MULTIFUNCTIONAL PROTECTION RELAY INPUT MODULE MODERNIZATION

Nikolay Todorov Tuliev, Stefan Jordanov Ovcharov, Peter Ivanov Yakimov, Emiliya Georgieva Balkanska

Department of Electronics, Technical University of Sofia, 8 Kliment Ohridski Str., 1000 Sofia, Bulgaria, phone: +359 2 965 3143, e-mail: ntt@tu-sofia.bg

The paper describes the advantages of the modern numerical protection relays. It is proven that the accuracy depends mostly on the input module. Different approaches in design of current and voltage input transducers are mentioned. After studying the parameters and characteristics of the latest integrated circuits of operational amplifiers and ADCs a new design of the analog input module is proposed. A detailed description of the hardware of the module is presented. After investigation of the circuits recommendations for better operation are given.

Keywords: Protection relay, ADC, measurement

1. INTRODUCTION

The modern numerical multifunctional protection relays used in the electric power system comprise analog signals conditioning module, logical signals conditioning module, microcontroller, logical output module, communications module, keyboard and visualization module, power supply.

The basic operations they perform are as follow:

- input analog signals measurement by quantisation and analog-to-digital conversion;
- digital information processing and analysis;
- alarm and control signals generation.

The number of the input analog signals depends on the network connection, the type and the purpose of the protection relay. Usually the input voltage signals are up to 4 and the input current signals in some relays (for example differential relay) may reach to 8 (16) [1,2].

The quality of a particular protection relay mostly depends on the parameters and characteristics of the input signals processing modules – accuracy, connection comfort and etc.

In most cases the voltage measurement circuits are not electrically isolated one another and this causes troubles in switching star-delta, and in some cases requires "virtual" zero point creation.

2. APPROACHES FOR CURRENT MEASUREMENT

As a definition the current circuits are electrically isolated. This happens with current transformers using which are expensive and massive components. To achieve accuracy better than 0,1-0,3% "active" current transformers are used. In greater number of measuring inputs the price and the dimensions of the current protection relay increase.

Another approach for current measurement is using shunt resistors. Not long ago this approach had limited application because of the difficulties with the electrical isolation – there should be a power supply for the isolated part. There should be ensured data transfer without errors also. This is caused by the limitations for the consumed power from the measurement circuit – the maximum voltage over the shunt resistor must not exceed 10-20 mV. Thus the signal must be amplified. Depending on the necessary accuracy after that it could be transferred like analog or to be measured and the digital information to be transmitted. There are solutions using differential opto-isolators for analog signal transferring giving good results at accuracy up to 0,5%. Traditionally used opto-isolators cause troubles with the power supply of the isolated part.

In designing modern electronic protection relay electrical isolation of the voltage inputs must be intended too. Of course in this case the problem is only in data transfer because the signal amplitude is high enough.

The electronic components now allow to design input modules with very low power consumption which does not exceed 30-50 mW, and this value has a big reserve. This consumption allows to use power supply modules with simple solutions and small dimensions.

Nowadays there is a big choice of high quality analog-to-digital converters with very low power consumption and simple control. The idea is the conversion to be done in the input module and to transfer the digital data. The resolution of these ADCs is enough to achieve measurement accuracy better than 0,1%. Because of the low changes of the signal from the voltage inputs even 10-bits ADCs could be used. For ranges eliminating and easy transition from one way of connection to another 12-bits and 14-bits ADCs are used.

The current circuits require bigger range. First of all according to the standard there are two ranges – 1A and 5A. For universality the input modules have to work without changes of the shunt resistor or the amplification ratio. In addition the idea is the obtained information to be used not only for the electronic protection relays operation but for the electric consumption measuring too. For this purpose 14-bits and 16-bits ADCs are enough.

Important problem in electrically isolated input modules operation is the measurement synchronization, especially when the electric consumption is measured too. The serial ADCs are very useful for this purpose. The conversion starts after definite number clock pulses and if the clock signal is the same for all modules there will be no problems with the synchronization.

Calculating the economical effectiveness of the proposed approach, it will be seen that the sum of the prices of the ADC, digital isolator and the HF power transformer is quite less than the active current transformer and this solution ensures the electrical isolation of the voltage inputs too. In addition in the approach with current transformer the problems with the measurement and the synchronization must be solved. So, the expensive and massive active current transformer is changed by HF power supply transformer and digital isolator.

3. DESCRIPTION OF THE INPUT MODULE HARDWARE

The input transducer is designed as a separate module. It is connected to the circuits of the measured quantity and electrically isolated from the other inputs circuits and from the main controller – the protection relay. This approach was mentioned and economically considered above. Depending on the purpose of the apparatus the resolution of the conversion could be from 12-bits to 16-bits. The goal of the concrete solution is ADCs with different resolution to be used without changes in the hardware. 12-bits, 14-bits and 16-bits ADCs of Burr-Brown (Texas Instruments) were chosen which are fully compatible. On the figures 1 and 2 are shown variants of the circuit with ADS8321 and ADS8326.

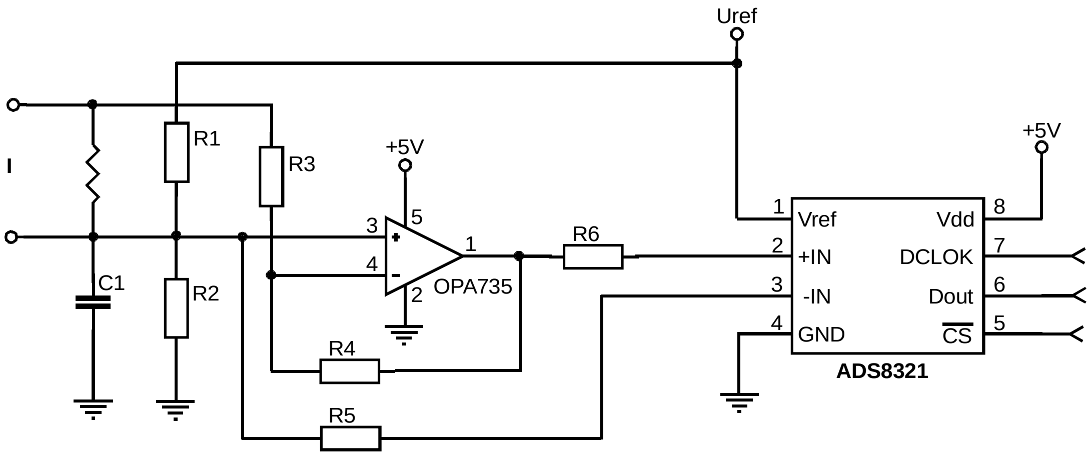

Fig. 1

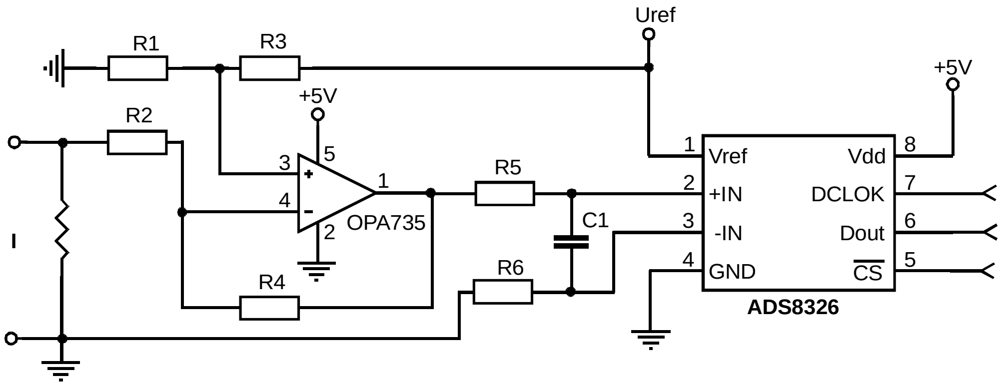

Fig. 2

The two converters have different input stages. The first has differential input, but the second – pseudo differential. The working range of the differential input is from –Vref to +Vref. The two inputs +In and –In of the ADC have working range 0-5V and 0-4V respectively (the supply voltage is Vdd=5V). The pseudo differential input has working range 0-Vref. The non-inverting input +In has range 0-Vref, and the inverting from -0,3V до +0,5V. This input is used for rejection the disturbances from the common wire and is connected to the low potential at the signal source. The printed circuit board is designed this way that the module to be used for measurement both current (fig. 1 and 2) and voltage (fig. 3 and 4) in dependence of the mounted components.

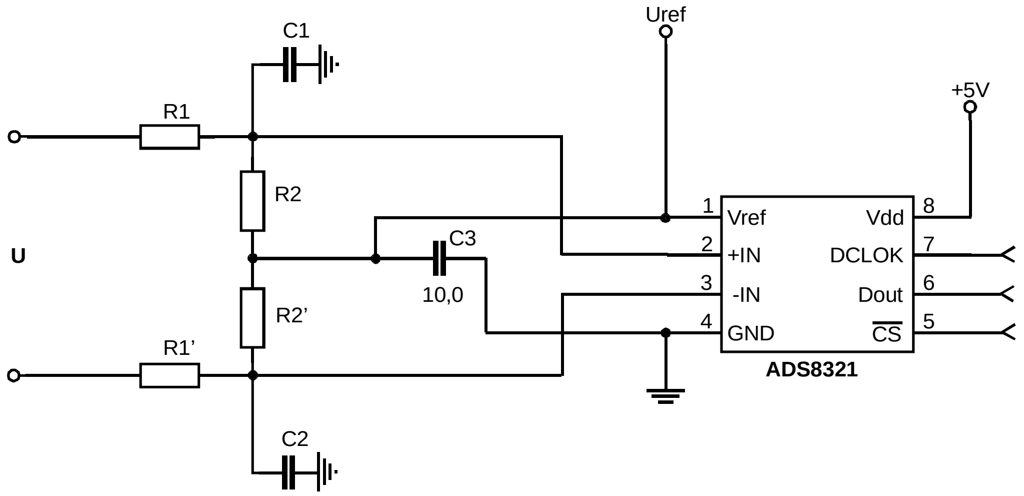

Fig. 3

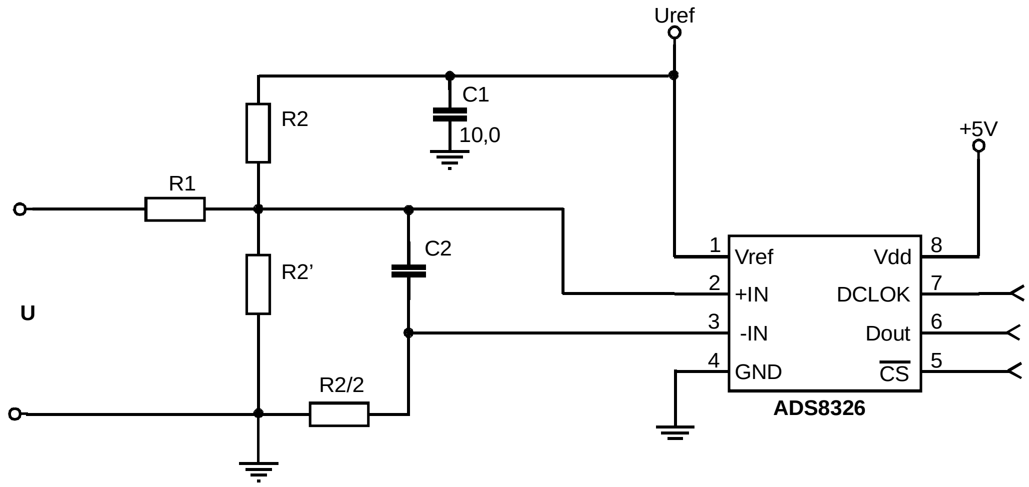

Fig. 4

There are presented two variants for current modules and two variants for voltage modules. Theoretically their parameters do not differ. These where one node of the input signal is connected to the common wire have better noise stability but the others are more convenient in technological way because of using resistors with equal values and similar RTC. Depending on the concrete application each solution could be used. According to the ADC manufacturer the time constants in both inputs should be equal in order to reduce the phase errors. The operational amplifiers which in most of the cases are necessary for current-to-voltage converters must have good parameters with 5V power supply and to have Rail to Rail output. In circuits where the input is connected to GND the input range of the operational amplifier must include 0V. OPA735 fulfils these requirements but there are lot's of amplifiers with similar parameters.

The amplification ratio is determined according to the range of the current converter and is limited between 10 – 100. When it is bigger than 30 the frequency characteristics of the amplifiers must be considered.

The control of the ADCs from this family is serial using three terminals – CS (chip select), Dclock (clock) and Dout (data out). The first two are inputs for the circuit and the third is an output. The conversion is synchronized by the clock input and continues 22 clock pulses. During the last 16 the two bytes result is obtained. ADC is activated when the level on CS is low. The first 5 clocks after the negative edge on CS are for input signal sampling, on the sixth the mode is switched to HOLD and 16 clocks conversion follow. According to the specifications of the ADCs from this family the sampling continues 4,5-5 clocks. This indetermination causes an error and it has to be born in mind analyzing the measurement accuracy.

The ADC communications signals must be electrically isolated. To reduce their number CS is created by Dclock according the requirements of the timing characteristics. As a "digital isolator" is used the two-channel circuit ADuM1201 of Analog Devices which has a channel for both directions (fig. 5). The maximum rate of communications is 25 Mbps and it is quite enough. The noise stability is better than 25kV/us and the isolation voltage exceeds the requirements for measuring inputs.

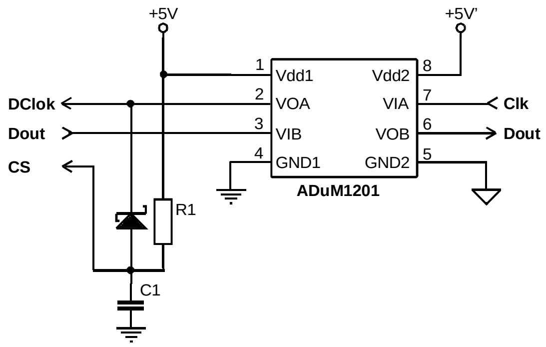

Fig. 5

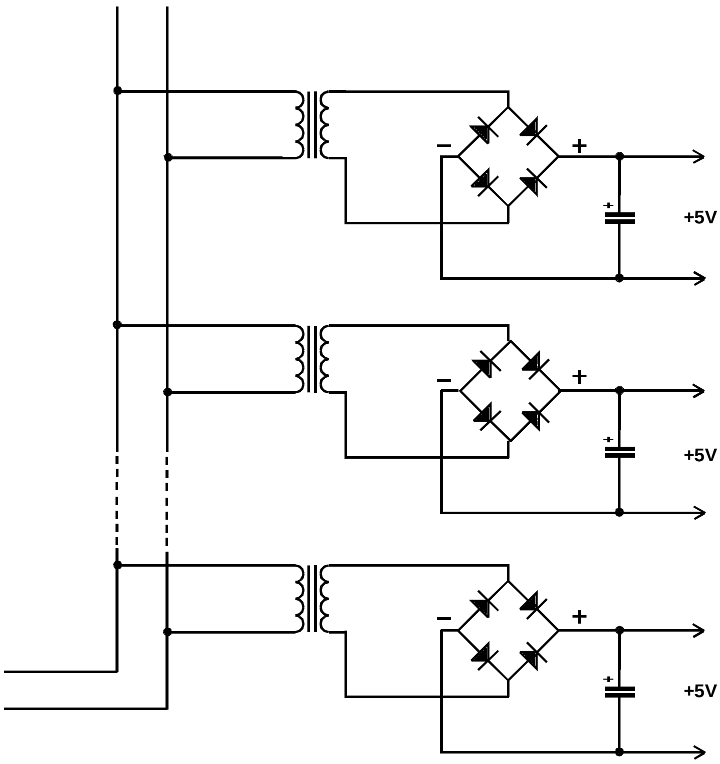

Fig. 6

Most of the ADCs from this family use external voltage reference. If a circuit with internal reference is used there must be have in mind that the output resistance of the voltage reference source is high (about 10kΩ). When this voltage is used in the rest part of the module circuit there will be necessary a buffer. Of course, the circuits with internal voltage reference are more expensive. On another side using external voltage reference gives bigger flexibility in ranges setting. All this show that the circuits with internal voltage reference do not have advantage except in cases when previous signal conditioning (amplification and translation) is not necessary.

The power supply of all modules is unipolar +5V. The supply current is 5-10 mA. This allows using small dimensions ferrite transformers which primary side is controlled by one driver for all input transducers – the sum of the consumed power is less than 0,5W (fig. 6). For disturbances reduction the conversion is synchronized by the working frequency of the power supply. The stabilization of the supply voltage in the module is not necessary. There is a need only for filtering because the power supply rejection in the ADCs from this family is better than 0,5 LSB when the Vdd is changed with 0,5V.

5. RESULTS AND CONCLUSIONS

During the experiments was found out a big influence of the digital signals on the conversion accuracy. The high rate of work of the digital isolators is a disadvantage in this case. Significant improvement is observed after delaying the fronts of Dclock. The concrete topology of the printed circuit board is of great importance – the paths of the signal and the disturbances through the parasitic capacitance of the supply HF transformer must be carefully separated.

6. ACKNOWLEDGMENT

The investigations and the paper preparation have been supported by Technical University of Sofia within the framework of the project №08046 НИ-3/2008.

7. REFERENCES

[1] SIPROTEC Protection Relays and Power Quality, Siemens AG, 2005

[2] SIPROTEC 4 7UT6 Differential Protection Relay for Transformers, Generators, Motors and Busbars, Siemens SIP, 2006

[3] Ovcharov St., M.Bogdanov, *An Investigation on a Transformer Converter of AC Current to AC Voltage*, Proceedings of the Fifth National Applied Science Conference with International Participation "ELECTRONICS-ET '96", September 27-29, 1996, Sozopol, book 1, pp. 98-102

[4] Ovcharov St., M.Bogdanov, *Investigation of the Amplitude and Phase Errors of Transformer Current to Voltage Converters*, Proceedings of the Sixth National Applied Science Conference with International Participation "ELECTRONICS-ET '97", September 24-26, 1997, Sozopol, book 1, pp. 97-102

[5] Hall effect current transducers, http://www.lem.com/hq/en/content/view/168/155/

[6] Micro Power Sampling ADC ADS8326, Texas Instruments Incorporated, http://focus.ti.com/docs/prod/folders/print/ads8326.html

[7] MicroPower Sampling Analog-to-Digital Converter ADS8321, Texas Instruments Incorporated, http://focus.ti.com/docs/prod/folders/print/ads8321.html

[8] Dual-Channel Digital Isolator ADUM1201, Analog Devices Inc., http://www.analog.com/en/interface/digital-isolators/adum1201/products/product.html