VALVE OPTOCOUPLERS

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The current article presents the attempt of combining semiconductor optoelectronic elements with vacuum tube devices. Three optocoupler schemes had been developed as the first integrates the properties of optocoupler and tetrode, second one – optocoupler and photomultiplier and the last – optocoupler and phototube. Advantages of the optocoupler – high amplitude of the output signal (hundreds of volts), small dark current, very small response time. Disadvantages – high supply voltage (hundreds of volts). Three new optocoupler schematics with triode, photomultiplier and phototube are developed. In comparison with known optocouplers, they have smaller response time, smaller dark current, bigger current transition ratio (CTR) and bigger output voltage amplitude.

Keywords: optocoupler, photomultiplier, phototube

1. OPTOCOUPLER WITH TRIODE (FIG. 1).

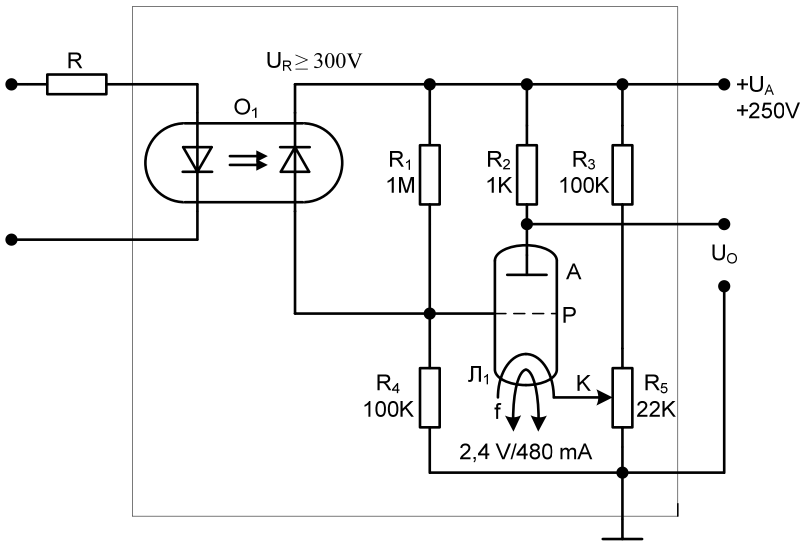

Fig. 1

High voltage photodiode (PD) optocoupler (GaAs LED and Si pin PD with (U_R > 300V) is used in the scheme along with the triode 2C49Д (Russia), which is meant to work in decimeter range and has metal–glass subminiature envelope of "pencil" type.

1.1 Basic parameters

- Heater voltage (2,5÷2,7) V, U_f = 2,4 V
- Heater current I_f = (480±10) mA
- Plate voltage in continuous mode 300 V, U_P = 250 V
- Plate voltage in pulse mode 700 V

- Plate current I_P = (21±7) mA
- Grid voltage – negative –40 V, U_G = –1V
- Turning off grid voltage for plate current when U_P = 700V: U_G = – 25 V
- Reverse grid current ≤ 0,3 µA
- Plate oscillation power in continuous oscillation mode ≥ 2 W, in pulse mode ≥ 55 W (200 MHz, U_P = 700 V, U_G = – 40 V, t_I = 1 µs, q = 250)
- Plate power dissipation with electrode radiator P_P = 4 W
- Grid power dissipation P_G = 0,8 W
- Mutual conductance S > 6 mA/V
- Voltage amplification factor K_U = 65 ± 10
- Filament average current I_{FAC} = 50 mA
- Pulse filament current 800 mA
- Leakage current between heater and filament ≤ 25 µA
- Vibrant noise voltage when R_P = 2 kΩ, ≤ 25 mV
- Voltage between heater and filament 100 V
- Capacitances: input 2,85 ± 0,4 pF, output ≤ 0,1 pF, transfer 1,65 ± 0,35 pF, filament – heater (2,4 ÷ 5) pF
- Longevity ≥ 500 h.

Main characteristics:

Plate – grid characteristic $I_P = f(U_G)$, U_P = const,

Anode characteristic $I_P = f(U_P)$, U_G = const.

Advantages of the optocoupler:

- High amplitude of the output signal (hundreds of volts)
- Small dark current
- Very small response time

Disadvantages:

- High supply voltage (hundreds of volts)

Designed optocoupler parameters:

Current transfer ratio (CTR)

(1) $$CTR = \frac{I_A}{I_F} = 100 \div 300\%$$

Voltage amplification factor of the optocoupler

(2) $$K_U = \frac{U_O}{U_F} = 100 \div 200$$

Response time 10 ns

Insulation voltage input – output 1,5 kV

Amplitude of output signal 250 V.

1.2 The conventional sign for the circuit with optocoupler and triode is proposed on figure 2.

Operating principles – when there is no current flowing trough the LED, the grid voltage is negative, the valve is in the off state and accordingly the output voltage is in high state. When there is a current through the LED, PD is illuminated, the grid potential increases and the valve turns on. Thus the output voltage will be in low state.

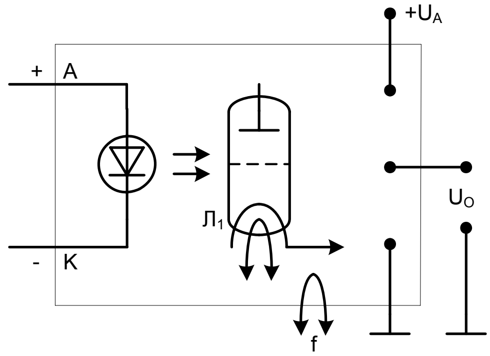

Fig. 2

2. OPTOCOUPLER WITH PHOTOMULTIPLIER

2.1 The circuit with optocoupler and photomultiplier is shown on fig. 3.

Advantages of the optocoupler:

- Very high CTR (hundreds time)
- Working with small current trough LED (μA)
- Short response time
- Small dark current (nA)
- High amplitude of the output signal (kV)

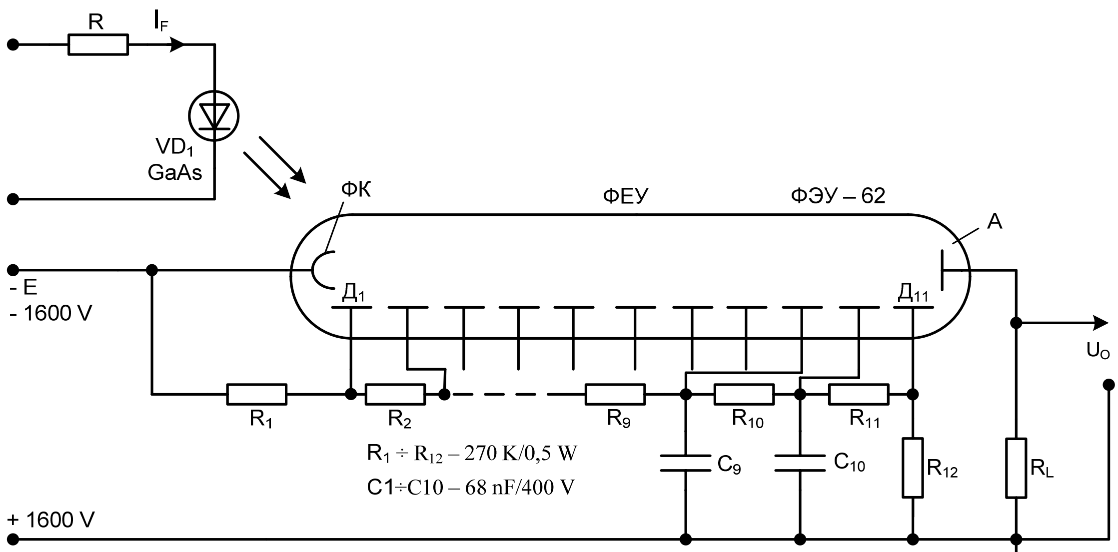

Fig. 3

Disadvantages:

High plate supply voltages

As the photomultiplier is used device ФЭУ – 62 (Russia)

Basic parameters of ФЭУ – 62:

- Photocathode – oxygen-silver-cesium, sensitive for the infrared part of the spectrum, cathode diameter – 10 mm

- Sensitivity range 400 ÷ 1200 nm (0,76 ÷ 0,82 μm)
- Photomultiplier spectral sensitivity (1,1 μm) ≥ 0,2 A/W
- Photomultiplier sensitivity > 15 μA/lm
- Dynodes number – 11
- Anode sensitivity 1 mA/lm (U_A = 1300 V), 10 mA/lm (U_A = 1600 V)
- Dark current ≤ 6.10^{-8} A
- Anode current 1.10^{-4} A
- Sensitivity threshold $1,12.10^{-10}$ $lm.Hz^{1/2}$
- Response time 5 ns
- Diameter of the cathode photosensitive area – 10 mm

Main characteristics:

- Linear light characteristic $I_A = f(\varphi)$
- Anode (current-voltage) characteristic $I_A = f(U_A)$
- Infrared LED GaAs with λ = (850 ÷ 900) nm is used to match the photomultiplier with the light source.

Optocoupler parameters:

- CTR ≥ 1000
- Insulation voltage input – output 1,5 kV
- Response time 5 ns
- Output current 1 mA.

Operating principles – when there is no current flow through the LED, the photomultiplier output voltage is low. When there is a minimal current flow through the LED, the photocathode is illuminated, cathode current is amplified and accordingly anode current begins to flow, therefore output voltage becomes high negative level. The positive pole of the supply source is connected to the ground for safety reasons.

2.2 The conventional sign of the proposed optocoupler is shown on fig. 4.

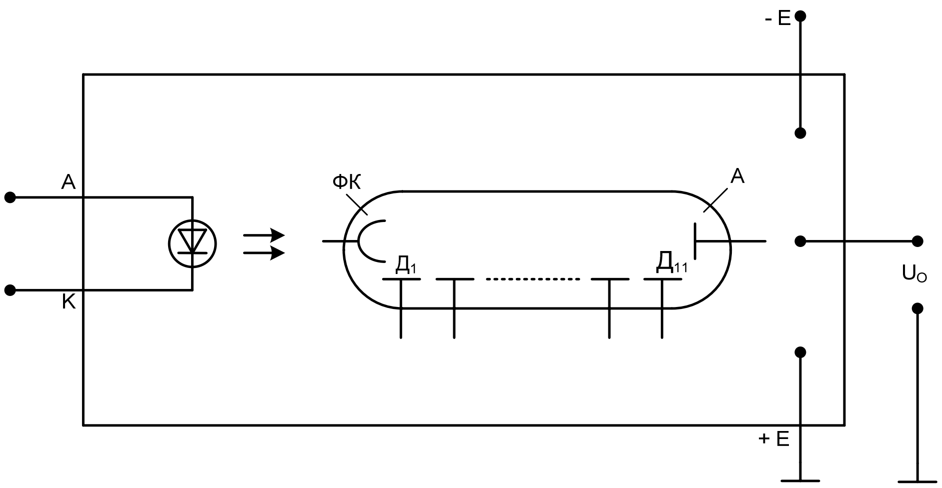

Fig. 4

3. OPTOCOUPLER WITH PHOTOTUBE (PHOTOELEMENT) – FIG. 5.

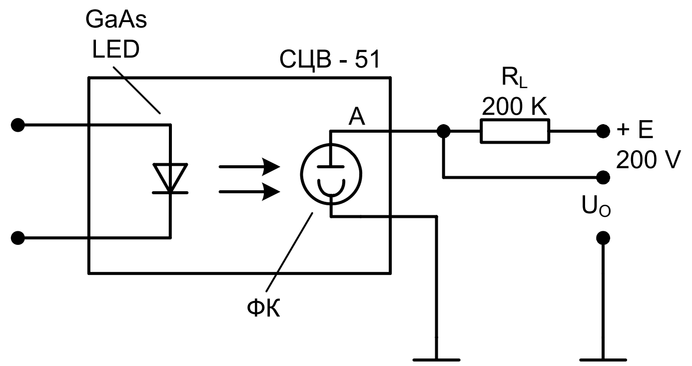

Fig. 5

Chosen phototube СЦВ – 51 (Russia) parameters:
- Operating (anode) voltage 240 V
- Integral sensitivity 75 ÷ 140 μA/lm
- Spectral sensitivity 0,6 ÷ 1,1 μm, (0,8 μm)
- Dark current 10^{-7} A
- Response time < 10 ns
- Antimony-cesium photocathode.

Operating principles – when there is no current through the LED, there is no illumination over valve photocathode and through the phototube only dark current flows. The output voltage is alternating or direct and its value is approximate to the supply voltage. The LED emits in the infrared part of the spectrum when there is current through it, respectively there is current flow through the phototube and the output voltage U_O becomes in low level state.

Optocoupler parameters:
- CTR 100%
- Insulation voltage input – output 1,5 kV
- Response time 10 ns.

4. CONCLUSIONS

Three new optocoupler schematics with triode, photomultiplier and phototube are developed. In comparison with known optocouplers, they have smaller response time, smaller dark current, bigger current transition ratio (CTR) and bigger output voltage amplitude.

5. REFERENCES

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