Development of Pulse and Digital Circuits for Industrial Applications

Elena Koleva[1]

Abstract – **Have been developed in practice the main pulse and digital circuits, shapers, multivibrators, monostable multivibrators, flip – flop, sawtooth generator, frequency dividers with the possibility of starting, stopping, control and maintaining galvanic decoupling between the control signals and outputs schemes for most developments. To build the circuits using different types of optocouplers and elements with negative resistance – tunnel diodes and unijunction transistors. Here are formulas for determining basic parameters of the circuits and developed methods for sizing of sawtooth and pulse generator.**

Keywords – **Pulse and Digital Circuits, Optrons, Tunnel Diodes, Unijunction Transistors.**

I. Development of Pulse and Digital Circuits with Optocouplers and Tunnel Diodes

The tunnel diode (TD) is an element with negative resistance (with N – shaped volt – ampere characteristic). Other elements with a negative resistance in the volt – ampere characteristic are Gunn diode, avalanche transistor, unijunction transistor, dinistor, diak, thyristor, simistor and etc. [1].

Characteristic of TD is that it is low voltage and fast low – current element. For developments choosing TD type АІ301Г (3І301Г) – Russia with the following parameters – Table 1:

TABLE I

Current in peak	I_{max} = 10 mA
Current in minimum	$I_{min} \approx$ 1,25 mA
Ratio	I_{max}/ I_{min} = 8
Voltage in maximum	U_{max} = 0,18 V
Voltage in minimum	U_{min} = 0,55 V
Voltage nominal	$U_{ном}$ = 0,8 V
Current nominal	$I_{ном}$ = 5 mA
Switching time	50 ns

Volt – ampere characteristic of TD is shown in Fig. 1.

The section 1-2 is section with a negative differential resistance.

Persistent areas of the characteristic are 0-1and 2-3.

The capacitor C_1 is charged by the U_{CC}, the resistors R_2 and R_3 as a phototransistor optocouplers is blocked.

The TD is in the first ascending section of the volt – ampere characteristic – section 0-1.

Gradually increase the voltage of the TD and it switches to the second ascending section of the volt – ampere characteristic (p. 3).

Phototransistor VT_1 opens up.

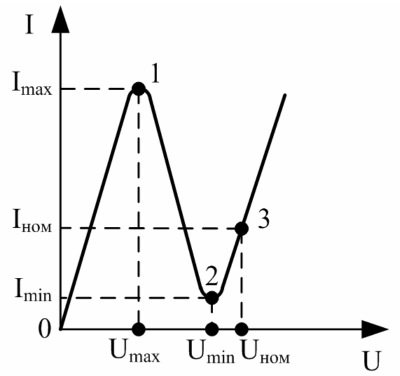

Fig. 1. Volt – ampere characteristic of TD

Circuit of controllable oscillating multivibrators with TD VD_1 and phototransistor optocouplers O_1 – Fig. 2, [3].

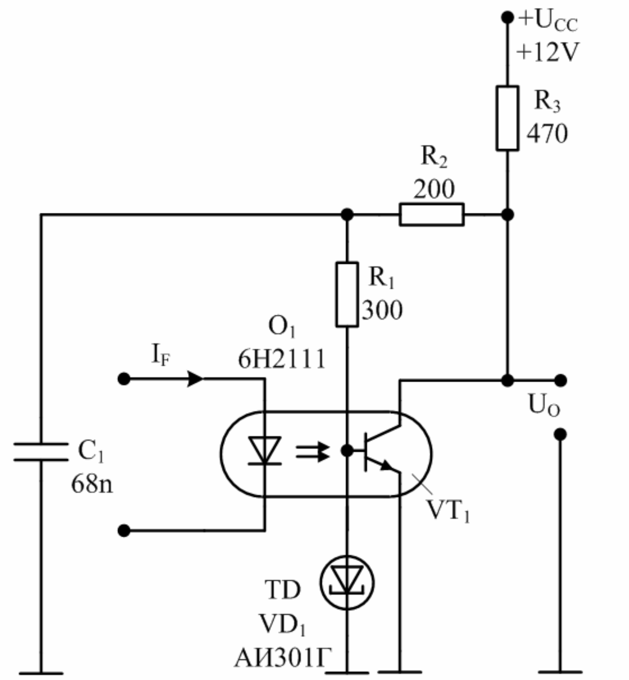

Fig. 2. Controllable oscillating multivibrator

The frequency of the generator can be operated in galvanically separated channel by the current through the LED I_F.

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Principle of operation of the circuit:

The capacitor C_1 is discharged through the resistor R_1, TD, the resistor R_2 and phototransistor.

TD and switches back to section 0-1, the phototransistor is closed and capacitor C_1 begins to charge again of the power supply through the resistors R_2 and R_3.

When the C_1= 68 nF, the times of charge and discharge capacitor C_1 are respectively t_3 = 8 µs, t_p ~ 5 µs, f ≈ 77 kHz (I_F = 0).

By the LED current I_F can adjust the frequency of the generator to 10 %. The period T is Eq. 1:

$$T = t_3 + t_P \qquad (1)$$

$$T \approx C_1.(R_3 + R_2 + R_1 // R_2).\ln\frac{U_{CC} - R_1.I_{\max}}{U_{CC} - R_1.I_{\min}} =$$

$$= 68.10^{-9}.(470 + 200 + 300 // 200).$$

$$.\ln\frac{12 - 300.10.10^{-3}}{12 - 300.1{,}25.10^{-3}} = 13{,}75\ \mu s$$

TD can be used for the formation of pulses with steep fronts for controlled of the LEDs of the optocoupler – Fig. 3.

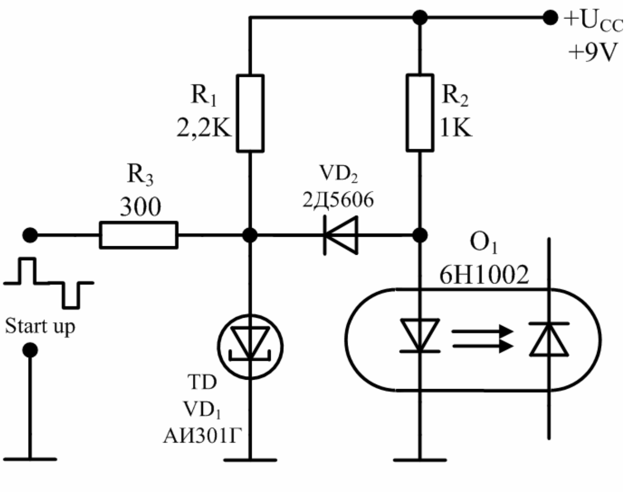

Fig. 3. Control of the LED of the optocoupler by formatting pulses tunnel diode

The circuit consisting of resistor R_1, resistor R_3 and TD form trigger, which is controlled (on and off) with two – pole pulse with amplitude a few volts.

The work of the circuit is to switching tunnel diode by section 0-1 in section 2-3 of the volt-ampere characteristic (see Figure 1) and back in the section 0-1 by the input pulses.

The supply voltage U_{CC} of the circuit is selected in the range – Eq. 2 and Eq. 3:

$$U_{CC\min} > U_{\min} + I_{\min}.R_1 = 0{,}55 + 1{,}25.10^{-3}.2.2.10^3 \geq 3{,}3\,V \quad (2)$$

$$U_{CC\max} < U_{\max} + I_{\max}.R_1 = 0{,}18 + 10.10^{-3}.2.2.10^3 \leq 22{,}18\,V \quad (3)$$

The amplitude of input pulses positive inlet is Eq. 4:

$$U_{(+)} > U_{\max} + I_{\max}.R_3 = 0{,}18 + 10.10^{-3}.300 = 3{,}18\,V \quad (4)$$

Then the current through the LED of the optocoupler is Eq. 5:

$$I_F = \frac{U_{CC} - U_F}{R_2} = \frac{9 - 1{,}2}{1000} = 7{,}8\ mA \qquad (5)$$

Fig. 4 is a circuit of monostable multivibrator with TD and phototransistor optocouplers O_1, [4].

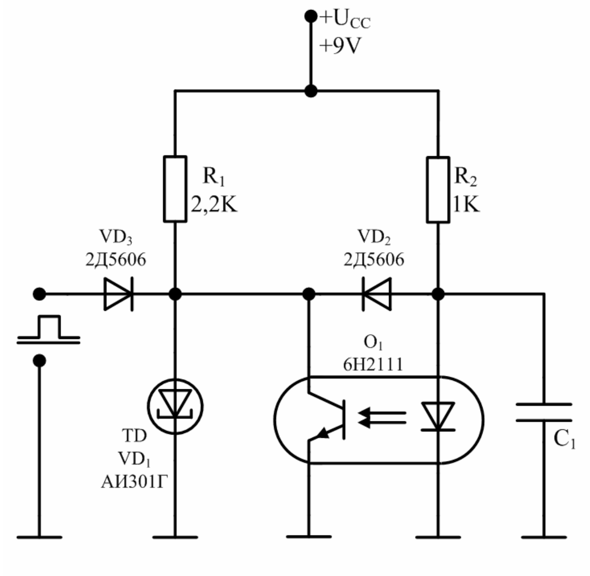

Fig. 4. Circuit of monostable multivibrator with TD and phototransistor optocoupler O1

The monostable multivibrator to restart with a single positive pulse with amplitude of few volts.

Positive input pulse switches TD in section 2-3.

The duration of the output pulse is determined by the charging time of capacitor C_1 through resistor R_2.

Discharge of the capacitor C_1 be made in the unclog diode VD_2 and the tunnel diode, where TD returns in section 0-1 of the volt-ampere characteristic. The amplitude of the starting pulse is:

$$U_{(+)} > U_{F3} + U_{\text{HOM}} = 0{,}7 + 0{,}8 = 1{,}5\,V \qquad (6)$$

Application of the developed circuits: forming controls the LEDs and laser diodes, for the development of pulse and digital circuits, oscillators and monostable multivibrators, triggers, frequency dividers and more.

Conclusion – when using TD as shapers of pulse for control of the light sources is obtained controlling pulses with steep fronts. At construction of the main pulse and digital circuits with TD and optocouplers enables a galvanically separated channel to be controlled circuits (switching, on and off switch, regulating the period and duration of the pulse and so on).

II. Development of Pulse and Digital Circuits with Optocouplers and Unijunction Transistors

For basic optocouplers of the developments is used the classic optocouplers – photoresistor, photodiode, phototransistor and photothyristor optocouplers.

For unijunction transistor (two base diode) is used transistors KT117B (Russia) with the following parameters:

- resistance between base 1 and base 2 $R_{B1B2} = (6 \div 9)$ kΩ;
- emitter on current $I_{Emax} \leq 20$ μA;
- emitter off current $I_{Emin} \geq 1$ mA;
- transfer factor – Russia, coefficient of neutralization – USA) $\eta = 0,5 \div 0,7$;
- voltage emitter - base 1 in the saturation mode – $U_{EB1sat} \leq 1,5$ V.

In the input volt – ampere characteristic of unijunction transistor has an area of negative resistance (section AB) – Fig. 5.

The volt – ampere characteristic is the dependence of current of the emitter PN junction I_E emitter – base 1 (E – B_1) as a function of the voltage emitter – base 1 - U_{EB1}.

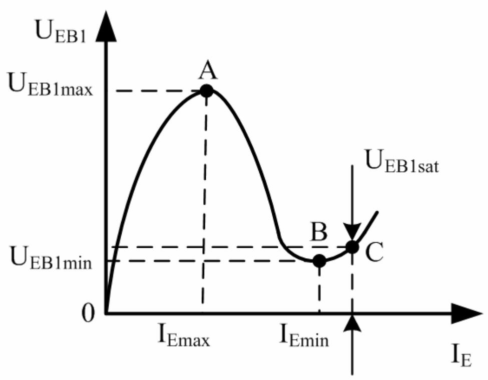

Fig. 5. Volt – ampere characteristic of unijunction transistor

The section OA is blokced condition of the unijunction transistor, and the section BC saturation is deep state of unijunction transistor. On volt – ampere characteristic in flicked characteristic points.

It appears that unijunction transistor is a threshold element.

Aplications of unijunction transistor are generators of linear, pulse and step voltage.

Controlled generator of asymmetric rectangular pulses (Fig. 6), implemented with a photodiode optocouplers O_1 and FET phototransistor -VT_1, [2].

Principle of the work:

The capacitor C is charged by the supply voltage in the resistor R and the photodiode of optocouplers O_1.

When the voltage reached a threshold voltage of the FET phototransistor it opens and the capacitor is discharged through it.

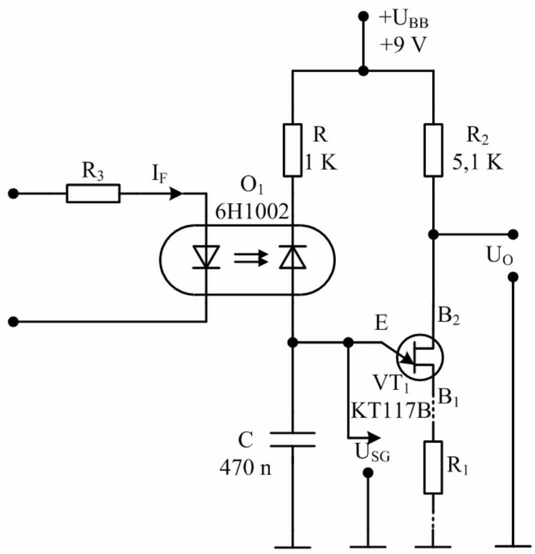

Fig. 6. Generator of asymmetric rectangular pulses

The photodiode optocoupler has a large differential resistance and determination of time capacitor is charged by linear law.

Charge time constant is Eq. 7:

$$\tau = \left[R + R_{PD}(I_F)\right].C \tag{7}$$

Where R_{PD} is the resistance of the photodiodes of optocoupler O_1.

From expression (7) shows that by the current through the LED I_F can adjust the period of the generator in a wide range (up to 5 times in amending the current I_F 10 mA). The circuit can be realized with photoresistor optocoupler or optocoupler with FET phototransistor.

Circuit of controlled oscillator multivibrator with blocking generations by phototransistor optocouplers O_1 – Fig. 7.

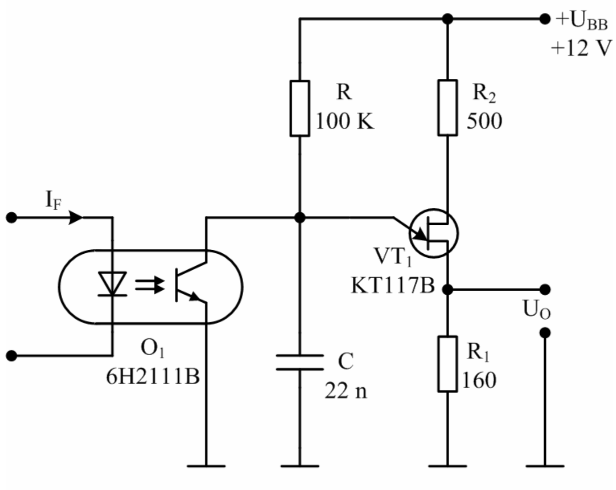

Fig. 7. Circuit of controlled oscillator multivibrator with blocking generations

When the $I_F = 0$, the controlled oscillator multivibrator operates in a continuous generations. For $I_F > 0{,}5$ mA, unijunction transistor maintain blocked, capacitor C is discharged and no generations.

Methodology for sizing the generator of Fig. 7:

1. Determination of transmission coefficient η of the unijunction transistor is Eq. 8:

$$\eta = \frac{U_{EB1\max} - E_{EB1sat}}{U_{B1B2}} = \frac{6V - 1{,}5\,V}{9\,V} = 0{,}5 \qquad (8)$$

2. Determination of the resistors R_1 ($R_{B1B2} = 6 \div 9$ kΩ for KT117V, choose an average value $R_{B1B2} = 7500$ Ω) is Eq. 9:

$$R_1 \approx \frac{0{,}2.R_{B1B2}}{U_{B1B2}} = \frac{0{,}2.7500}{9} = 166\ \Omega \qquad (9)$$

Choose the resistor $R_1 = 160$ Ω.

3. Determination of the resistor R_2 is Eq. 10:

$$R_2 \approx 0{,}015.U_{B1B2}.R_{B1B2}.\eta = 0{,}015.9.7500.0{,}50 = 506\ \Omega \qquad (10)$$

Choose the resistor $R_2 = 500$ Ω.

4. Determination of the voltage turn U_{EB1max} of the unijunction phototransistor is Eq. 11:

$$U_{EB1\max} \approx U_{B1B2}.\frac{\eta + \dfrac{R_1}{R_{B1B2}}}{1 + \dfrac{R_1}{R_{B1B2}} + \dfrac{R_2}{R_{B1B2}}} \approx 5{,}75\ V \qquad (11)$$

Here U_{B1B2} be replaced by $U_{BB} = 12$ V.

5. Determination of time of the resistor R are Eq. 12 and Eq. 13:

$$R < \frac{U_{B1B2} - U_{EB1\max}}{I_{E\max}} = \frac{9 - 5{,}75}{20.10^{-6}} = 162\ k\Omega \qquad (12)$$

$$R > \frac{U_{B1B2} - U_{EB1\min}}{I_{E\min}} = \frac{9 - 1{,}2}{1.10^{-3}} = 7{,}8\ k\Omega \qquad (13)$$

7,8 kΩ <R <162 kΩ, choose R = 100 kΩ.

6. Determining the period of generations T, where $C = 22.10^{-9}$ F – Eq. 14:

$$T \approx R.C.\ln\frac{1}{1-\eta} = 100.10^3.22.10^{-9}\ln\frac{1}{1-0{,}50} = 1{,}52\ ms \qquad (14)$$

(f = 655 Hz)

To maintain blocked generator emitter voltage of the unijunction phototransistor should be 1,2 V – Eq. 15:

$$\frac{U_{BB}}{R + R_{CE(I_F)}}.R_{CE(I_F)} = 1{,}2\ V \qquad (15)$$

In $U_{BB} = 12$ V, R = 100 kΩ by the Eq. 16 is given.

Photocurrent of the phototransistor of the oprocoupler is Eq. 17:

$$I_{ph}(I_C) = \frac{U_{B1B2}}{R + R_{CE(I_F)}} = \frac{12}{100.10^3 + 11.10^3} \approx 108\ \mu A \qquad (17)$$

The photocurrent 108 μA is obtained at $I_F > 0{,}5$ mA.

Few companies produced optocouplers with unijunction phototransistors such series AOT102A ÷ Г (Russia).

III. Conclusion

The combination of the optocouplers and the unijunction phototransistors significantly increases the functionality of the generators implemented with these elements. Control by external galvanic channel – start, stop, control of the period (frequency) in wide ranges and more.

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