CONTROLLABLE PHOTOPOTENTIOMETRIC OPTOCOUPLERS

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Photopotentiometric optocouplers (PPO) are electronic equivalents of mechanical resistor potentiometers. With PPOs the output quality is resistance (voltage or current) and it is converted into a function by the LED current rather than by the rotation angle of the potentiometer axle

Keywords: Optocouplers, Photopotenciometer, Control, LED

1. INTRODUCTION

The law for changing the potentiometer resistance by means of the rotation angle can be linear, logarithmic and antilogarithmic.
PPOs can be designed with one or two optocouplers.

2. CIRCUITS OF PHOTOPOTENTIOMETRIC OPTOCOUPLERS

The simplest PPO circuit with a photodiode optocoupler is shown in fig. 1.

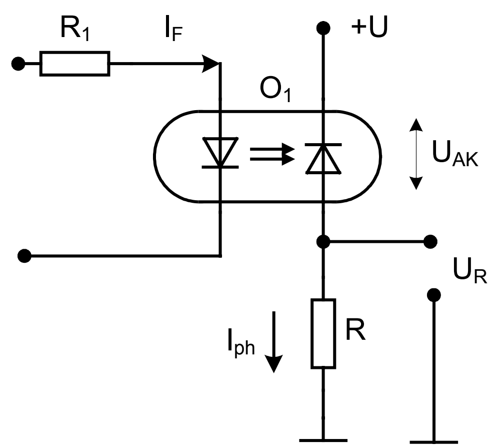

Fig. 1

The photodiode of the optocoupler O_1 and the resistor R form a controllable voltage divider. The photocurrent in the output circuit is:

(1) $Iph = CTR.\ I_F$

The output voltage is: ($I_D << Iph$)

(2) $U_R = Iph\ .\ R = CTR.\ I_F\ .\ R = const.\ I_F$

(3) $U = U_{AK} + U_R$

Let U = 12 V, CTR = 10%, R = 10 kΩ

when $I_F = 1$ mA, Iph = 100 μA, $U_R = 1$V

$I_F = 10$ mA, Iph = 1mA, $U_R = 10$ V

The change range of the output voltage is:

(4) D = 10/1 = 10

A greater change range of the output voltage can be obtained when an operational amplifier is used - fig. 2.

(5) $$U_O = -U_I \cdot \frac{R_F}{Rph(I_F)}$$

For example, when $I_F = 20$ mA Rph = 100 Ω

$I_F = 0$ mA Rph = 100 MΩ и $R_F = 100$ MΩ

The range:

(6) $$D = \frac{100M\Omega}{100\Omega} = 10^6$$

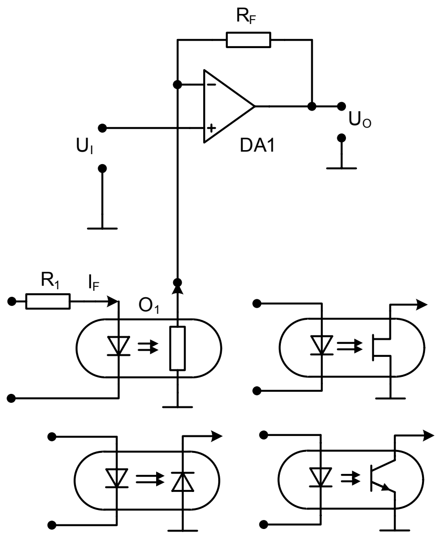

Fig.2

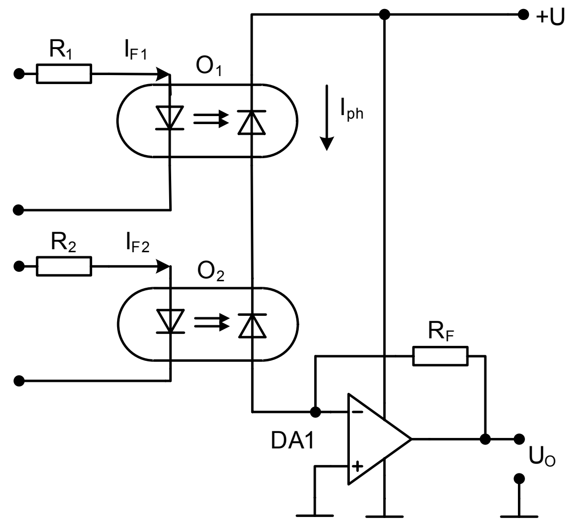

Fig. 3

For a linear change of the PPO output voltage by the LED current - I_F a trans-impedance amplifier (DA1) current-voltage should be used – fig. 3.

(7) $U_o = - I_{ph} . R_F$

(8) $U_o = CTR_2 . I_{F2} . R_F$

Let $CTR = 10\ \%$, $R_F = 1\ M\Omega$, $I_{ph} = 5\ \mu A$, $U_o = - 5 . 10^{-6} . 1 . 10^6 = 5\ V$

PPOs are suitable for operating with low LED currents up to 1 mA.

3. Circuits of Stereophotopotentiometric Optocouplers

In order to obtain a stereopotentiometer, PPOs must have two channels – fig. 4.

(9) $U_{O1}, U_{O2} = f\,(I_F)$

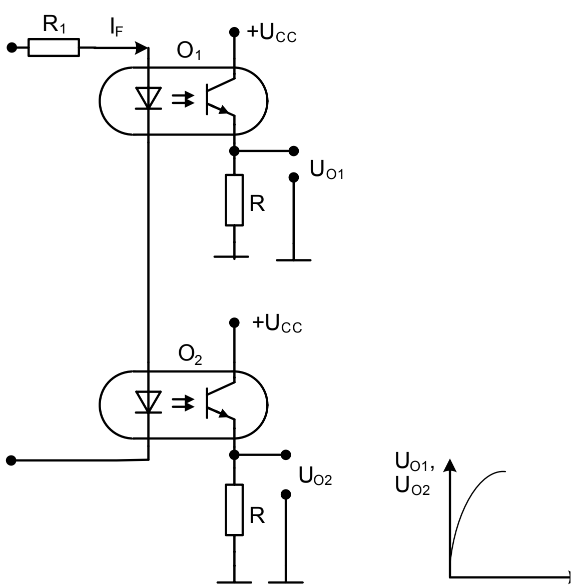

Fig. 4

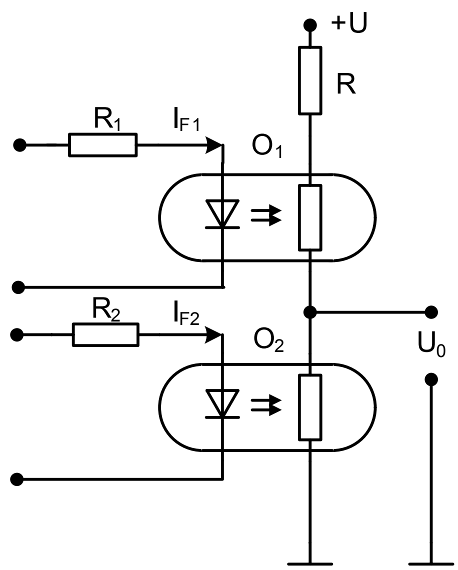

Fig. 5

4. PHOTOPOTENTIOMETRIC OPTOCOUPLERS WITH DYNAMIC LOAD

The law for changing the output voltage by the current I_F is logarithmic. PPOs are built with two basic optocoupler types:

- Photoresistor optocouplers (PRO) – fig. 5
- Photodiode optocouplers (PDO) – fig. 6
- Phototransistor optocouplers (PTO) – fig. 7
- Darlington phototransistor optocouplers (DFTO) – fig.8
- Optocouplers with field phototransistors (OFPT) – fig.9
- Optocouplers with an air gap (OAG) – fig.10
- Reflective optocouplers (RO) – fig.11

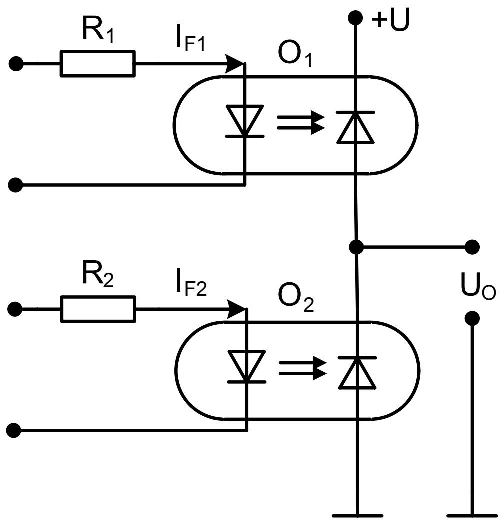

Fig. 6

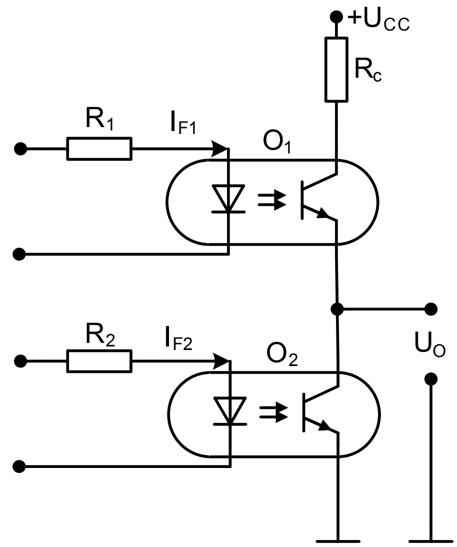

Fig. 7

When $I_{F1} = 0$ $I_{F2} = 0$ and there is a symmetry in the circuit, the output voltage is:

(10) $$Uo \approx \frac{1}{2} U_{CC}$$

Let's look at the PPO in fig.7: $U_{CC} = 12$ V

$I_{F1} = 0$ $I_{F2} = \max$ Uo min = U_{CEsat2} = 0,1 V

$I_{F1} = \max$ $I_{F2} = 0$ Uo max = $U_{CC} - U_{CEsat1}$ = 12 – 0,1 = 11,9 V

The change range of the output voltage is:

(11) $$D_U = \frac{Uo\max}{Uo\min} = \frac{U_{CC} - U_{CEsat1}}{U_{CEsat2}} = \frac{U_{CC} - 0{,}1}{0{,}1} = \frac{12 - 0{,}1}{0{,}1} = 119\left(> 10^2\right)$$

The change range of the current is:

$I_{F1} = 0$, $I_{F2} = 0$, $I_{D1} \approx I_{D2} = I_D$, let $I_D = 100.10^{-9}$ A(25° C) when $R_C = 10$ kΩ $U_{CC} = 12$ V

(12) $$I_C = \frac{U_{CC} - U_{CEsat1} - U_{CEsat2}}{R_C} = \frac{12 - 0{,}1 - 0{,}1}{10k\Omega} = 1{,}18mA$$

(13) $$D_I = \frac{I_C}{I_D} = \frac{1{,}18.10^{-3}}{100.19^{-9}} = 1{,}18.10^3 \ (>10^3)$$

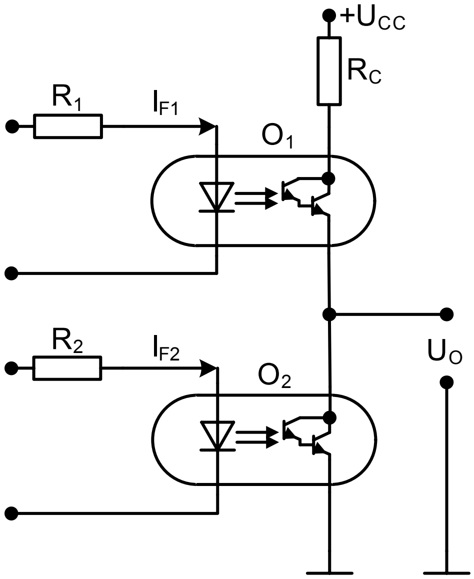

Fig. 8

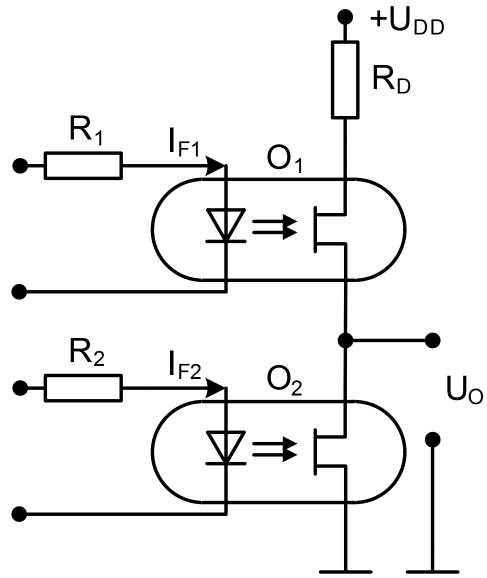

Fig. 9

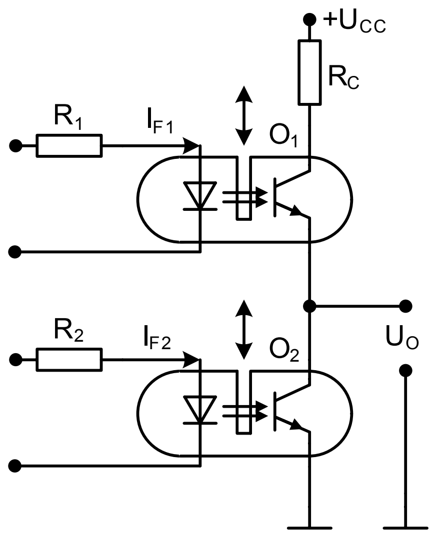

Fig. 10

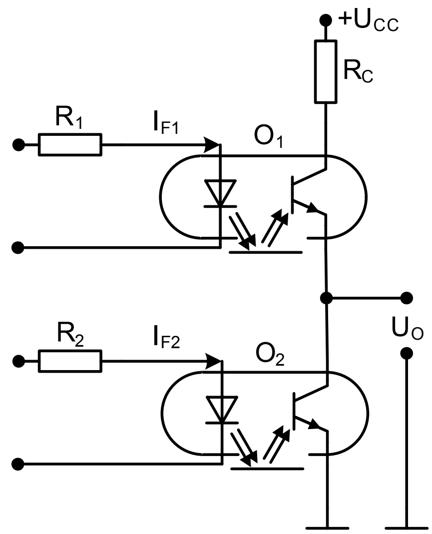

Fig. 11

The change range of the resistance collector/emitter R_{CE} of the phototransistor is:

(14) $$R_{CEH} = \frac{0{,}5U_{CC}}{I_D} = \frac{6V}{100.10^{-9}} = 600k\Omega$$

(15) $$R_{CEL} = \frac{U_{CEsat}}{I_C} = \frac{0{,}1V}{1mA} = 100\Omega$$

(16) $$D_{R_{CE}} = \frac{R_{CEH}}{R_{CEL}} = \frac{600.10^3}{100} = 6.10^3$$

5. Graphic Analytical Way of Calculating of PPO

A graphic-analytical way of calculating a PPO with phototransistor optocouplers (PTOs) is proposed:

1. From the transfer characteristic of the PTO:
$Iph\ (I_C) = f\ (I_F)$ U_{CE} = const for $I_{FX} \longrightarrow Iphx$
2. From the input characteristic of the PDO:
$Iph = f\ (U_{CE}); I_F$ = const for I_F, Iphx $\longrightarrow U_{CEX}$
3. $R_{CEX} = \frac{U_{CEX}}{I_{phx}}$
4. Building the dependence $R_{CE} = f(I_F)$ (non-linear)
For photodiode optocouplers (PDOs):
1. From the transfer characteristic of the PDO:
$Iph = f\ (I_{FX})$ U = const $I_{FX} \longrightarrow Iphx$
2. From the output characteristic:
$Iph = f\ (I_F)$ for Iphx, $I_{FX} \longrightarrow U_{AKX}$
3. $R_{AKX} = \frac{U_{AKX}}{I_{phx}}$
4. Building the dependence $R_{AKX} = f\ (I_F)$
Comparison of the PPO with different types of optocouplers – table 1:

Table 1

PPO type	**Non-linearity, %**	**Change range**	**Basic changeable parameter**	**Frequency band, kH**
PRO	5 ÷ 10	$< 10^6$	resistance	10
PDO	1 ÷ 5	$< 10^4$	current	1 000
PTO	15	$< 10^6$	current	100
DPTO	20	$< 10^6$	current	30
OFPT	1 – (low)	$< 10^6$	resistance	80

The PPOs proposed can have more than 2 channels (3-8).

6. CONCLUSION

Contactless circuits of controllable photopotentiometric optocouplers – mono and stereo have been proposed, as well as analytical and graphic methods for calculating the photopotentiometric optocouplers. A comparison of PPOs according to the optocoupler type has been made.

7. REFERENCES

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