Single Phase Electricity Meter Based on Mixed-Signal Processor MSP430FE427

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Abstract- An overview of single phase electronic electricity meter using the most recent Texas Instruments mixed signal procesor MSP430FE42x is given. This device offers many advantages like minimum external components, software configurable calibration parameters, automatic calibration process. Use of this device is a smart way to design an electricity meter.

I. Introduction

Power and energy measurement knows many methods. Those suitable for digital electricity measurement may use Hall effect. [1], pulse-width modulation (time-division multiplier), [2], analogue multiplying [3], three-terminal thermoconverter (TTTC), [4], digital multiplication, [5] and others. Every of these methods has its specifical advantages and disadvantages. The accuracy and price of implementation of any method are also different.

Digital power and energy measurement is based on sampling and digitizing of the instant values of the voltage and current in regular time intervals, their arithmetic multiplying in digital form and averaging of the products. Digital method of measuring electricity is more accurate than the analogue. Advantages of this digital devices are obvious: high accuracy, complex net parameters measurements, possibility of remote automated data processing and many other functions resulting from the microprocessor-based digital system possibilities. Digital processing guarantees short- and long-term stability as well as high accuracy of measurement.

II. Electricity meter description

The MSP430FE427 device has been specifically developed for energy metering applications. It includes many of the necessary circuits needed for electronic electricity meter: Analog front-end, digital MCU, LCD driver, memory, clock, as shown in figure 1.

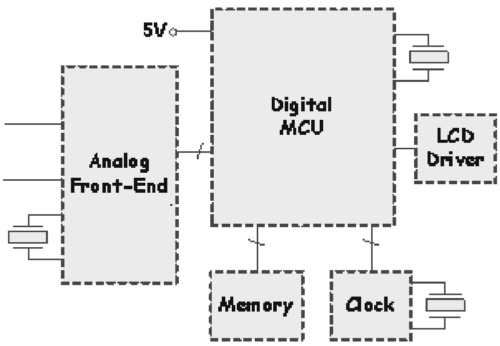

Figure 1 All devices included in MSP430FE427

A. Structure of the electricity meter

Input circiut for voltage measurement consists of resistor net which adjust the mains voltage to input range of A/D converter. Measurement of current is done with current transformers. One is placed in phase line, the second in null line. This organization is necessary for tamper detection. Maximum sampling frequency of voltage and both currents is 4096 samples per second. These samples are multiplied in ESP430CE1 which calculates every second the basic net parameters like rms values of voltage, currents, active energy, phase shift and so on. ESP430CE1 is a signal processor included in MSP430FE427. It takes care of all about the measurement and calculations. It works independent of the main processor leaving it free for other tasks. The main processor takes the results of calculations form the ESP through interrupts.

B. ESP430CE1 Calculations [6]

Active energy calculation

$$W_{act} = \frac{(ACTENERGYx)}{Cz_X} = (ACTENERGYx) * k_{Ix} * k_{V1} * \frac{4096}{f_{ADC}} [Ws] \quad \textbf{(1)}$$

W_{actx} – active energy (x = 1 or 2 respectively to current I1 or I2)
C_{Zx} – constant of electricity meter (for I1 and/or I2)
k_{V1} – meter specific constant
k_{Ix} - meter specific constant
f_{ADC} – sampling frequency of A/D converters

$$k_{V1} = \frac{U_{MAX}}{2^{15}} \quad \textbf{(2)}$$

$$k_{Ix} = \frac{I_{xMAX}}{2^{15}} \quad \textbf{(3)}$$

$$(ACTENERGYx) = \frac{1}{4096} * \sum_{i=1}^{4096} (WAVEFSV1) * (WAVEFSIx) \quad \textbf{[steps}^2\textbf{]} \quad \textbf{(4)}$$

WAVEFSV1–immediate value of voltage,
WAVEFSIx–immediate value of current (I1 or I2)

Active power calculation

$$P_{act} = \frac{(ACTENERGYx)}{Cz_X} * \frac{f_{ADC}}{4096} = (ACTENERGYx) * k_{Ix} * k_{V1} [W] \quad \textbf{(5)}$$

Rms value of voltage

$$(V1RMS) = \sqrt{\frac{1}{4096} * \sum_{i=1}^{4096} (WAVEFSV1)^2} [steps] \quad \textbf{(6)}$$

$$v1_{RMS} = k_{V1} * (V1RMS) \quad \textbf{[V]} \quad \textbf{(7)}$$

RMS value of current I1

$$(IRMS) = \sqrt{\frac{1}{4096} * \sum_{i=1}^{4096} (WAVEFSI1)^2} [steps] \quad \textbf{(8)}$$

$$i1_{RMS} = k_{I1} * (IRMS) \quad \textbf{[A]} \quad \textbf{(9)}$$

C. Automatic calibration process

The automatic calibration means a calibration of electricity meters without a human intervention. The Host Computer is the device which controlls the whole calibration. It simply compares the values of energy from the Calibration Equipment and the values which are provided by the calibrated electricity meters [7]. The Host Computer then calculates the errors of energy for each electricity meter and sends the correction parameters to each of them. The calibration constants of each electricity meter are stored in their FLASH memory.

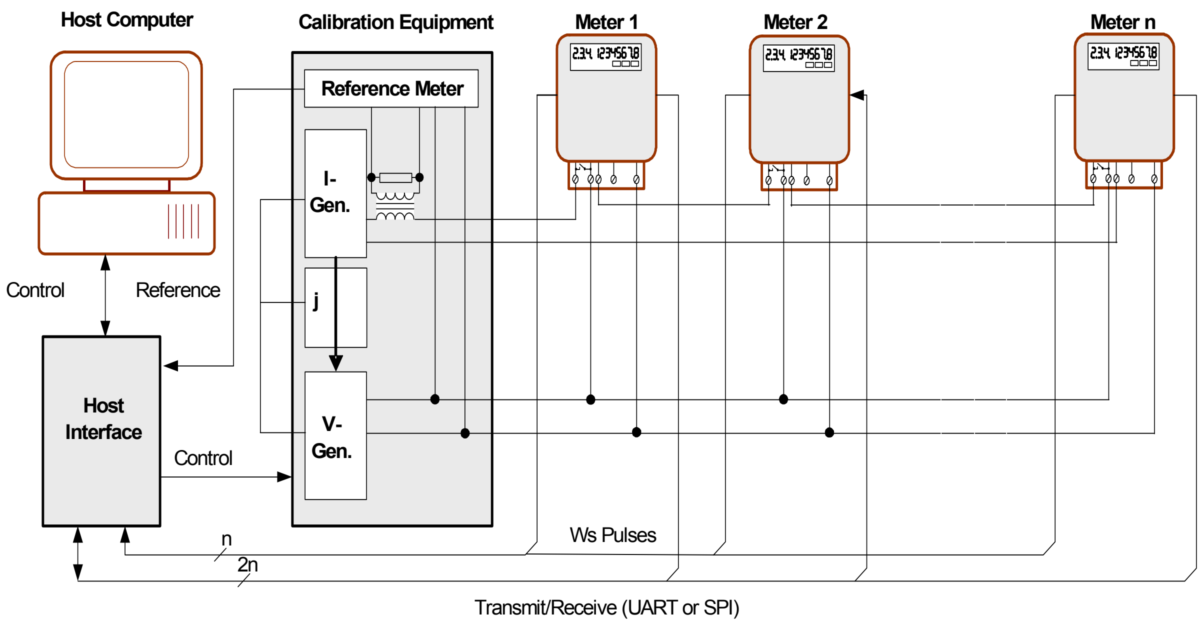

Fig. 2 Automatic calibration process

The Host Computer and Electricity meters are connected via RS-232 interface. As from Figure 2 can be seen there are more electricity meters calibrated simultaneously. Without any communication protocol there can be only two devices communicating together. For this task we choosed a communication protocol *ZPA-RS485* from Křižík GBI. This protocol creates data packets, which includes a start condition of the packet, the addres of the desired device, the data to be transferred (message) and some supervision of correct packet transfer. The message can be a command for one of the electricity meters with some aditional values and so on. The host computer is the device (master), which can send commands. Every electricity meter has its own address, so they can separate the data assigned to them.

With this approach it will be possible to calibrate more electricicity meters in shorter time.

D. Accuracy and energy measurement results of electricity meter

Figure 3 shows the results of active energy measurement for different currents and phase shifts. The maximum error of energy measurement if for the current of 0.2 A and phase shift of -60°. For now, the electricity meter falls with some back-up into accuracy class of 1 %. These results are not final and we believe they will get better.

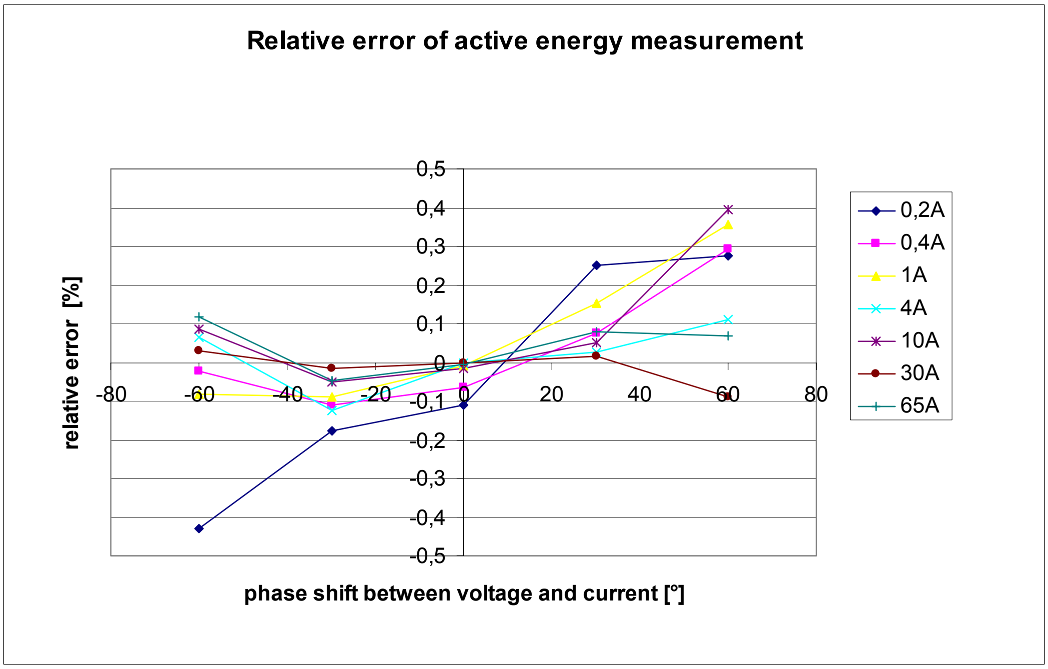

Fig. 3 - Relative error of active energy measured for different currents and phase shifts

III. Conclusions

The MSP430FE427 mixed signal processor has been specifically developed for measurement of electricity. It includes most of necessary circuits usually used by electronic electricity. These features reduce the manufacturing costs of electricity meters. It also offers the automatic calibration process of electricity meters. In the future we will explore the possibilities of data transfer from the electricity meter.
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