ISSN 1392 – 1215 ***ELECTRONICS AND ELECTRICAL ENGINEERING*** ***2009. No. 8(96)***

ELEKTRONIKA IR ELEKTROTECHNIKA

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Simulation of Optoelectronic Analog Circuits with PSPICE package

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Introduction

The purpose of the work is simulation of two circuits for transmitting analog signals within the audio range with low distortion and good galvanic separation by means of a PSPICE software package.

Phototransistor optocouplers of a normal and inverse operating mode of the optocoupler phototransistor have been used. The time diagrams of the signals and the amplitude-frequency characteristic have been given. The simulation results and those from the equations worked out have been compared, and the error determined.

Transmission of analog signals when the opt coupler phototransistor operates in a normal mode (Fig. 1.).

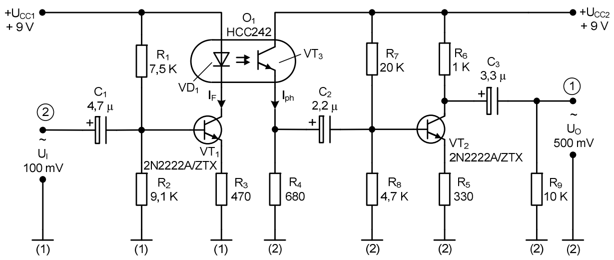

Fig. 1. A company circuit [2, 3]

The simulations results are shown in Fig. 2 and Fig. 3. Fig. 2 shows the time diagrams of the set points 1 and 2 – output and input signals, and Fig. 3 the amplitude-frequency characteristic.

With simulation (Fig. 2), the input ac signal is $U_{O\sim}$ = 500 mV, and the output signal is U_I = 100 mV. The voltage amplification factor is

$$K_U = \frac{U_O}{U_I} = \frac{500}{100} = 5\,. \quad (1)$$

With simulation, the LED current of the operating point in a dc and dynamic mode is:
I_{FDC} = 8,6 mA, I_{FAC} = (8,25 ÷ 8,45) mA.

With simulation, the current of the operating point of the phototransistor is: I_{phDC} = 12,2 mA, I_{phAC} = (11,9 ÷ 12,5) mA.

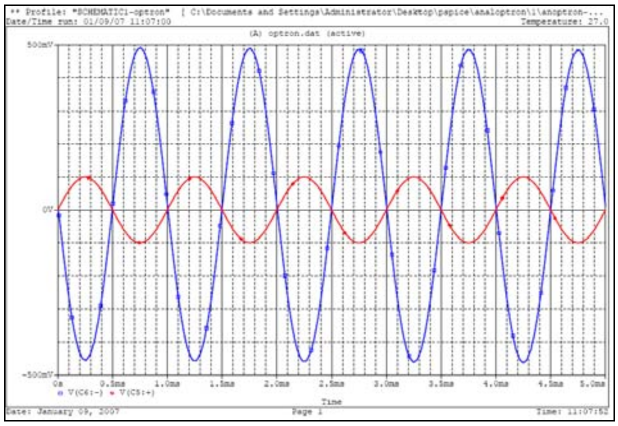

Fig. 2. Time diagrams of the set points 1 and 2 – output and input signals

The frequency range is up to 20 kHz (Fig. 3).

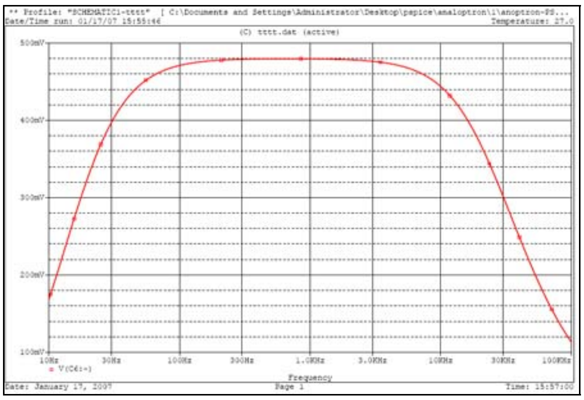

Fig. 3. The amplitude – frequency characteristic

Methods for dimensioning the circuit

The base voltage against the transistor mass VT_1 is:

$$U_{B\perp} = \frac{U_{CC1}}{R_1 + R_2}.R_1 = \frac{9}{7,5+9,1}.9,1 = 4,93V\,; \quad (2)$$

$$U_{B\perp} = U_{BE} + U_{R3}\,; \quad (3)$$

$$U_{R3} = I_F.R_3 \; at \; I_F = 9mA. \qquad (4)$$

When the current-voltage characteristic a linear operating mode of the LED has been chosen and $U_{BE} = 0{,}7V$.

$$U_{R3} = U_{B\perp} - U_{BE} = 4{,}93 - 0{,}7 = 4{,}23V , \qquad (5)$$

$$R_3 = \frac{U_{R3}}{I_F} = \frac{4{,}23}{9.10^{-3}} = 470\Omega , \quad I_F = \frac{U_{R3}}{R_3} = 9mA . \qquad (6)$$

Verification:

$$U_{CC1} = U_F + U_{CEVT_1} + U_{R3} , \qquad (7)$$

at $U_F = 1{,}2V, U_{R3} = 4{,}23V, U_{CC} = 9V$,

$U_{CE\,VT_1} = 9 - 1{,}2 - 4{,}23 = 3{,}57V$.

Therefore the transistor VT1 operates in a linear mode. The Current Transfer Ratio of the phototransistor optocoupler is 130 %.

Then $I_{ph}(I_{C3}) = I_F.CTR = 9.10^{-3}.1{,}3 = 11{,}7\,mA$, therefore the current of the operating point of the phototransistor is:

$$I_{ph}(I_{C3}) = \frac{U_{CC2} - U_{CE3}}{R_4} = \frac{9 - 1{,}5}{680} \approx 11mA . \qquad (8)$$

Simulation and calculation errors are $I_{F(simulated)} = 8{,}6mA$; $I_{F(calculated)} = 9mA$, from expression (6), the error is 4,6 %, $I_{ph(simulated)} = 12{,}2mA$; $I_{ph(calculated)} = 11mA$, from expression (8), the error is 9,8 %.

Transmission of analog signals when the opt coupler phototransistor operates in an inverse mode (Fig. 4).

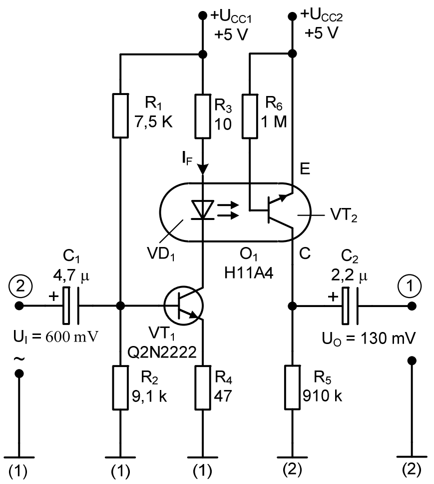

Fig. 4. Opt coupler phototransistor operates in an inverse mode

The circuit has been developed by the authors. The simulated time diagrams at p. 1 (output) and p. 2 (input) are shown in Fig. 5, and the amplitude – frequency characteristic in Fig. 6.

With simulation, for the LED the following is obtained $I_{F\,DC} = 28{,}6\;mA$; $I_{F\,AC} = 16 \div 40mA$.

With simulation, for the phototransistor the following is obtained $I_{EC}(I_{ph})_{DC} = 0{,}722\mu A$; $I_{EC\,AC} = 0{,}35 \div 1{,}2\,\mu A$.

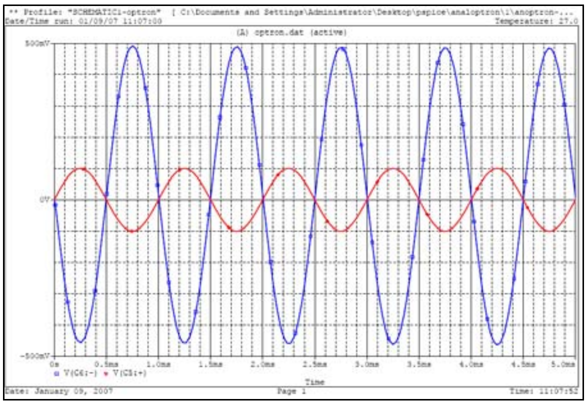

Fig. 5. The simulated time diagrams at p. 1 (output) and p. 2 (input)

Fig. 6 shows that the upper cut-off frequency of the circuit is over 30 kHz.

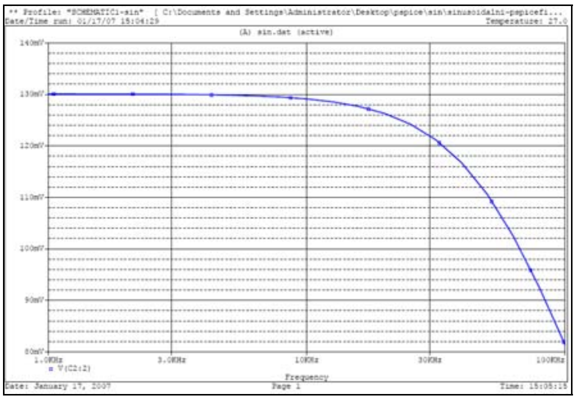

Fig. 6. The amplitude – frequency characteristic

For calculating the non-linear distortion, I harmonic – 130 mV, II harmonic – 10 mV.

Methodology for dimensioning the circuit, LED dc is:

$$I_{F\,DC} = \frac{U_{CC1} - U_F - U_{CEVT_2}}{R_4 + R_3} = \frac{5 - 1{,}2 - 2{,}1}{47 + 10} = 28\;mA , \qquad (9)$$

$$I_{ph(EC)} = CTRI_F = \frac{3}{100}.28.10^{-3} = 780.10^{-6}\,A , \qquad (10)$$

$$U_{R5} = I_{ph}.R_5 = 780.10^{-6}.910.10^{-3} = 709\;\;mV , \qquad (11)$$

$$U_{EC(inverse)} = U_{CC2} - U_{R5} = 5 - 0{,}709 = 4{,}23\,V . \qquad (12)$$

The error is:

$$\varepsilon = \frac{I_{F(simulated)} - I_{F(calculated)}}{I_{F(simulated)}} = \frac{28{,}6 - 28}{28{,}6} = 2\% . \qquad (13)$$

Experimental time diagram for Fig. 4 is shown in Fig. 7.

Table 1. Results comparison

Simulation with PSPICE	Practical experiments
input amplitude – U_I = 500 mV; output amplitude – U_O = 130 mV; frequency f = 1 kHz from (Fig. 5)	input amplitude – U_I = 500 mV; output amplitude – U_O = 120 mV; frequency f = 30 kHz from (Fig. 7)

Note: Experimental time diagrams for all circuits have been reduced with digital oscilloscope “Tektronix TDS 3014B”.

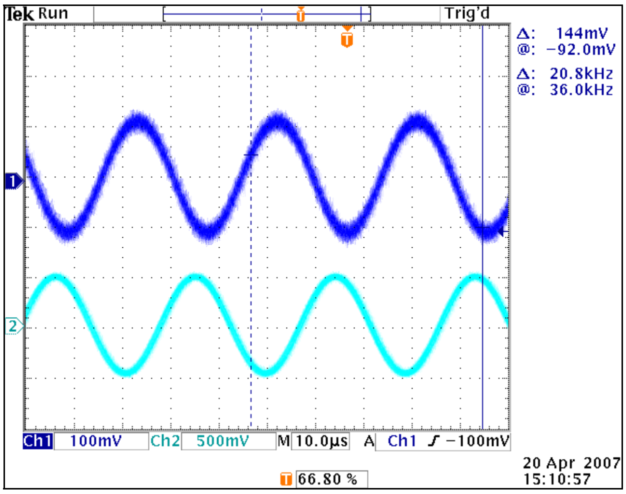

Fig. 7. Experimental time diagram

Conclusions

Two types of optoelectronic analog circuits have been developed. They have been simulated by means of a PSPICE package. Methods for calculating the basic parameters have been elaborated. The circuits have been developed in practice. The simulation and calculation error has been determined – it does not exceed 10 %.

When the optocoupler phototransistor operates in an inverse mode, the frequency band of the stage expands notwithstanding the decrease of the adjacent voltage amplification factor.

Refernces

1. **Kolev I. S.** Optoelectronics. Gabrovo, University Publishing Hoise „V. Aprilov”. – 2004.
2. **Kolev I. S.** Infrared Optoelectronics. Gabrovo, University Publishing Hoise „V. Aprilov”. – 2004.
3. **Kolev I. S.** Development, research and modeling pulse, digital and logic circuits with optoisolators and digital optron integrated circuits. Thesis for a Doctor’s degree. – 2006.
4. **Kolev I. S., Koleva E. N.** Optoelectronics. S., Technique. – 2007.

Received 2009 04 23

E. Koleva, I. Kolev, I. Balabanova. Simulation of Optoelectronic Analog Circuits with PSPICE package// Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 8(96). – P. 59–61.

The purpose of the work is simulation of two circuits for transmitting analog signals within the audio range with low distortion and good galvanic separation by means of a PSPICE software package. Phototransistor optocouplers of a normal and inverse operating mode of the optocoupler phototransistor have been used. The time diagrams of the signals and the amplitude-frequency characteristic have been given. Methods for calculating the basic parameters have been elaborated. The circuits have been developed in practice. The simulation and calculation error has been determined – it does not exceed 10 %. When the optocoupler phototransistor operates in an inverse mode, the frequency band of the stage expands notwithstanding the decrease of the adjacent voltage amplification factor. Ill. 7, bibl. 4, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

Е. Колева, И. Колев, И. Балабанова. Моделирование оптоэлектронных микросхем Analog с PSPICE пакетом // Электроника и электротехника. – Каунас: Технология, 2009. – № 8(96). – С. 59–61.

Целью работы является моделирование двух цепей для передачи аналоговых сигналов в диапазоне звука с низким уровнем искажений и хорошее гальваническое разделение путем проведения PSPICE программного пакета. Фототранзисторный оптрон с обычным и обратных режима работы оптрон фототранзистор были использованы. Временая диаграмма сигналов и амплитудно-частотная характеристика получили. Методы расчета основных параметров были разработаны. Цепи были разработаны на практике. Моделирование и расчет ошибка была определена - она не может превышать 10 %. Когда фототранзисторный оптрон работает в инверсном режиме, в полосе частот расширяется, несмотря на снижение прилегающих напряжения коэффициент усиления. Ил. 7, библ. 4, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

E. Koleva, I. Kolev, I. Balabanova. Optoelektroninių „Analog“ mikroschemų modeliavimas su programų paketu PSPICE // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 8(96). – P. 59–61.

Atliktas analoginių signalų perdavimo modeliavimas su PSPICE programų paketu. Modeliavimas atliktas garso bangų diapazone dviejų tipų grandinėmis. Fototranzistorinei optinei porai veikiant tiesioginiu ir inversiniu režimais, gautos signalų laikinės ir dažninės amplitudės charakteristikos. Pateikti pagrindinių parametrų apskaičiavimo metodai. Modeliavimui taikytos grandinės buvo išanalizuotos ir praktiškai. Taip pat buvo nustatyta modeliavimo ir skaičiavimo paklaida, kuri neviršija 10 %. Pastebėta, kad fototranzistorinei optinei porai veikiant inversiniu režimu dažnių juosta plečiasi, nors mažėjančio įtampos stiprinimo koeficientas mažėja. Il. 7, bibl. 4, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).