DEVELOPMENT OF AVALANCHE PHOTOTRANSISTOR OPTOCOUPLERS AND CIRCUITS WITH AVALANCHE PHOTOTRANSISTOR OPTOCOUPLERS

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When the transistors operate in an avalanche mode, the amplitude of the output signal at steep fronts is high (dozens of volts). Usually the values of the collector currents are very low (up to several mA) and those of the supply voltages are high (50 ÷ 200 V). The current-voltage characteristic has a negative section. The disadvantage of the avalanche transistor circuits is the high residual voltages (dozens of volts).

The advantages of the avalanche mode are: reduced dark current caused by reduced phototransistor sensitivity, linearity of the transfer characteristic, etc. The disadvantages are: high differential output resistance and reduced current transmission coefficient K_I. The present studies and circuit model prove that the Si phototransistor of the phototransistor optocoupler can operate in an avalanche mode. These developments can be applied to controllable circuits of generators with high pulse amplitude and steep fronts.

Keywords: avalanche phototransistor, optocoupler, multivibrator

1. ECUIVALENTS OF AVALANCHE PHOTOTRANSISTOR OPTOCOUPLERS

Avalanche phototransistor optocouplers are not manufactured. Therefore we suggest three ways of solving this problem:

1. Operation of the optocoupler Si phototransistor in an avalanche mode (fig. 1 ÷ fig. 6).
2. Use of an avalanche phototransistor and its control by means of standard optocouplers – photoresistor, photodiode and phototransistor optocoupler.
3. Use of an avalanche phototransistor and its control by means of standard photodetectors (fig. 2 – by a photoresistor; fig. 3, fig. 5 and fig. 6 – by a photodiode; and fig. 4 – by a phototransistor).

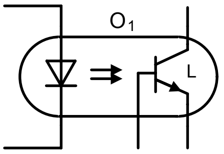

Fig. 1

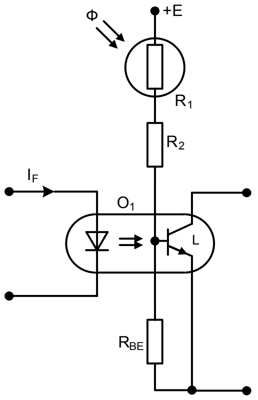

Fig. 2

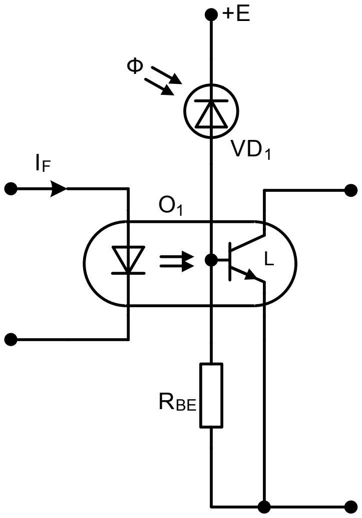

Fig. 3

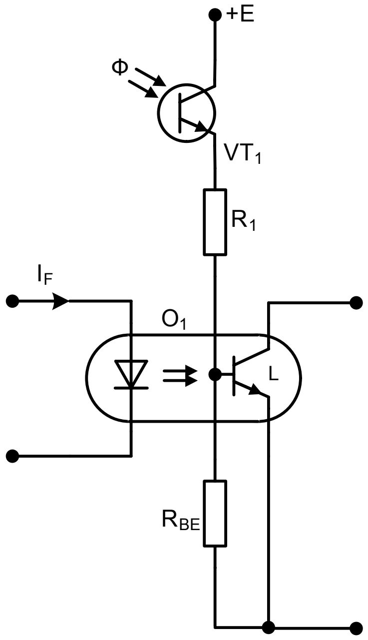

Fig. 4

The parameters of the Si phototransistor (used in the circuits proposed) in an avalanche mode are given below.

Voltage of the avalanche breakdown of the PN junction	$U_M = 35 \div 50$ V
Switch-on voltage	U_{β}' (U_{on}) ≈ 40 V
Residual voltage	U_{β} (U_{off}) ≈ (15 ÷ 20) V
Integral current sensitivity	$S_I = 1.10^{-4}$ μA/lx
Illumination	$E = (4 \div 7)10^3$ lx
Base-emitter resistor	$R_{BE} = 1$ MΩ
Rise (fall) time	t_r (t_f) = 40 ns

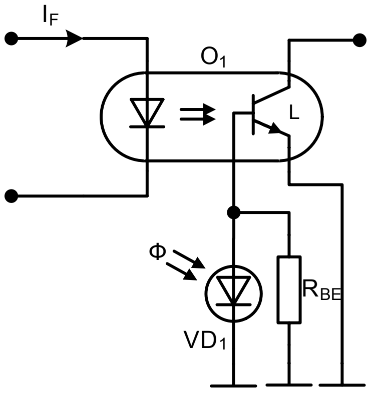

Fig. 5

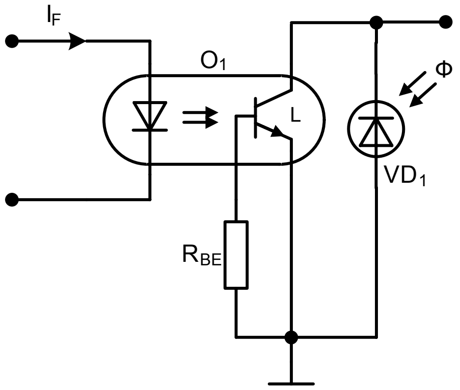

Fig. 6

Figure 7 shows the output current-voltage characteristic of a phototransistor optocoupler operating in an avalanche mode. The switch-on voltage U_{on} (U_{β}') can be regulated by the LED current I_F.

2. DEVELOPMENT OF CIRCUITS WITH AVALANCHE PHOTOTRANSISTOR OPTOCOUPLERS

Application – The actual application of the optocoupler is shown in fig. 8. This is a circuit of an asymmetric autofluctuation multivibrator. The capacitor C_1 is charged through the resistor R_1, and discharged through the forward-biased phototransistor and the resistor R_2.

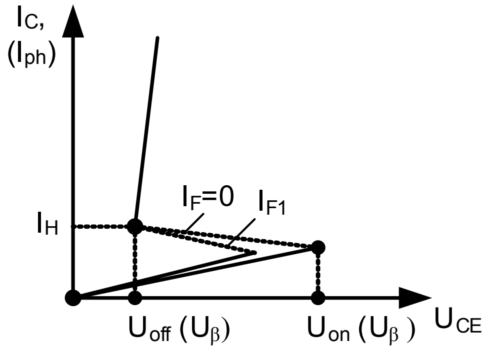

Fig. 7

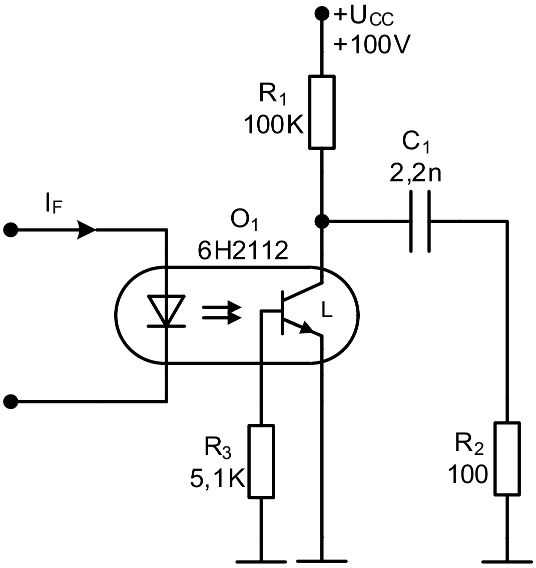

Fig. 8

If $R_2 << R_1$, the period of the generated pulses is:

$$T \approx R_1.C_1 \ln\frac{U_{CC}-U_{off}}{U_{CC}-U_{on}(I_F)} = 100.10^3.2{,}2.10^{-9}\ln\frac{100-20}{100-40} \approx 63\,\mu s \qquad (1)$$

In this case the amplitude of the output pulses is ~ 40 V, where fronts are~ 50 ns and frequency 1,5 kHz ± 10% which changes through the LED current I_F.

The breakdown voltage U_{on} is determined by the expression:

$$U_{on}(U'_\beta) \approx U_M \sqrt[n]{1-\frac{h_{21B}.I_E + I_D + K_I.I_F}{I_C}} + I_C(r_C{}^* + R_1) \qquad (2)$$

where U_M – voltage of the avalanche breakdown of the PN junction, n – non-dimensional quantity (indicator for Si n = 2 ÷ 5), $r_C{}^*$ - differential resistance of the collector PN junction, K_I – current transmission coefficient, I_D – dark current.

An autofluctuation multivibrator circuit is shown in fig. 9. If $R_2 << R_1$, the period of the generated pulses is determined by the expression (1). The pulses of the multivibrator shown in fig. 9 are inverse to the ones of the multivibrator shown in fig. 8.

A Glynn circuit operating in a stand-by mode is shown in fig. 10.

In initial state in the absence of an input initiating pulse, the optocoupler phototransistor is ON. The voltage on the phototransistor is U_{off}. The capacitor C_1 is discharged to the same voltage. When a short negative initiating pulse of ~ 20 V amplitude is passed at the input, the phototransistor switches off and the capacitor C_1

is charged through the resistor R_1. When the voltage of the capacitor C_1 reaches the value of U_{on}, the [phototransistor switches on.

If $R_2 << R_1$, Glynn period is determined by the expression (1).

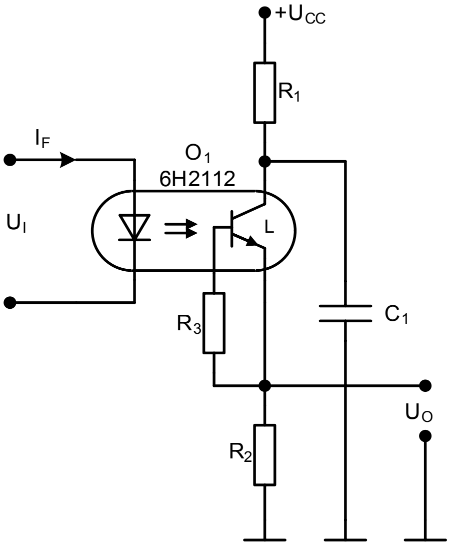

Fig. 9

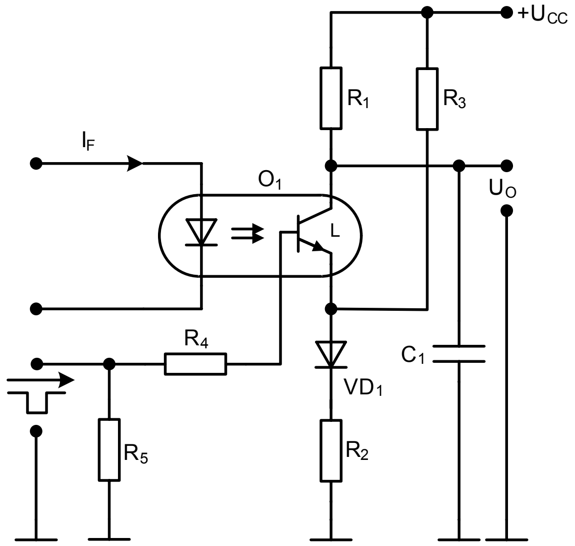

Fig. 10

The autofluctuation multivibrator shown in fig.11 is realized by means of a Ge transistor operating in an avalanche mode. The optocoupler photodiode operates in a quasi short circuit mode since the resistor R_3 is of low value.

The photodiode photocurrent, which is also a base current for the transistor VT_1, is:

$$I_{ph} = K_i.I_F \tag{3}$$

When the current I_F is increased, the period T can be regulated up to four times.

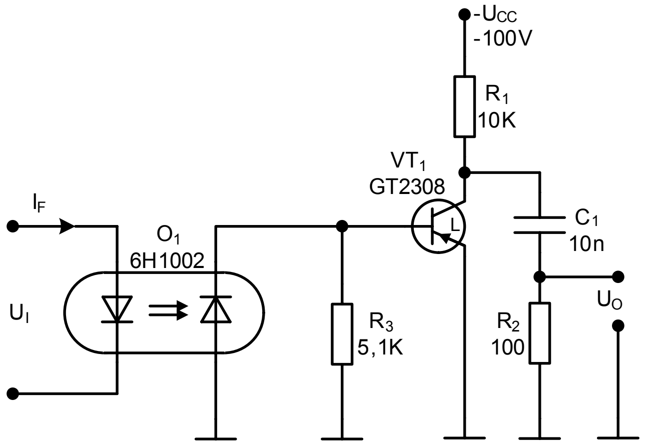

Fig. 11

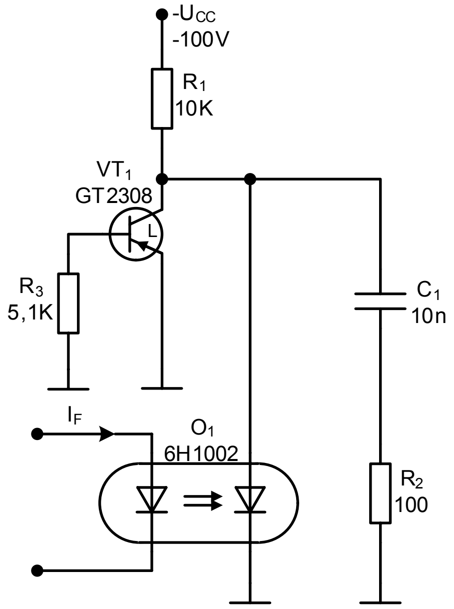

Fig. 12

With the multivibrator shown in fig 12, the optocoupler photodiode отделя part of the charging current of the capacitor C_1. The period of the generated pulses is:

$$T = R_1.C_1 \ln \frac{U_{CC} - K_I.I_F R_1 - U_{off}}{U_{CC} - K_I I_F.R_1 - U_{on}} = \tag{4}$$

$$=10.10^3.10.10^{-9}.\ln \frac{100 - 5.10^{-2}.10.10^{-3}.10.10^3 - 20}{100 - 5.10^{-2}.10.10^{-3}.10.10^3 - 40} = 31\,\mu s$$

3. CONCLUSIONS

Development of autofluctuation and stand-by multivibrators, generators of linear and staircase voltage in a stand-by and autofluctuation mode, triggers controlled by a galvanically separated channel, etc.

4. REFERENCES

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