OPTOCOUPLER CIRCUITS WITH ELECTRICAL AND OPTICAL FEEDBACKS

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With all optocouplers there is galvanic separation between the input and the output circuit, and there are not any electrical and optical feedbacks. The present paper considers the introduction of electrical and optical feedbacks in the optocouplers thus getting the latter obtain new properties, different from those of the traditional optocouplers, such as a hysteresis in the characteristics, sections of negative resistance, stabilization of the luminous flux, amplification and conversion of the optical signal and the image, etc. Feedback optocouplers can be grouped as follows: optocouplers with an electrical feedback (serial and parallel) and optocouplers with an optical feedback (positive and negative). Most of the circuits have been tested in practice, and methodologies for their dimensioning have been developed.

Keywords: optocoupler, electrical feedback, optical feedback

1. OPTOCOUPLERS WITH A DIRECT ELECTRICAL SERIAL FEEDBACK AND AN INTERNAL OPTICAL POSITIVE FEEDBACK (OPF)

They have been realized by means of a phototransistor optocoupler – fig.1.

Circuit operation:

Initially, when the input voltage U_I is increased, the current flows along the circuit – the resistor R_1 – the LED VD_1, the LED of the optocoupler O_1, the resistor R_3 and mass. When the voltage U_I is further increased, an optical positive feedback (OPF) is obtained and the Darlington phototransistor is ON, thus the voltage U significantly decreases and the current I increases.

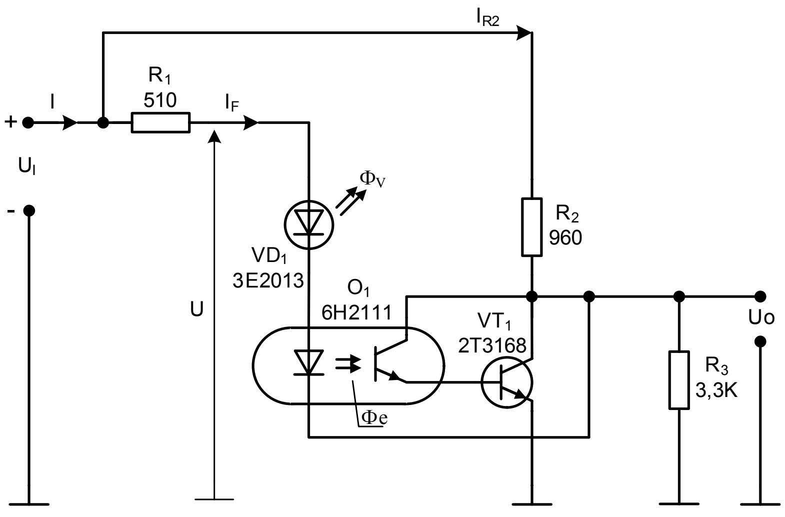

Fig. 1

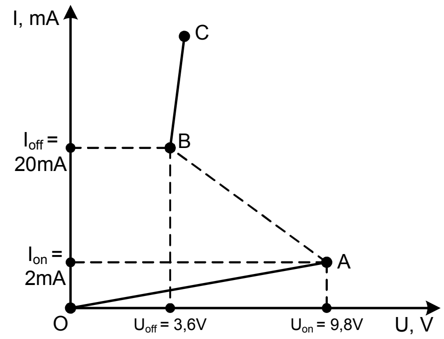

Fig. 2

To develop an OPF, the following is required:

$$\beta_K \, . \, K_i > 1 \qquad (1)$$

where K_i – the current transmission coefficient of the feedback-free optocoupler O_1, β_K – the transmission coefficient of the circuit of the feedback.

The current-voltage characteristic of the circuit I = f(U) is shown in 2.

There are three sections:

Section OA – OFF state of the circuit (stable section).

Section AB – unstable negative section in the current-voltage characteristic.

Section BC – ON state of the circuit (stable section).

The current-voltage characteristic has a S-type negative section.

There are two main points in the circuit:

- p. A – switch on (U_{on} = 9,8 V, I_{on} = 2 mA when R_1 = 510 Ω, R_2 = 960 Ω, R_3 = 3,3 kΩ)
- p. B – swith off U_{off} = 3,6 V, I_{off} = 20 mA

The negative section in the current-voltage characteristic can be used for building single-capacitor autofluctuation multivibrators.

Until the moment of switching on the circuit, the current along the LEDs is determined by the expression (there is not any current flowing along the resistor R_2):

$$I_F = \frac{U_I - U_{VD1} - U_{F1}}{R_1 + R_3} = \frac{9{,}8 - 2 - 1{,}2}{510 + 3300} \approx 2{,}2\,mA \qquad (2)$$

where U_{VD1} – the forward voltage of the LED, U_{F1} – the forward voltage of the LED of the optocoupler O_1.

The optocoupler current transmission coefficient, along with the amplifier transistor VT_1, is:

$$K_{i\Sigma} = K_i \, . \, h_{21E} = 1.100 = 100 \qquad K_i = 100\%,\ h_{21E} = 100 \qquad (3)$$

The total current I in p. B is ($R_3 >> R_2$):

$$I = I_F + I_{R2} \qquad (4)$$

In a saturation mode, I_{R2} and the collector current of the transistor VT_1 is ≈ 20 mA (fig. 2, p. B of the characteristic).

$$I_{C1sat} \approx \frac{U_{off} - U_{CEsat1}}{R_{VD1} + R_F} + \frac{U_I}{R_2} = \frac{3{,}6 - 0{,}2}{\frac{2V}{20\,mA} + \frac{1{,}2}{20\,mA}} + \frac{12{,}7}{960} = 18{,}5\,mA \qquad (5)$$

The frequency rate of change of the static negative resistance from p. A to p. B is:

$$\Delta R_N = \frac{R_A}{R_B} = \frac{9{,}8V/2\,mA}{3{,}6V/20\,mA} = 27 \qquad (6)$$

The circuit has an electrical output U_o and an optical output Φ_V. If the resistor R_2 is missing ($R_2 = \infty$), the circuit switches on when U = 3,2 V, and there is not a negative range.

(I = 15 mA, U = 3,5 V; I = 5 mA, U= 3,37 V; I = 0,5 mA, U = 3,12 V) – the circuit becomes a voltage stabilizer.

Another version of an optocoupler circuit with an optical positive feedback and an electrical serial feedback is shown in fig.3. It has been realized by means of a Darlington phototransistor optocoupler O_1.

2. OPTOCOUPLERS WITH AN INTERNAL OPTICAL NEGATIVE FEEDBACK AND ELECTRICAL PARALLEL FEEDBACK – FIG. 4.

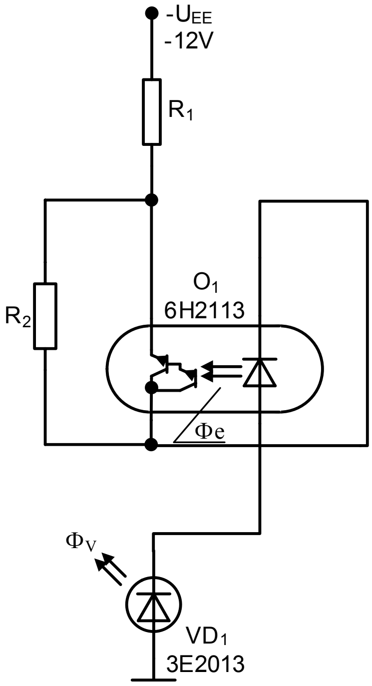

Fig. 3

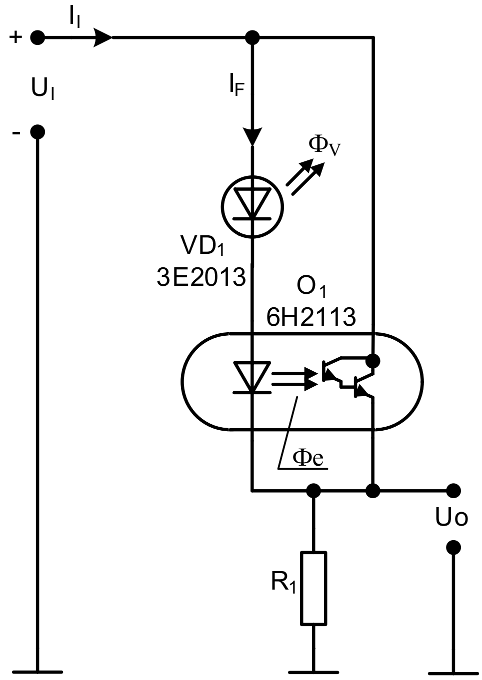

Fig. 4

This circuit has an optical output Φ_V and an electrical output U_o. It is used for stabilizing the luminous flux Φ_V emitted by the LED VD_1 when the input voltage U_I is changed.

Operation of the circuit:

When the input voltage U_I is increased, the current along VD_1 and the LED of the Darlington phototransistor optocoupler O_1 also increases thus resulting in the increase of the luminous flux Φ_V. The LED of the optocoupler illuminates the Darlington phototransistor thus reducing the collector-emitter resistance and shunting the two LEDS so that the current along the LEDs decreases and the luminous flux Φ_V set the resistor R_1 regains its initial value. The relationship between I_F and Φ_V is linear up to t°C = 45°C.

$$I_F = \frac{U_I}{R_1 + \left[R_{CE} // \left(R_{VD1} + R_F\right)\right]} \tag{7}$$

The optocoupler Darlington phototransistor operates in an active mode $U_{CE} \approx 3$ V, the current at the LED is about 15 mA. When I_F = 15 mA, the following is obtained: I_C = 25 mA.

$$I_F = \frac{12V}{220\Omega} + \left[\frac{3V}{15mA} // \left(\frac{2V}{15mA} + \frac{1{,}2V}{15mA}\right)\right] \approx 40mA$$

at U_I = 12 V, R_1 = 220 Ω, from the current-voltage characteristic of the Darlington phototransistor optocoupler.

In this case the optocoupler Darlington phototransistor is the regulating (compensating) element.

3. Circuits with an Internal Electrical Serial Feedback and an External Direct Optical Feedback – fig. 5.

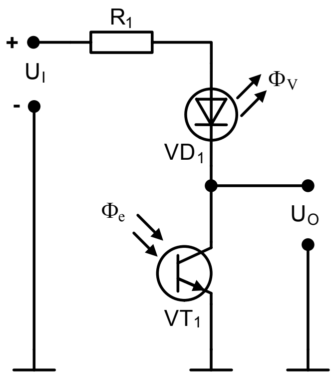

Fig. 5

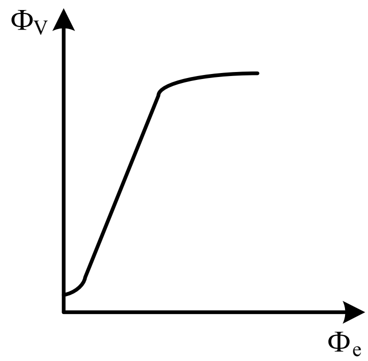

Fig. 6

These circuits have an optical input Φe and an optical Φ_V, where the following condition can be satisfied:

$$\Phi_V > \Phi e \text{ – amplification of light} \qquad (8)$$

They are used for converting the image from one optical spectrum into another. For example:

IR → V, V → IR – conversion

IR → $IR^{/}$, V → $V^{/}$ - amplification, where IR – infrared spectrum, V – visible spectrum, index „$^{/}$" – amplified signals.

The optical transfer characteristic is shown in fig. 6.

4. Conclusions

In the circuits presented above the main property of every optocoupler – the galvanic separation has been lost. However new properties have been obtained – two stable states with a negative section in the current-voltage characteristic, stabilization of the luminous flux, conversion and amplification of optical signals.

5. References

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