with distance adjustment

3. Principle of operation

If on the surface of the polarizer filter falls a light beam of (I_o) intensity (figure 2), according to Malus law, the intensity of the light beam (I) on the output of the analyzer filter will be given by the relation (1) [7],

$$I' = \frac{I_0}{2} \cdot \cos^2 \alpha \quad (1)$$

Where: α is the angle between the polarization planes of the two polaroid filters.

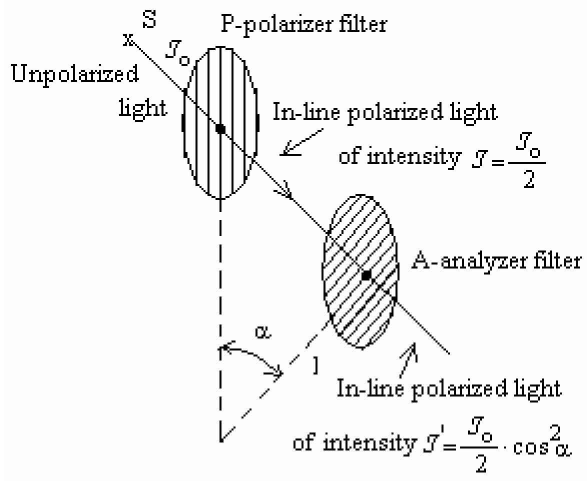

Fig. 2 Assembly of polaroid filters

<u>Observation:</u>

Relation (1) is true, when the polaroid filters are ideal (the transmission coefficient in the vibration plane is

T=1, while, in any other plane, the absorption coefficient is A=1).

Because the light beam's intensity on the output of the analyzer filter depends on the angle formed between the polarization plane of the analyzer filter and the one of the polarizer filter, for a constant value in time of the source light's light sterance, the relative rotation of the analyzer-receiver system towards the source-polarizer system will determine changes in the incident light flux on the receiver's surface [8].

This light flux change will lead to the current intensity modification on the receiver's output.

If the angle between the polarization planes of the two filters doesn't change in time, but the distance between the two systems varies, the transducer changes a translation movement into a variable electric current.

The translation movement of a system towards the other one can be used for the adjustment of the optocoupler's mechanic-electrical characteristic used for transforming the rotation movement into a variable electric current.

4. Studying the dependence of the output current intensity of the polaroid optocoupler LED–phototransistor on the dihedral angle (α) and on the distance (d) between (T_x) and (R_x) modules.

The studied optocoupler uses as transmitter a super bright white LED whose intensity on the direction of the longitudinal axis is (10365±226) mcd for a current of (19±0.01) mA, and the receiver element is a BPV 11 type Silicone NPN Phototransistor, [9].

The phototransistor functions with its basis in void. The emitter-collector voltage is 18V.

To study the dependence of the output current intensity of the LED-phototransistor polaroid optocoupler on the dihedral angle (α) and on the distance (d) between (T_x) and (R_x) modules, were taken the characteristics: $I_C=I_C(\alpha)_{d=\text{const.}}$ and $I_C = I_C(d)_{\alpha=\text{const.}}$.

The circuitry used to establish these characteristics is show in figure (3).

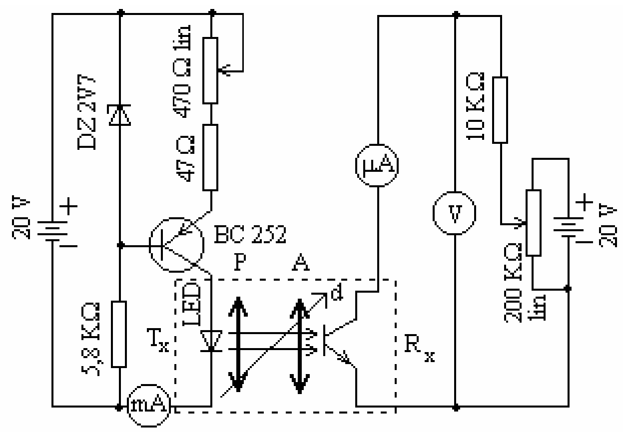

Fig. 3 Circuitry used in the study of the LED-phototransistor polaroid optocoupler with distance adjustment

The driving circuit of the LED is a constant current generator. The intensity of the current through the LED is adjusted using the linear potentiometer of resistance 470Ω.

4.1. Plotting the characteristics family $I_C=I_C(\alpha)_{d=\text{const.}}$

The characteristic $I_C=I_C(\alpha)_{d=\text{const.}}$, represents the dependence of the output current intensity of the optocoupler, on the dihedral angle (α), when the current's intensity through the LED and the distance between the transmitter and the receiver modules (d) remain constant.

Table I. Table of the output electric current's intensities of the polaroid optocoupler LED–phototransistor expressed in (μA), for different angle (α) values and distance between (T_x) and (R_x) modules.

α (DEG)	**d (mm)**					
	69.4	**82**	**92**	**102**	**112**	**122**
0	440	320	245	185	150	115
10	425	310	240	180	145	110
20	400	290	220	165	130	100
30	350	255	190	145	110	85
40	275	200	155	115	90	65
50	205	150	115	85	65	50
60	135	105	75	55	42.5	35
70	80	60	40	30	25	20
80	46	35	24	16	14.5	11
90	36	25	18	15	11	9

By graphically representing the data from table I, are obtained the characteristics family $I_C=I_C(\alpha)_{d=\text{const.}}$.

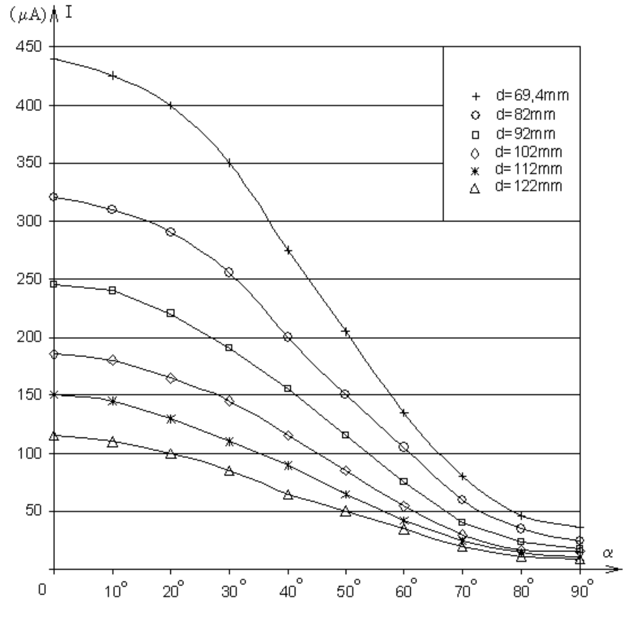

Fig. 4 Graphic representation of the characteristics family of the polaroid optocoupler LED–phototransistor, $I_C=I_C(\alpha)_{d=\text{const.}}$

4.2. Plotting the characteristics family $I_C = I_C(d)_{\alpha=\text{const.}}$

The characteristic $I_C = I_C(\alpha)_{d=const.}$, represents the dependence of the output current intensity of the polaroid optocoupler on the distance between the transmitter and the receiver modules (d) when the dihedral angle (α) and the current's intensity through the LED remain constant

For plotting the characteristics family $I_C=I_C(\alpha)_{d=const,}$ data from table I are used.

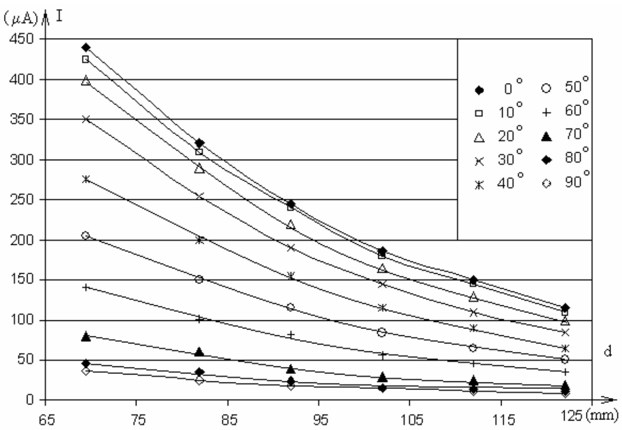

Fig. 5 Graphical representation of the characteristics family $I_C = I_C(\alpha)_{d=const.}$

4.3 Interpretation of the LED–phototransistor polaroid optocoupler's $I_C=I_C(\alpha)_{d=const.}$ and $I_C=I_C(d)_{\alpha=const}$ characteristics.

In figure 6, is presented the light characteristics family $I_C= I_C(E_V)_{V=const.}$ of the BVP 11 phototransistor.

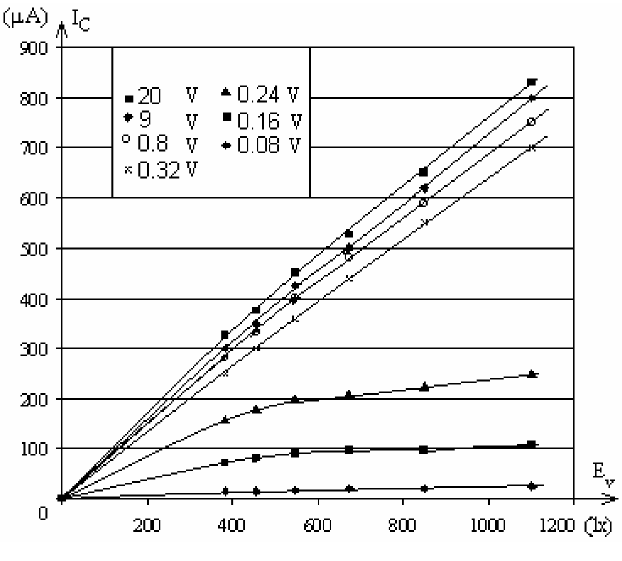

Fig. 6 The characteristics family $I_C = I_C(E_V)_{V=const.}$, of the BPV 11 type NPN Phototransistor.

From figure 6 one can notice that, in the case when the emitter-collector voltage of the BPV11 phototransistor is 18 V, the characteristic $I_C = I_C(E_V)_{V=const.}$ is described by a function like:

$$I_C = C_1 \cdot (E_v)^a = C \cdot \left(\frac{I_v}{d^2}\right)^a \qquad (2)$$

where: C_1 – a proportionality constant, E_V – light illumination, I_V – light intensity, d – the distance between (T_x) and (R_x) modules, and „a" is a parameter, a < 1, but very close to the unit.

In practice, this relation can be used if "the rule of the ten diameters" is fulfilled (detector's diameters must be ten times smaller than the distance (d) between the source and the detector).

Measurements errors obtained in this case are smaller than 1%.

Knowing that the light intensity is proportional with the intensity of the light beam which falls on the photosensitive surface of the phototransistor, from relations (1) and (2) results:

$$I_C = C \cdot \frac{\cos^{2a}\alpha}{d^{2a}} \qquad (3)$$

where C is a proportionality constant specific to the optocoupler.

As the polaroid filters aren't ideal, the emergent light flux is different from zero even, in the case when the polarization planes of the two filters are perpendicular between them.

In this case, relation (3) becomes;

$$I_C = C \cdot \frac{\cos^{2a}\alpha + f}{d^{2a}} \qquad (4)$$

where (f) represents the fraction of the light beam's intensity falling on the analyzer filter and manages to pass through it in case of extinction.

When the distance between (T_x) and (R_x) modules is constant, relation (4) can be written as:

$$I_C = C_2 \cdot \left(\cos^{2a}\alpha + f\right) \qquad (5)$$

where C_2 is constant.

Relation (5) is a function in the from $I_C=I_C(\alpha)_{d=const.}$.

This function is maximum in the point α = 0°and it has a minimum value in the point α = 90° and presents a point of inflexion for (α) value given by expression (6):

$$tg\alpha_i = \frac{1}{\sqrt{2a-1}} \qquad (6)$$

If the distance between (T_x) and (R_x) modules is modified and the dihedral angle (α) remains constant, relation (4) can be written as:

$$I_C = \frac{C_3}{d^{2a}} \qquad (7)$$

where C_3 is constant.

From relation (7) can be noticed that function $I_C=I_C(\alpha)_{d=const.}$ doesn't present points of extreme or inflexion. If $d \to \infty$, $I_C \to 0$ and if $d \to 0$, $I_C \to \infty$.

This dependence represented on the interval $d \in [69{,}4mm, 122mm]$, can be noticed in the graphic from figure (5).

4.4 Graphical representation of the theoretical characteristics of the polaroid optocouplers LED-phototransistor $I_C = I_C(\alpha)_{d=const.}$

In order to graphically represent function (4), one must determine the values of constants (C) and (f).

Although these constants are determined for one of the characteristics family of the polaroid optocoupler

LED–phototransistor, their value is the same for the whole characteristics family.

To determine the values of constants (C) and (f), one particularizes equation (4) for values of angle (α) of 0° and 90°, when the distance between (T_x) and (R_x) modules is d=102 mm.

By calculating, relation (4) becomes:

$$I_C = 1734 \frac{mA}{mm^2} \cdot \frac{\cos^{2a}\alpha + 0,09}{d^{2a}} \quad (8)$$

In figure (7) a graphical representation of relation (8) is rendered.

For comparison with experimental data, in these graphics are also presented the points corresponding to the characteristics family $I_C = I_C(\alpha)_{d=const.}$.

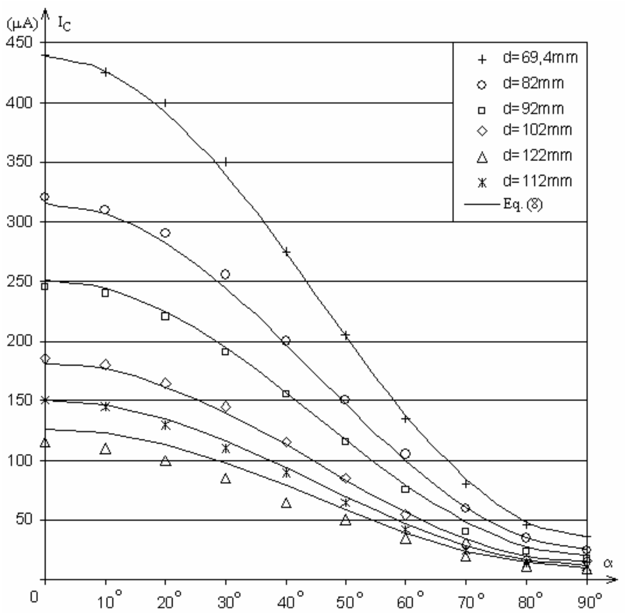

Fig. 8 Graphical representation of the theoretical characteristics family of the polaroid optocoupler LED–phototransistor $I_C = I_C(\alpha)_{d=const.}$

The size of parameter (a) determined empirically is a = 0.987

In the graphic from figure 8 we used this value of parameter (a) for the representation characterized by the following values of the parameter (d): 69.4 mm, 82 mm and 92mm.

In the case of distances between modules (T_x) and (R_x): 102 mm, 112 mm and 122 mm, it was used the value a=1.

This correction was made because, the bigger the distance between (T_x) and (R_x) modules is, the more the used system becomes an exception from the ideal case of centred optical system, the experimental values of the output current intensity being smaller than theoretical ones.

5. Conclusions

The polaroid optocoupler LED-phototransistor is an optoelectronic circuit device whose output current intensity can be modified as a result of some rotation and /or translation movements of the receiver module towards the transmitter module.

The transformation of a rotation and/or translation movement into a variation of the current's intensity, allows the use of this device as a mechanic-electrical transducer.

Optocouplers are optoelectronics devices whose main trait is the galvanic separation of two optically coupled electrical systems that have different voltage.

At the same time, if the polaroid optocoupler is used to optically couple two electronic stages, the electrical signal can be modulated mechanically.

As the modifications of this signal can be simultaneity achieved in two independent ways: by a rotation movement and by the relative translation movement of (T_x) module towards (R_x) module: they allow the use of the device within some complex mechanic-electrical system.

This device combines transducers' advantages, to connect the two physical systems operating with different nature signals, with those of optocouplers, offering a good galvanic isolation between the constitutive elements.

Polaroid optocouplers are designed for applications in the field of robotics and mecatronix automations.

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