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Adjustment method for embedded metrology engine in an EM773 series microcontroller

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ABSTRACT

This paper presents the problems of implementation and adjustment (calibration) of a metrology engine embedded in NXP's EM773 series microcontroller. The metrology engine is used in a smart metering application to collect data about energy utilization and is controlled with the use of metrology engine adjustment (calibration) parameters. The aim of this research is to develop a method which would enable the operators to find and verify the optimum parameters which would ensure the best possible accuracy. Properly adjusted (calibrated) metrology engines can then be used as a base for variety of products used in smart and intelligent environments. This paper focuses on the problems encountered in the development, partial automatisation, implementation and verification of this method.

1. Introduction

Energy management systems are becoming more and more integrated with home automation systems with the aim of enabling increased consumer participation and better control of energy consumption. Because energy costs are getting higher, careful control over all types of consumer devices is desirable. To control the operation of electrical consumers and the energy consumption, various sensor grids [1] composed of energy measuring systems [2,3], procedures [4–10] and standards [11] have been developed.

Power consumption in households in Slovenia reached 3.140 GW h [12] in 2009. The Statistical Office of the Republic of Slovenia reported that the number of households in 2009 was approximately 791 000 [13]. From this it is possible to calculate that a household in Slovenia uses about 10.87 kW h of electrical energy per day. The Statistical Office has also released a report describing how this power is most likely used [14]. From these data the entire daily power usage can be divided into specific consumer areas within households. With power usage for a specific consumer area and the average power usage for specific consumers [15], a rough estimate of how many devices of a certain type are found in an average household can be extrapolated. The results are listed in Table 1.

One such device, which utilizes the EM773 microcontroller with an embedded metrology engine, is used in this study [16,17]. This article presents the development of a method for extrapolating the optimum set of adjustment parameters for metrology engine adjustment.

1.1. A short overview of existing solutions

There are many adjustment (calibration) procedures available for similar devices but they are mostly tailored to the products [18–21], or are used as a guide to preform calibration with the use of certain equipment [22]. This is the main reason why we developed our own adjustment procedure for our chosen device. The main motivation is to try and develop the process to improve the accuracy of electrical consumption measurements on this device platform. If successful the upgraded device will serve as a base platform for variety of smart meter devices.

1.2. A short description of the paper structure

The article is composed from six sections. In Section 2, the metrology engine is presented and initial calculation for adaptation to measure larger currents are performed. In Section 3, the adjustment procedure is presented and the initial experiments are performed. On the basis of results from Section 3, the optimum set of calibration parameters is extrapolated in Section 4. In Section 5, the new metrology parameters are verified, and the last section concludes the paper.

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2. Metrology engine

The EM773 microcontroller has been chosen as the base of an energy metering network because at the time, when the basic design was developed, it was the only solution that came with integrated hardware support for energy metering. It features a metrology engine and it came at a very low price. The NXP Company also provides a developed reference design and full firmware library [17] through which the metrology engine is controlled.

2.1. Hardware

The metrology engine acquires a variety of electrical consumption parameters. The base parameters, such as voltage, are sampled directly. Current is measured indirectly by sampling the voltage drop on a shunt resistor—Fig. 1.

A shunt resistor is a low resistance value (5 mΩ) high accuracy resistor. The small resistance value of the shunt makes it difficult to measure small currents because the voltage drop on the shunt is very low. To enhance the measurement resolution, the metrology engine employs two separate measuring inputs. One uses high amplification for measuring small currents, and the other uses lower amplification, which covers the rest of the measurement range. The measurement range of each input can be adjusted.

To determine how to optimally split the measurement range, a list of possible consumers in a typical household must be analysed. It is also important to estimate how many devices with certain power consumption are likely to be used with the smart metering device. From the data in Table 1, a cumulative distribution of consumers according to their power usage is plotted with the use of EasyFit software [23]—Fig. 2.

Table 1
Most common electrical consumers in a typical household.

Consumer	Power usage for consumers (%)	Power rating for consumer	Number of devices
Lighting	8.8	30 W	32
TV	6.2	150 W	4
PC	3.2	240 W	2
Refrigerator	8.4	420 W	2
Washing machine	5.6	512 W	1
Freezer	8.3	800 W	1
Dishwasher	3.5	1.2 kW	1
Cooking	4.6	1.2 kW	1
Ovens and microwave ovens	4.5	1.45 kW	1
Heating	11.2	1.5 kW	1
Air-conditioner	1.4	1.9 kW	1
Water heater	19.5	2.475 kW	1
Clothes dryer	1.6	2.790 kW	1
Other	13.4	180 W	8

An ideal splitting point between the high and low measurement ranges can be extrapolated from Fig. 2. The power at which the cumulative distribution of consumers equals 0.5 should guarantee equal distribution of consumers in both measurement ranges. The optimum value is extrapolated to be 141.78 W, which translates to 0.59 A. To divide the measurement range at this optimum value, a set of amplifiers must now be adjusted so that high gain can reach saturation at this current. Once the saturation of the high gain input is detected, the metrology engine automatically switches to low gain current input. The metrology engine employs four amplifiers: one for each input and one to generate the reference voltage (Fig. 1). They are implemented with the use of a high-performance operational amplifier, configured as negative feedback, where R1 and R2 are resistors determining the amplification factor—Fig. 3.

The current input amplifiers need to be adjusted, as they need to be designed so that they reach saturation at specific current values. The high gain amplifier needs to reach saturation at approximately 0.59 A, and the low gain at the maximum specified current for the device, which is stated to be 16 A.

Before amplification parameters are calculated, saturation points for each input must be determined. The easiest way to get the data is to analyse the NXP's reference design [17]. NXP's smart socket is designed to measure currents up to 10 A. From the experimental results, acquired on a sample unit of NXP's smart socket, the following parameters for each current channel are extrapolated. Default values are presented in Table 2.

As the specification has the same voltage rating, no new calculation is needed for the adjustment of the amplification factor for the voltage input channel. High gain current limitation is measured to be 0.6 A. Because the difference from the ideal

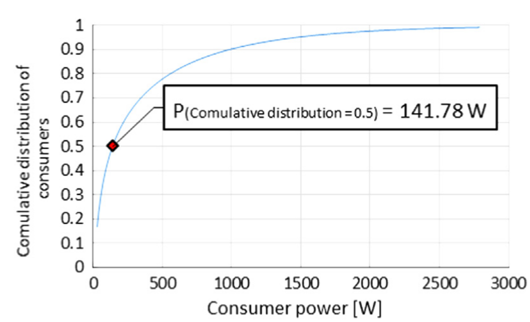

Fig. 2. A cumulative distribution of consumers in an average household.

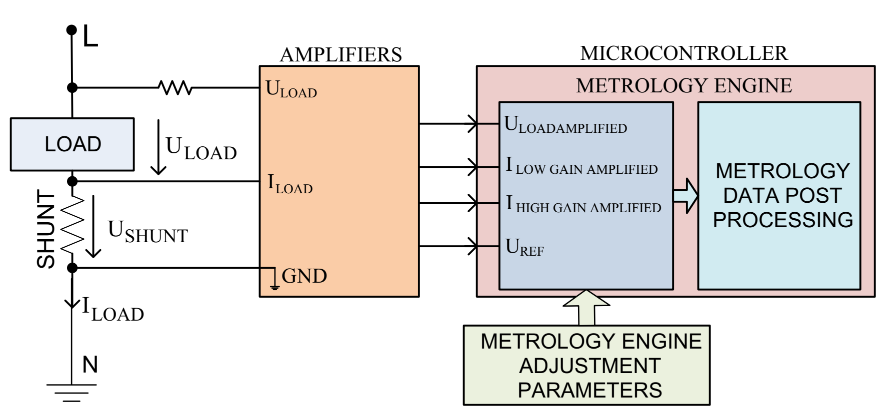

Fig. 1. The basic scheme of a smart metering mechanism.