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Product Quality and Safety

Energy management controller

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Abstract. *The idea of designing a controller for electrical energy management is due to the need for energy saving and intelligent management of the consumed energy. The article presents the designed and studied device designed to limit the consumption of electrical energy within one day and the magnitude of the load current in single-phase circuits. Thus, the consumer (household consumer) of electrical energy can use the energy at time and in amount at will, but within pre-set limits. The paper discusses the principle of operation of the device for power consumption management, its main characteristics, and applications.*

Keywords: limitation of electrical energy, load current, single-phase circuit, electrical energy consumption

Introduction

The economical use of electricity is one of the main requirements today, both in industry and in everyday life. With good management of the energy consumed by consumers, the cost of payment can be significantly reduced. Electronic meters are used today to measure electrical energy. They are designed on the basis of specialized integrated circuits. With the use of Analogo – Digital Converters (ADC), the analog signals from the current and voltage measurement are converted into digital form, and the calculation of their product, which determines the power consumption, is calculated by a microprocessor (Miquel et al., 2013). The main requirements in the design of digital meters are: the cost of the device, its efficiency and overall dimensions. The principle diagram of a modern digital power meter is shown in Figure 1.

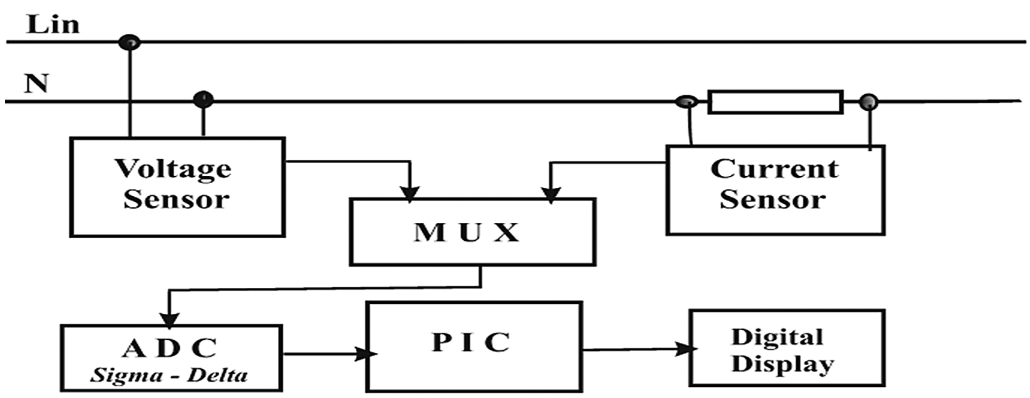

Figure 1. Principle diagram of an electronic electric meter

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Sensors are used to measure the magnitude of the consumed current and the supply voltage. The voltage sensor is constructed usually with a resistor divider, taking into account the phase voltage and the voltage on the load. To measure the magnitude of the current, a current transformer is most often used.

Analog output signals from the sensors enter the inputs of an analog multiplexer that periodically feeds these signals to the ADC input. Analog signals are converted to digital form by Sigma – Delta ADC with high resolution. The digital information processing and the computation of the power and energy consumed by the user are calculated by a peripheral interface controller PIC. The Untroler is displayed in language C. It makes a calculation of the energy consumed for one hour, as well as the fee to be paid. The isodic data of the meter is displayed on the liquid crystal display, which is controlled by the PIC (Luan et al., 2009).

The purpose of the designed and studied device in this article is to limit the electricity consumption within one day and the magnitude of the load current in single-phase electrical circuits. Thus, the consumer, most often a household consumer of electrical energy can use the energy at time and in amount at will, but within pre-set limits (William et al., 2006).

The main goal in creating the controller is the maximum correspondence between the price of the energy limited by the device and the price of the energy measured by the customer‘s individual electricity meter (Li et al., 2009). Thus both the interests of the customer and the interests of the electricity supplier are protected to the maximum, preventing mutual conflicts (Md. Mejbaul et al., 2011). The problem of mismatch between the amount of electrical energy consumed and its cost is particularly critical with the potential introduction of a "prepayment of electricity service" which significantly improves the ability of customers to make payments.

Material and methods

Schematic, program and methodological approaches to the energy management controller design.

The following schematic, technical, programming and methodological approaches to designing the device were used:

- The device shows a small error when measuring electrical energy and current, the typical relative error does not exceed 0.5%;
- The price per kWh can be easily reprogrammed with an accuracy of 0.1 stotinka;
- The controller reads the consumed electricity at day and night tariff on the signal of an external clock which is installed in the electrical panel and controls the individual electricity meters;
- The reading periods of the individual meters and the period of electricity consumption managed by the controller are synchronized through a simple "Initial Reset" procedure performed by a data collector.

The main features

The main features of the controller for power consumption management are:

- The device is non-adjustable - there is no need for periodic internal adjustment and calibration;
- All basic modes and parameters are set via infrared port from a specialized remote control with a menu in Bulgarian;
- All basic parameters are stored for an indefinite period of time in non-volatile memory;
- The limit of the electrical energy consumption per 24-hour period /programmable/ is from 0 to 40 kWh, with a resolution of 0.02 kWh, at 10 random levels;
- Levels of limitation /programmable/ of the current consumption - from 0 to 25 A, 10 levels, maximum switching current 40A;
- The limit of the consumed electrical energy for a 24-hour period /programmable/ - from 0,01 lv to 40,00 lv, with a resolution of 0,1 st, at 10 arbitrary levels;
- The controller allows the use of saved electrical energy from previous time periods in a number of daily limits /programmable/ - 0 to 10 limits.

Design of the energy management controller

The principle block diagram of the power management controller is shown on Figure 2.

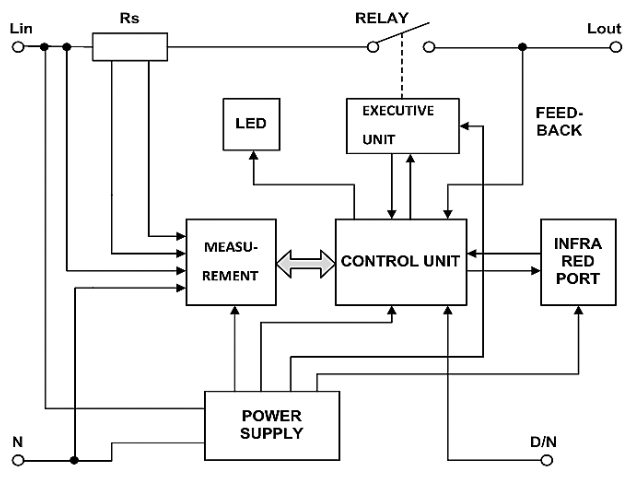

Figure 2. Block diagram of the power management controller

The mains voltage and the current through the load are measured by the unit MEASUREMENT of the device. The current measurement is performed by an ultra low resistance shunt on a four-wire circuit. The measuring unit is constructed on the basis of the AD7755/Analog Devices integrated circuit. The circuit provides accurate power and energy measurements as the measurement error over a dynamic range of 500:1 is less than 0.1% (Young-Sung et al., 2010). The unit converts the measured analog signals to digital and allows direct connection to a microprocessor system. The power supply is unipolar and the power it consumes is of the order of 15mW. The block structure, AD7755 integrated circuit, and analytical description of the signal processing performed are shown in Figure 3.

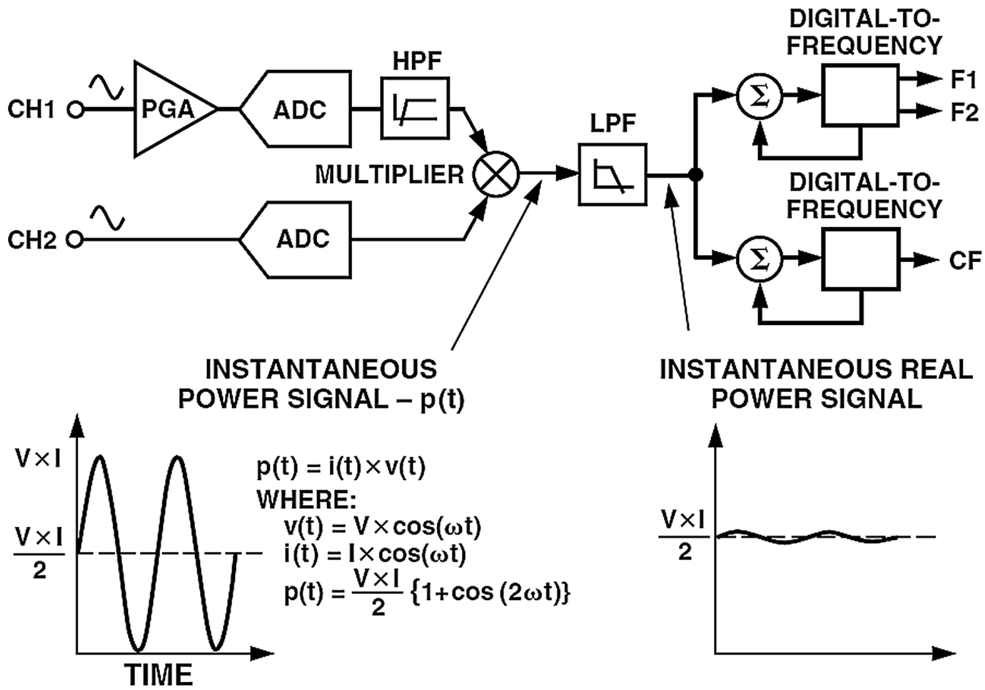

Figure 3. Signal processing block diagram

Results and discussion

Two ADCs digitize the voltage signals from the current and voltage transducers. These ADCs are 16-bit second order sigma-delta with an oversampling rate of 900 kHz. This analog input structure greatly simplifies transducer interfacing by providing a wide dynamic range for direct connection to the transducer and also simplifying the antialiasing filter design. A programmable gain stage in the current channel, which allows the connection of a shunt resistor with low resistance or current transducer interfacing. A high pass filter in the current channel removes any dc component from the current signal. This eliminates any inaccuracies in the real power calculation due to offsets in the voltage or current signals. The real power calculation is derived from the instantaneous power signal (PIC16F676, 2007 Microchip Technology Inc.)

The instantaneous power signal is generated by a direct multiplication of the current and voltage signals. In order to extract the real power component (i.e., the dc component), the instantaneous power signal p(t) is low-pass filtered. Figure 3 illustrates the instantaneous real power signal and shows how the real power information can be extracted by low-pass filtering the instantaneous power signal. This scheme correctly calculates real power for nonsinusoidal current and voltage waveforms at all power factors. All signal processing is carried out in the digital domain for superior stability over temperature and time.

The low frequency output F1/F2/, of the AD7755 is generated by accumulating this real power information. This low frequency inherently means a long accumulation time between output pulses. The output frequency is therefore proportional to the average real power. This average real power information can, in turn, be accumulated (e.g., by a counter) to generate real energy information. Because of its high output frequency and hence shorter integration time, the CF output is proportional to the instantaneous real power. This is useful for system calibration purposes that would take place under steady load conditions.

The CONTOL UNIT (Figure 2) of the energy management controller receives the signal F1 from the output of the circuit AD7755. The component CONTOL UNIT is based on the PIC16F676 single-chip microcontroller. CONTOL UNIT compares the measured energy and current values with the preset limits and makes a corresponding decision directed to the EXECUTIVE UNIT (Figure 1). CONTOL UNIT displays the status of the controller via LED.

The EXECUTIVE UNIT produces pulses of appropriate duration and amplitude to control the power relay. A polarized relay with two separate on and off control coils is used for the power relay. In static mode, the polarized relay does not require power. This significantly reduces the overall consumption of the device. The correct switching of the relay is monitored by feedback – Feedback. If the correct switching cannot be performed, an error signal is activated, visualized by flashing of the LED indicator. The LED indicator shows the status of the controller - normal operation, programming or presence of an error. It also visualizes the amount of consumed instantaneous electricity by flashing at different frequencies.

The electrical energy management controller receives all current settings and transmits data on the measured energy and its internal state via a bidirectional INFRARED PORT (Figure 2). The D/N signal is used to read the consumed electricity at a value corresponding to the day or night tariff. This signal is generated by an external clock that also controls the individual electricity meters of the energy consumer. All component units receive adequate power from the POWER SUPPLY (Figure 2).

Specialized Remote control is used for settings, entering commands, and reading data from the power management controller (Figure 4). The information from the remote control is displayed on a two-line display in Bulgarian.

Figure 4. Signal Specialized remote control of the controller

The remote control communicates with the controller‘s INFRARED PORT and exchanges data to the different hierarchical levels of the controller‘s software using appropriate access passwords.

Conclusion

What we have achieved comprises the design and development of a working system that provides accurate reporting of the consumer’s electricity consumption in terms of the price to pay. Compared to the famous circuit solutions, the designed electrical energy control controller is a relatively inexpensive, reliable and simple to install device. Its use facilitates the relationship between the power supply provider and the consumer under conditions for prior negotiation of the amount of electricity provided or the amount to be paid. On further development of the system, a suitable optical interface for data transmission can be added to a host computer.

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