Development of Industrial Circuits with Semiconductor Diodes and Optoelectronic Elements

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Abstract – **In this paper are considered practical optoelectronic circuits for industrial applications with improved parameters based on a combination of optoelectronic and electronic components.This ledto some benefits such as increasing the performance of the circuits protect input and output circuits for large-value reverse voltages and limit the pulse current through the emitters.**

Keywords – **Semiconductor Diodes, Light Emitting Diodes (LEDs), Optoelectronic Elements.**

I. Introduction

The main applications of semiconductor diodes in optoelectronic circuits are [3]:

- Protectionof LEDs and Laser diodes from reverse voltages;
- Inclusion of LED to alternating or two – pole voltage;
- Protection of input or output circuits of optoelectronic circuits by reverse or rise voltage, or fixing signals voltage levels (diode limiters);
- Limiters in current loop of the LED;
- Change of regimes work of transistor switches, acceleration circuits, differentiating circuits, non – saturation switches;
- Pick – up of current to DC/ AC circuits;
- Diode – resistor and diode – transistor logic circuits;
- Forming, threshold, comparing and relay circuits.

II. Industrial Circuits with Semiconductor Diodes and Optoelectronic Elements

A. Control of LEDs of non – saturated transistor switches – Fig. 1

The fast – action of the transistor switches is important for the control of light sources – LEDs and laser diodes. The non – saturated transistor switches has high performance by the saturated transistor switch in the circuit OE.

To not take VT_1 transistor in saturation mode and reduce of the fast – action of the switch, is used a fixed diode VD_1, which carried nonlinear optical negative feedback.

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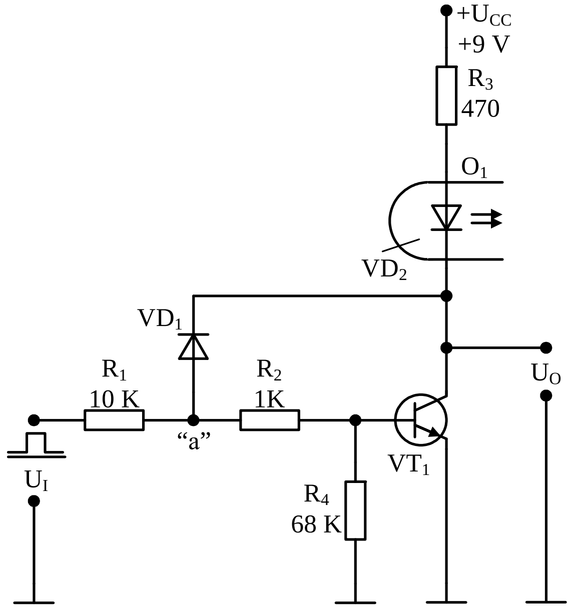

Fig. 1. Circuit for control of LEDs of non – saturated transistor switches

When the collector voltage of transistor VT_1 become – more than the value is Eq. 1:

$$U_{CE} > U_{F1} + U_a = U_{F1} + \frac{U_I - U_{BE1}}{R_1 + R_2}.R_2 + U_{BE1} =$$

$$= 0{,}7 + \frac{5 - 0{,}7}{10.10^3 + 1.10^3}.1.10^3 + 0{,}7 \approx 1{,}8\,V \qquad (1)$$

Diode VD_1 is the voltage and opens the collector of the transistor VT_1 is fixed at 1,8 V, but not as usual 0,1 ÷ 0,3 V. Times on and off the transistor VT_1 reduced to 20 %. The disadvantage of the circuit is – the small current through the LED of key non – saturated compared with saturated switch. Current through the LED ofthe non – saturated switch is Eq. 2:

$$I_F = \frac{U_{CC} - U_{F1} - U_{CE1}}{R_3} = \frac{9 - 1{,}2 - 1{,}8}{470} \approx 13\,mA \qquad (2)$$

For saturate switch is Eq. 3:

$$I_F = \frac{U_{CC} - U_{F1} - U_{CEsat1}}{R_3} = \frac{9 - 1{,}2 - 0{,}1}{470} \approx 16\,mA \qquad (3)$$

It is seen that the current through the LED at switch non – saturated reduced nearly 20 %.

B. Protection of input and output loops of optoelectronic circuits by over voltages

Protection of input loops from the negative (inverse) input voltages – Fig. 2 and Fig. 3.

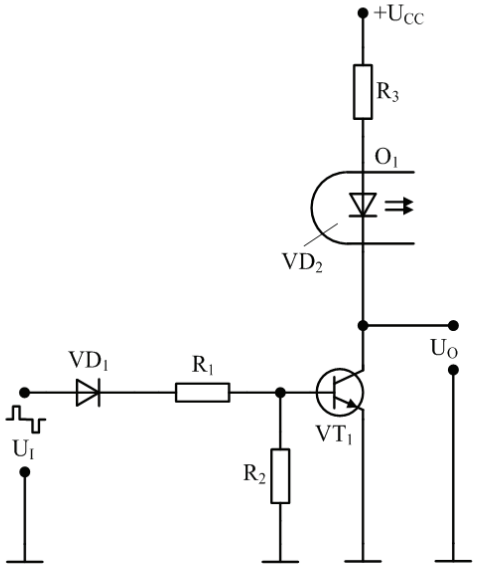

Fig. 2. Optoelectronic circuit for protection of input loop

In the circuit of Fig. 2 to optoelectronic switch is madeonly positive input voltages with an amplitude > UF_1 (0,7 V), where the circuit of Fig. 3 all positive input voltages, the negative input voltages are fixed at UF_1 = - 0,7 V.

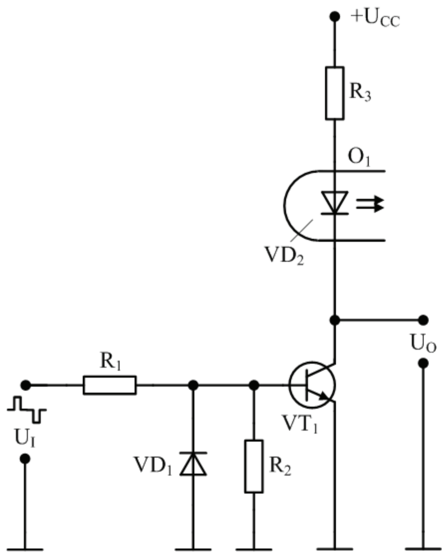

Fig. 3. Optoelectronic circuit for protection of input loop

Protection of the output loops of optoelectronic circuits from negative voltages – Fig. 4, Fig. 5 and Fig. 6.

In the circuit of Fig. 4 and Fig. 5 the diode VD_1 protects the transistor VT_1 and LED VD_2 by reverse voltage U_{CC}. The diode VD_1 can be LED, [4].

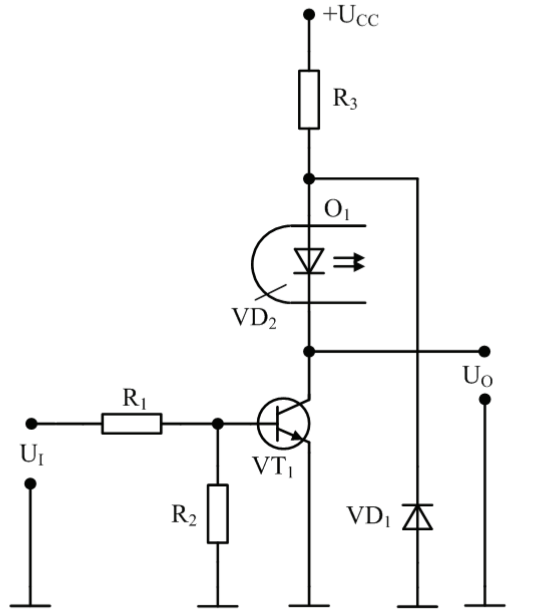

Fig. 4. Optoelectronic circuit for protection of output loop

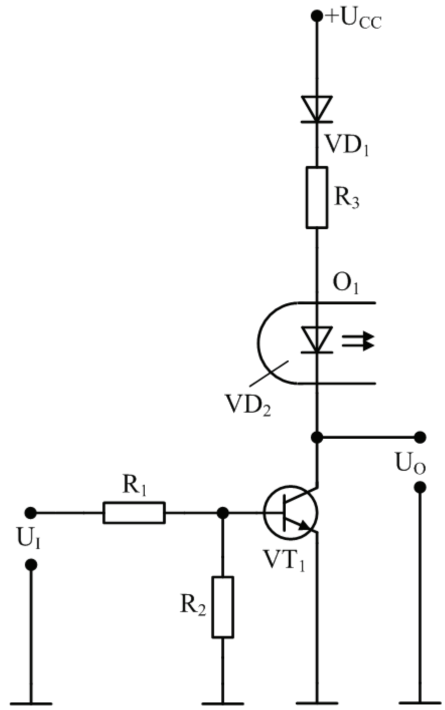

Fig. 5. Optoelectronic circuit for protection of output loop

In the circuit of Fig. 6 diodes VD_1 protect the circuit from reverse of the supply voltage. In the circuit of Fig. 6 the protection from reverse supply voltage U_{CC} is done either with diodes VD_1 or diodes VD_2.

The LED VD_3 radiated in reverse supply voltage U_{CC}.

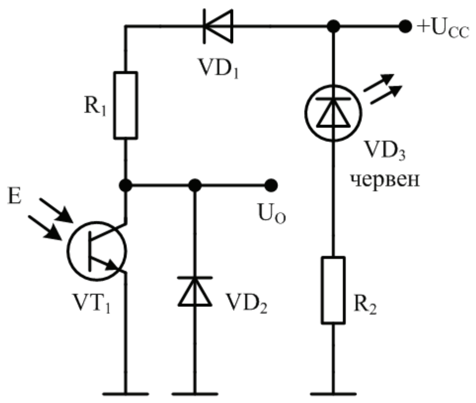

Fig. 6.Optoelectronic circuit for protection of output loop

Limitof the pulse current through the LEDs. In the work of the LED with short pulses (10 μs) and power current pulses (1 ÷ 2) A used a low – omnic resistor (10 Ω) or more LEDs several series connected diodes to limit current during LED – Fig. 7 and Fig. 8, [1].

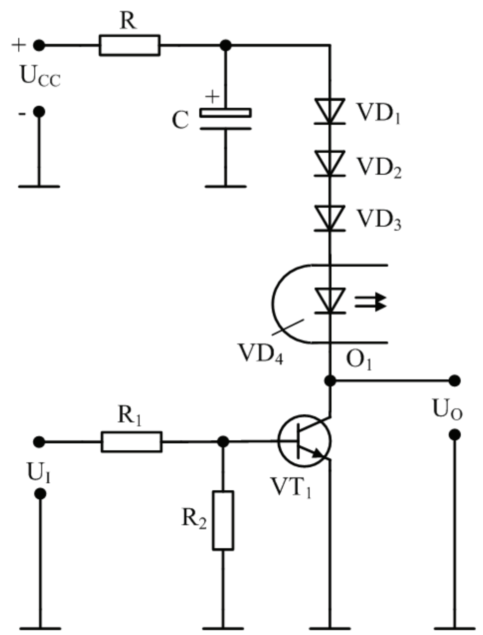

Fig. 7. Circuit of limit of the pulse current though the LED

Powerful electrical pulse is obtained either by discharging the capacitor C in LED – Fig. 7 or the inclusion of the LED for a short time to the supply voltage – Fig. 8.

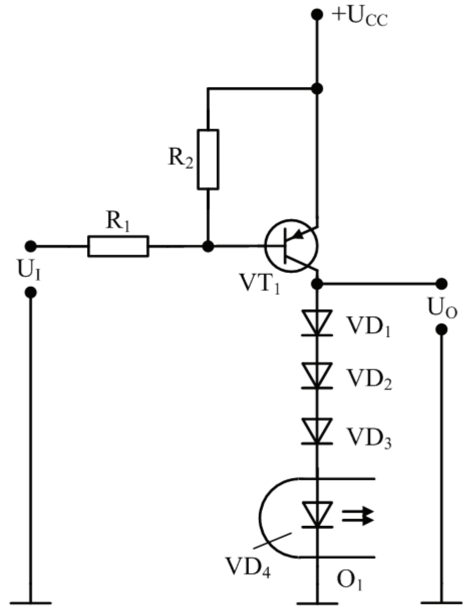

Fig. 8.Circuit of limit of the pulse current though the LED

In both cases the pulse current through the LED is Eq. 4:

$$I_{FP} = \frac{U_{CC} - U_{F4} - U_{CEsat1}}{R_{F1} + R_{F2} + R_{F3}} = \frac{9 - 1{,}2 - 1{,}3}{1 + 1 + 1} \approx 2\ A \quad (4)$$

Typically, transistors VT_1 are darlington U_{CEsat} and the voltage is high (more than 1 V).

C. Increasing of the fast – action of LEDs in saturated transistor switches– Fig. 9, Fig. 10

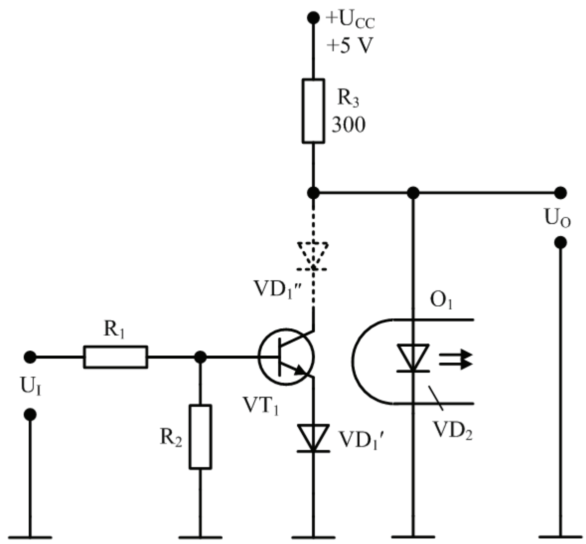

Fig. 9. Circuit for increasing of the fast – action of the LED in saturated transistor switch

When the transistors VT_1 are blocked ($U_I = 0$ V – Fig. 8 and $U_I = 5$ V – Fig. 9) during the current LED are Eq. 5 and Eq. 6:

$$I_F = \frac{U_{CC} - U_{F2}}{R_3} = \frac{5 - 1{,}2}{300} \approx 13\,mA \quad (5)$$

$$U_{F2} = U_{CEsat1} + U_{F1} = 0{,}1 + 0{,}7 = 0{,}8\,V \quad (6)$$

When the transistors VT_1 are in on – regime the voltage on the current IF_1 trough the LED is not zero, as in the switchesin Fig. 1 ÷ Fig. 7.

Low current flowsin the LED, several hundred μA, [2]. This inclusion leads to increased of the fast – action of the LED to 20 %. In the circuit of Fig. 8 when the output voltage U_O by saturated and blocked transistor VT_1 are Eq. 7 and Eq. 8:

$$U_{OH} = U_{F2} = 1{,}2\,V \quad (7)$$

$$U_{OL} = U_{CEsat1} + U_{F1} = 0{,}1 + 0{,}7 = 0{,}8\,V \quad (8)$$

The diode VD_1 can be incorporated into the collector or the emitter circuit. Unlike the circuit in Fig. 9 and Fig. 10, the diodeVD_1 is replaced by the LED and included two additional diodes VD_3 and VD_4.

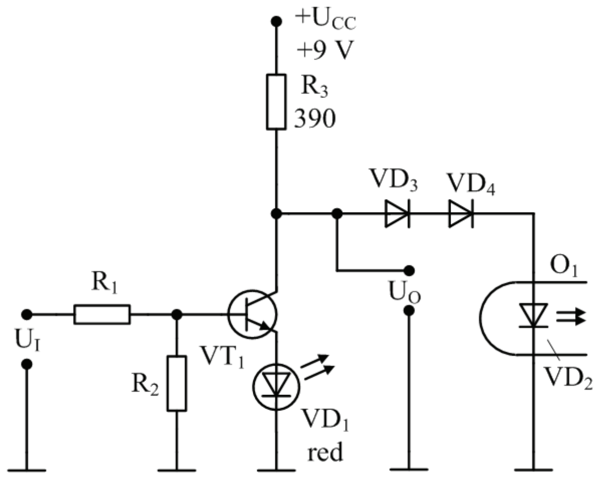

Fig. 10.Circuit for increasing of the fast – action of the LED in saturated transistor switch

When the transistor VT_1 is blocked (U_I= 0 V), current trough the LED is Eq. 9:

$$I_{F2} = \frac{U_{CC} - U_{F3} - U_{F4} - U_{F2}}{R_3} =$$

$$= \frac{9 - 0{,}7 - 0{,}7 - 1{,}2}{390} \approx 16{,}4\,mA \quad (9)$$

The output voltage U_O in this case is Eq. 10:

$$U_{OH} = U_{F3} + U_{F4} + U_{F2} = 0{,}7 + 0{,}7 + 1{,}2 = 2{,}6\,V \quad (10)$$

If $U_I = 5$ V, the transistor VT_1 is saturated and output voltage is Eq. 11:

$$U_{OL} = U_{CEsat1} + U_{F1} = 0{,}1 + 2 = 2{,}1V \quad (11)$$

Then voltage on the LED $VD_2$is Eq. 12:

$$U_{F2} = U_{OL} - U_{F3} - U_{F4} = 2{,}1 - 0{,}7 - 0{,}7 = 0{,}7\,V \quad (12)$$

and in LED – low current flows, hundreds of μA.

The current in the LEDVD_1 is Eq. 13:

$$I_{F1} = \frac{U_{CC} - U_{CEsat1} - U_{F1}}{R_3} = \frac{9 - 0{,}1 - 2}{390} \approx 18\,mA \quad (13)$$

Application of the developed circuits: protection of the LEDs and Laser diodes, input, output or supply chains of reverse voltage, current limiters, increase the fast – action of the transistor switches and the LEDs, current sensors, protection from phase – down failure.

III. Conclusion

Parts of the developed circuits increase the reliability of optoelectronic switches – Fig.2÷Fig.6, protecting them against improper inclusion and increased reverse voltages.

Increase of the fast – action of optoelectronic swiches – Fig. 1, Fig. 9, and Fig. 10.

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