APPROACHES FOR ANALOG FRONT END DESIGN IN ELECTRIC POWER SYSTEM PARAMETERS MEASURING

Peter Ivanov Yakimov, Angel Todorov Stanchev, Nikolay Todorov Tuliev, Stefan Yordanov Ovcharov

Faculty of Electronic Engineering and Technologies, Technical University – Sofia,
8 Kliment Ohridski bul., 1000 Sofia, Bulgaria, phone: +359 2 965 3265, e-mail: pij@tu-sofia.bg

The main parameters of the three-phase electric power system are voltage, current, frequency, active power, reactive power, power factor, active energy and reactive energy. The increase of the electric energy price forces design and introduction of precise measuring devices with high accuracy. As the nature of the signals is analog and the data processing in the modern measuring devices is digital, the analog front end is of great importance. The purpose of the analog front end is to conform the range of the input signals to this of the used analog-to-digital converters and to transmit the discrete values to the central processor. The paper presents approaches in design of analog front end in measuring devices for electric power system parameters.

Keywords: analog front end, measuring transducer, energy metering.

1. ELECTRIC POWER SYSTEM PARAMETERS MEASURING

One of the main goals of the research in the field of electroenergetics is to improve the efficiency of the electric power system. The effective control of the system requests a large amount of information for the parameters in great number of points. This requires monitoring of the system parameters in different places – power plants, substations, power lines and etc. The main parameters of the three-phase electric power system are voltage, current, frequency, active power, reactive power, power factor, active energy and reactive energy. The increase of the electric energy price forces design and introduction of precise measuring devices with high accuracy. There are in use transducers, which measure the values of the main parameters of the three phase electric power system. Fig. 1 shows the block diagram of an universal measuring transducer. The structure may be divided into three main parts – analog front end, data processing module and interface module. Usually the transducer comprises six analog inputs – three for the voltages and three for the currents. The input signals are applied to the voltage and current sensors. Most frequently voltage sensors are voltage transformers or resistive dividers and current sensors are current transformers or shunts. The purpose of the analog

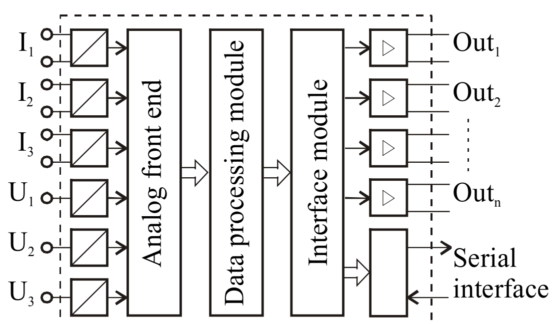

Fig. 1. Universal three phase measuring transducer

front end is to receive the signals from the input sensors and to convert them to digital data.

The data processing module calculates the values of the electric power system parameters. The information for the values is converted by the interface module and transmitted using analog and digital interfaces.

2. ANALOG FRONT END DESIGN METHODS

As the nature of the signals is analog and the data processing in the modern measuring devices is digital, the analog front end is of great importance. The accuracy and the speed of operation of the transducer depend on it. The design of the analog front end affects the operation of the whole transducer, so a serious attention has to be paid on it. It determines the tasks the data processing module has to perform. The digital data processing is based on microcontrollers.

Two methods of approach in analog front end design using microcontrollers will be discussed – using on-chip or external analog-to-digital converter.

2.1. Analog front end design using on-chip analog-to-digital converter

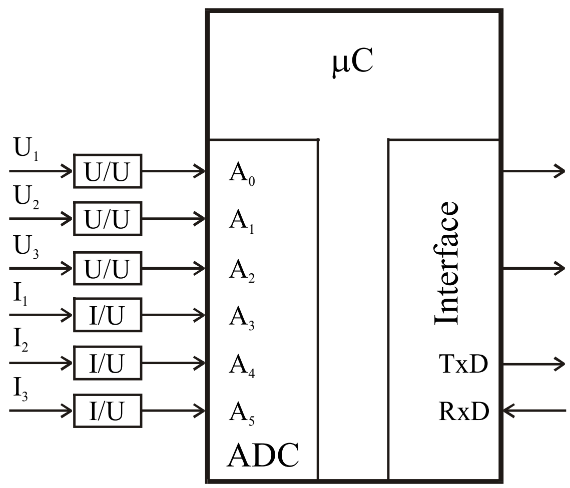

Fig. 2. Microcontroller based universal measuring transducer

Fig. 2 shows implementation of a microcontroller in electric power system parameters measuring. Modern microcontrollers comprise the basic modules of the diagram on fig. 1. The analog front end includes input voltage-to-voltage (U/U) and current-to-voltage (I/U) sensors and the on-chip analog-to-digital converter of the microcontroller. On-chip memories and CPU perform the function of the data processing module. On-chip serial and parallel interfaces organize the interface module.

The accuracy class of the transducer determines the accuracy of the on-chip analog-to-digital converter and sets the errors of the input sensors. The choice of the microcontroller is limited by the requirements to the analog-to-digital converter, on-chip memories and interfaces.

The advantage of the circuit is the low number of components, which leads to reliability increment and price decrement.

The disadvantage is caused by the multiplexed input of the ADC. In this case the samples from the different signals are taken at different moments – T_{S1}, T_{S2}, T_{S3}, T_{S4}, T_{S5}, T_{S6} and every signal will be ahead of the first voltage with different time t_1, t_2, t_3, t_4, t_5 (fig. 3). These times are equal to the conversion time of the analog-to-digital converter multiplied by the consecutive number of the sampling signal. This leads to phase errors in power measurement which compensation requires hardware and software resources.

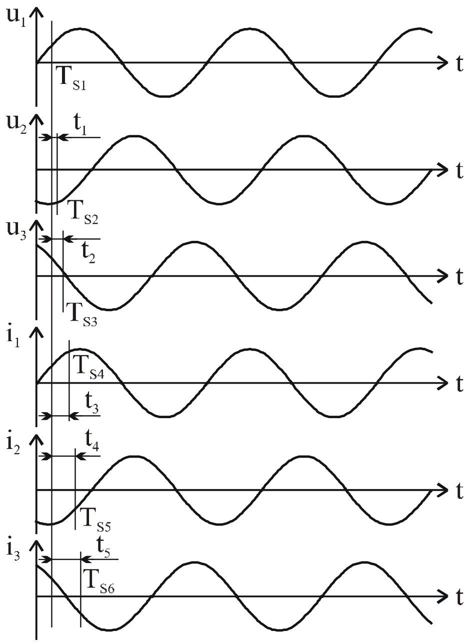

Fig. 3. Electric power system signals sampling with multiplexed input ADC

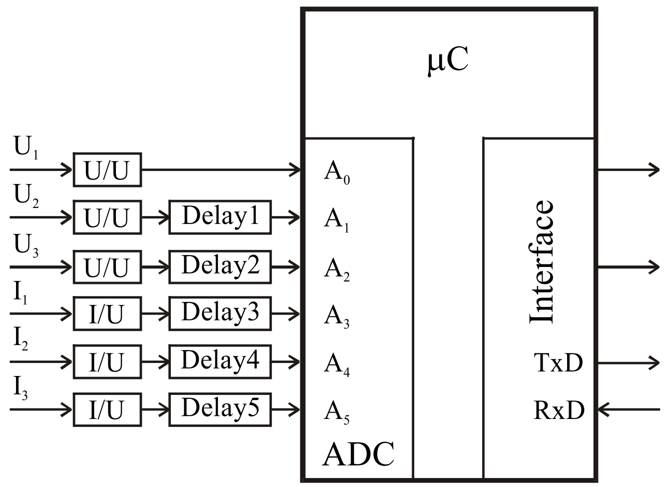

Fig. 4. ADC conversion time compensation

On fig. 4 is shown a possible solution of the disadvantage including circuits with different delay between the input sensors and the analog-to-digital converter. Every signal has to be delayed in order to compensate the time it will be ahead until the ADC is converting the previous signals. The compensation delay time can be tuned in the hardware by using components with variable values or in the software by storing the sample values in a memory buffer and calculate with using values from the previous moments. The tuning will be exact when the measured values of the phase angles of all signals are equal to the real ones.

2.2. Analog front end design using external analog-to-digital converter

The pointed disadvantage could be overcome using external analog-to-digital converter with possibility for simultaneous sampling of at least six signals. This will eliminate the phase error and will not require any hardware and software techniques for compensation.

Such integrated circuit is ADS7864 of Burr-Brown (fig. 5). This is 500kHz, 12-Bit, 6-Channel Simultaneous Sampling ADC with parallel interface and control inputs to minimize software overhead. It is intended for 3-phase power control.

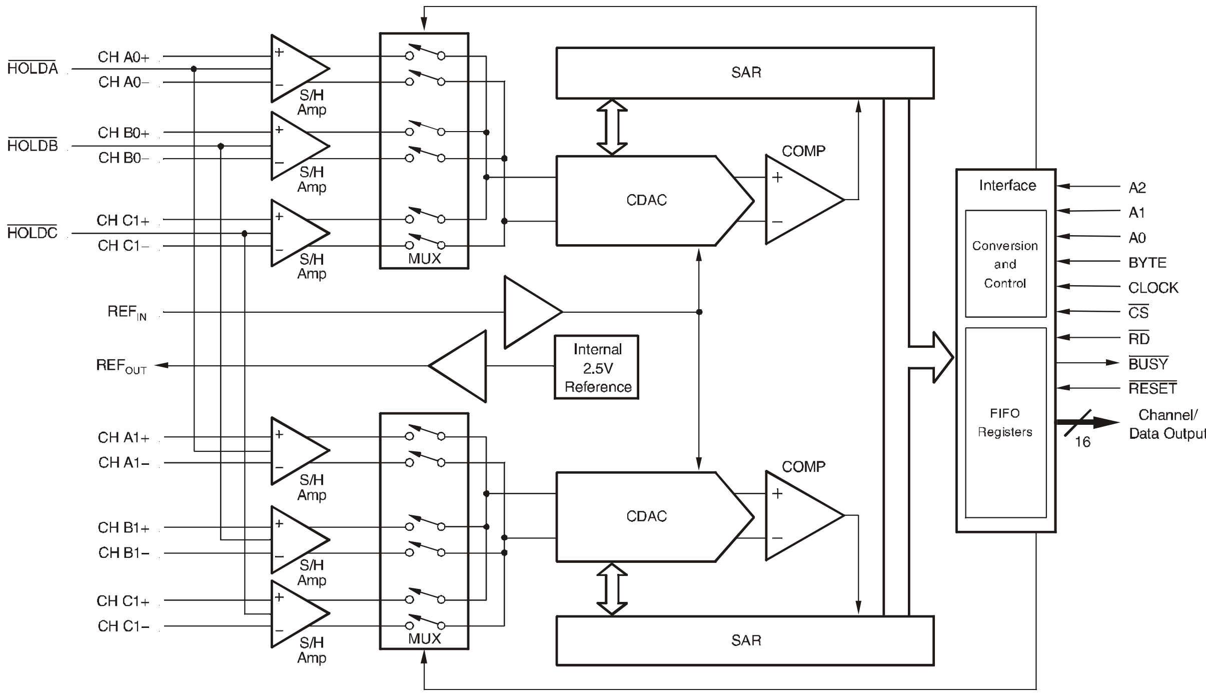

Fig. 5. Block diagram of ADS7864

The ADS7864 is a high speed, low power, dual 12-bit analog-to-digital converter (ADC) that operates from a single +5V supply. The input channels are fully differential with a typical common-mode rejection of 80dB at 50kHz which is important in high noise environments. The part contains dual 2μs successive approximation ADCs, six differential sample-and-hold amplifiers, an internal +2.5V reference with REF_{IN} and REF_{OUT} pins and a high speed parallel interface. There are six analog inputs that are grouped into three channels (A, B and C). Each A/D converter has three inputs (A0/A1, B0/B1 and C0/C1) that can be sampled and converted simultaneously, thus preserving the relative phase information of the signals on both analog inputs. Each pair of channels has a hold signal (HOLDA, HOLDB, HOLDC) to allow simultaneous sampling on all six channels. The part accepts an analog input voltage in the range of $-V_{REF}$ to $+V_{REF}$, centered around the internal +2.5V reference.

3. RESULTS

In the Research & Development Laboratory on Semiconductor circuits of Technical University – Sofia have been designed measuring transducers for electric power system parameters values.

Using the structure from fig. 4 and 8-bit microcontroller have been designed and produced universal transducers that achieve accuracy class 0,5.

In order to obtain better accuracy there was a need to apply new solution. The design included 16-bit microcontroller and external analog-to-digital converter ADS7864. As a result has been designed and produced universal transducer with accuracy class better than 0,2.

4. FURTHER INVESTIGATION IN ANALOG FRONT END DESIGN

Nowadays semiconductor manufacturers have applied low cost CMOS processes and circuit technology to energy measurement integrated circuits enabling manufacture of cost effective electronic energy meters with high accuracy. Digital processing meets all the requirements of a highly integrated, low-cost energy meter.

The ADE77581 of Analog Devices is a high accuracy 3-phase electrical energy measurement IC with a serial interface and two pulse outputs. The first of them gives active power information, and the second provides instantaneous reactive or apparent power information. The ADE7758 incorporates second-order Σ-Δ ADCs, a digital integrator, reference circuitry, temperature sensor, and all the signal processing required to perform active, reactive, and apparent energy measurement and *rms* calculations in various 3-phase configurations, such as WYE or DELTA services, both with three or four wires. It provides system calibration features for each phase, i.e., *rms* offset correction, phase calibration, and power calibration.

The ADE7758 has a waveform sample register that allows access to the ADC outputs. The part also incorporates a detection circuit for short duration low or high voltage variations. The voltage threshold levels and the duration (number of half-line cycles) of the variation are user programmable. A zero-crossing detection is synchronized with the zero-crossing point of the line voltage of any of the three phases. This information can be used to measure the period of any one of the three voltage inputs. It is also used internally to the chip in the line cycle energy accumulation mode. This mode permits faster and more accurate calibration by synchronizing the energy accumulation with an integer number of line cycles.

The ADE7758 has a total of six analog inputs divided into two channels: current and voltage. The current channel consists of three pairs of fully differential voltage inputs. The voltage channel has three single-ended voltage inputs. Both the current and voltage channel have a PGA with possible gain selections of 1, 2, or 4. The same gain is applied to all the inputs of each channel.

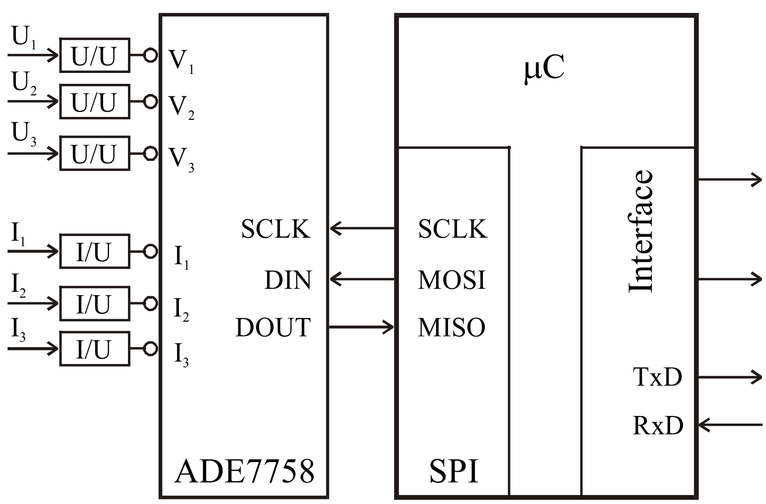

Fig. 6. Universal measuring transducer using specialised IC

Data is transferred with the ADE7758 via the SPI serial interface.

The resources of ADE7758 allow it to replace the analog front end and data processing module from the diagram on fig. 1. A possible design of an universal measuring transducer is shown on fig. 6. The microcontroller performs interface functions. It configures and controls the operation of ADE7758 and realizes the transmission of information using the analog and digital interfaces.

5. CONCLUSIONS

The design of the analog front end in electric power system parameters measuring is of great importance and should meet the requirements for accuracy and reliability. The next factor affecting the choice is the price.

The implementation of specialised energy measurement integrated circuits is a perspective direction in this field and it will be used in further investigation and research.

6. REFERENCES

[1] www.gmc – instruments. com

[2] Stephen English and Rachel Kaplan, A 3-Phase Power Meter Based on the ADE7752, AN-641 APPLICATION NOTE, Analog Devices.

[3] Stephen English and Dave Smith, A Power Meter Reference Design Based on the ADE7756, AN-564 APPLICATION NOTE, Analog Devices.