Automated Meter Reading System for Heat Costs Allocation

IOAN LIE, VIRGIL TIPONUȚ, IVAN BOGDANOV, SABIN IONEL,
CĂTĂLIN DANIEL CĂLEANU
Applied Electronics Department, Faculty of Electronics and Telecomunications
“Politehnica” University of Timisoara
V. Parvan Av, no.2, 300223 Timisoara
ROMANIA
ioan.lie@etc.upt.ro http://www.etc.upt.ro

Abstract: - The paper presents the design and the implementation of an automated meter reading system for heat costs allocation. The system was developed on three levels: the data acquisition level – where data are recorded from field with costs allocators installed on the radiators; a data concentration level – were data registered by allocators are read at a predetermined time interval with data concentration units and a data processing level – for uploading information in a PC hosted data base for various works afterwards. For each level was defined the hardware requirements and the software specifications including the communications modules, the meter and the user interfaces. A PWM data encoding was proposed as an alternative encoding for wireless communication through RF between data acquisition and concentration levels. The system uses RF for data transmission but also includes a pair of RFID modules facilitating remote programming and diagnostic procedures. In order to fulfill the low power requirements the dedicated modules costs allocator and data collection unit were implemented around MSP430 low power microcontrollers.

Key-Words: - Costs allocator, Sensor network, Temperature measuring, Data concentrator, Radio communication, Automatic meter reading, RFID, Low power

1 Introduction

Organizations which provide electric, gas, water and heating service to users are commonly referred to as “utilities”. Utilities determine charges and hence billings to their costumers by applying rates to quantities of the service that the customer uses during a predetermined time period, generally a month. This monthly usage is determined by reading the consumption meter located at the service point (usually located at the point where the utility service line enters the costumer’s house store or plant) at the beginning and ending of the usage month. The numerical difference between these meter readings reveals the kilowatts of electricity, cubic feet of natural gas or water used during the month. Utilities correctly perceive these meters as their “cash registers” and they spend a lot of time and money obtaining meter reading information.

An accepted method for obtaining these monthly readings entails using a person (meter reader) in the field which who is equipped with a hand held computer, who visually reads the dial of the meter and enters the meter reading into the hand held. This method, which is often referred to as “electronic meter reading” or EMR, is still used extensively today. While EMR products today are reliable and cost efficient compared to other methods where the meter reader records the meter readings on paper forms, they still necessitate a significant force of meter readers walking from meter to meter in the field and physically reading the dial of each meter.

The objective of reducing the meter reading field force or eliminating it all together has give rise to the development of “automated meter reading” or AMR products. The technologies currently employed by numerous companies to obtain meter information are: Radio frequency (RF), Telephone, Coaxial cable, Power line carrier (PLC).

All AMR technologies employ a device attached to the meter, retrofitted inside the meter or built into/onto the meter. In the meter reading industry this device is commonly referred as Meter Interface Unit or MIU. Many of the MIU’s of these products are transceivers which receive a “wake up” polling signal or a request from their meter information from a transceiver mounted in a passing vehicle or carried by the meter reading, known as mobile data collection unit (MDCU). The MIU then responsively broadcasts the meter number, the meter reading and other information to the MDCU. After obtaining all the meter information required, the meter reader attaches the MDCU to a modem line or directly connects it to the utility’s computer system to convey the meter information to a central

billing location. While these types of AMR systems do not eliminate the field force of meter readers, they do increase the efficiency of their data collection effort and, consequentially, fewer meter readers are required to collect the data.
Somme AMR systems which use RF eliminate the field force entirely by using a network of RF devices that function in a cellular or fixed point fashion. That is, these fixed point systems uses communication concentrators to collect, store and forward data to utilities central processing facility. While the communication link between MIU and the concentrator is almost always RF, the communication link between the concentrator and the central processing facility can be telephone line, licensed RF, cable fiber optic, public carrier RF.
There is desired an improved meter reading system (including device and methodology) which improves upon the available AMR products through simplification and ease to use.

Nowadays, without doubt, heating systems are in continuous changing, modernization. Heating and water supply services have been constantly improved by raising the efficiency of the thermal stations and networks which has been reflected in increasing the peoples comfort and decreasing the costs. An important step in normalization of the producer-distributor-consumer relation is the countering of these utilities in their transfer locations. An equitable distribution of the costs can't be assured and a real consumption invoice can't be obtained if the thermal energy is not properly measured [1]. For measuring heating and hot waters consumption thermal counting meters are used. The thermal counting meters are designed to compute the heat consumption in the consumption location and to provide quantitative and qualitative information about thermal agent parameters. The technical word used for those devices is heat cost allocators. The electronic heat costs allocator uses one sensor to measures the radiator temperature and a second one to measures the room's temperature [2].

Beside those main functions, costs allocators began to incorporate a MIU in order to implement the functions related to the transmission of the measured results and other useful information. By adding radio transmitters can be implemented the automatic download of measured data to a data concentrator device located out of client's private space. Therefore, is not necessary the periodical access of an operator into a private space. The data collected by special Data Collection Units (DCU) can be uploaded into a data base on a PC, therefore being possible any processing of the recorded data base.

2 System's Requirements

Data acquisition and management systems can be successfully implemented for a large domain of applications, being the first technological step to the automatic control of a process. The purpose of this paperwork is to design a system for heating costs allocation and also to present a solution. The data acquisition and management system was developed on three levels:
- Data acquisition level – data are recorded with modules spread on the field, respective costs allocators installed on the radiators.
- Data concentration – data recorded by allocators are periodically read with data concentrators.
- Data processing – data are stored in a PC's data base with a program which allows works afterwards.

Using the enumeration above, system's architecture looks like the figure 1: The communication between the modules belonged to the three system's levels are bidirectional. By implementing this, it will be a more efficient control over the modules' function.

Therefore, the concentrator module needs to be able to actualize the time reference of the costs allocator module. In a similar way has to be implemented an actualization of the time reference between the PC and the data concentrator.

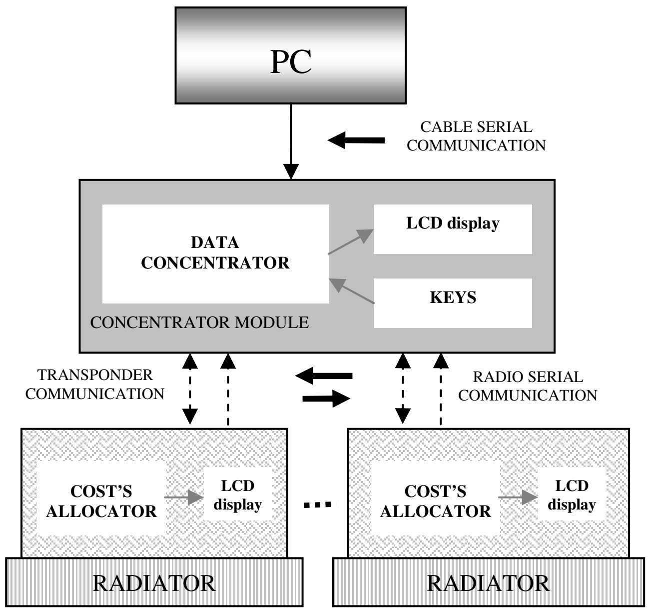


Figure 1 – The system's architecture

Costs concentrator will receive once in 24 hours the data recorded at the allocator's level. Those data can be read at any time by using a command emitted from the data concentrator's level. Data stored in the data concentrator can be discharged in a data base in the PC by using a command within the program which works at the PC's level.

Data concentrator and the data discharging program will be able to test the communications and the functionality of the user interfaces by displaying various values on the allocator's and data concentrator's LCD.

To provide a highly efficiency of the system is impose that the communication between acquisition and data concentrator to be realized wireless. Therefore, is excluded the periodical access of a human operator in the private space. The individual energetic consumption determination will be made by measuring the environment and the radiator's instantaneous temperature with a pre-established frequency and tacking into account the radiator's characteristics.

3 Hardware architecture

The system is made from three subsystems which communicate between them in three different ways. The Costs allocator and the Data concentrator are dedicated systems, made around two microcontrollers from MSP430 family and the third component of the system is a PC.

Costs allocator has the role to take the data from the process, the air and radiator's temperature, to calculate based on those data the energy consumption and to transmit the information to data concentrator. Is made around MSP430F417 microcontroller and it has two temperature sensors, a LCD display and dedicated interfaces for communication through radio and RFID.

Data concentrator has the role to centralize the data received from the allocators and to configurate and synchronize the allocators in the field.

PC is for discharging the data stored in data concentrator's memory and adding them into a data base. It has a XP operating system which is running a program developed in Microsoft Visual Studio 6.0.

3.1. Allocator's structure

The costs allocator's structure is presented in figure 2. MSP430 incorporates a RISC central unit (CPU) 16 bits, specialized peripherals, ROM and RAM, all of them internally interconnected through a data buss, using Von-Newman architecture.

The peripheral includes resources usual for any microcontroller: digital input/output, serial and I^2C interfaces, timers/counters. There are variants that have a LCD controller which allows driving until 160 LCD segments. On some variants are available peripherals oriented on analogical interface like ADC converters and a comparator integrated and flexible with delay and counting system

By its flexibility, the clock system represents an exclusive characteristic of this microcontroller and it was specially designated for low consumption applications. The timers, the comparator and the LCD controller are among the components involved in the realization of the allocator's functions.

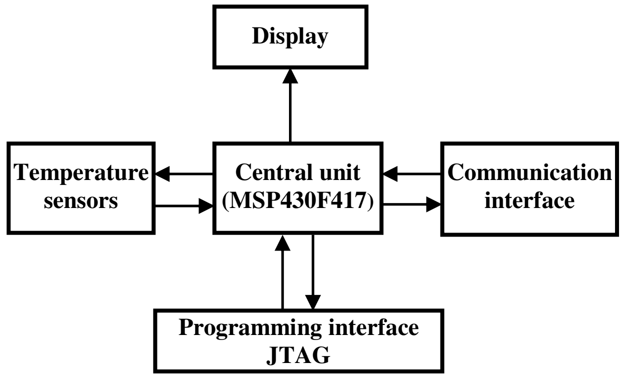


Figure 2 – The structure of an allocator

3.2 Measuring method description

The MSP430 Comparator can be optimized to precisely measure resistive elements using single slope analog-to-digital conversion. For temperature measurement, this can be converted into digital data by comparing the discharge time of a capacitor through a temperature sensor, Rmeas, to that through a reference resistor, R_{REF}, as shown in Fig. 3. This procedure is successively performed for each one of the temperature sensors, one for the radiator temperature, R_{HOT} and one for environment temperature, R_{AIR}. The reference resistor value (R_{REF}) is compared to the one of the sensor (R_{HOT}, R_{AIR}) and so it is obtained the sensor resistor and finally the temperature value from the sensor transfer characteristic.

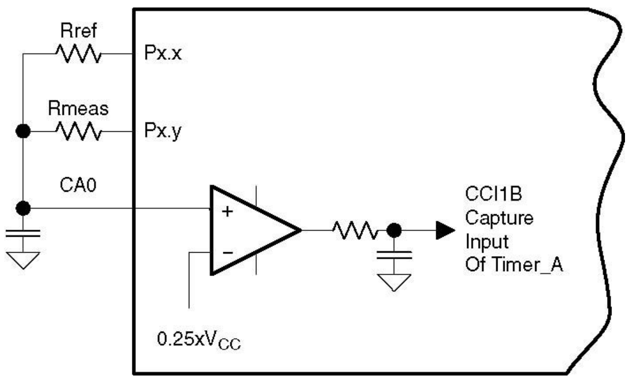


Figure 3 –Temperature measurement setup

The MSP430 resources used to calculate the temperature sensed by Rmeas are:

- Digital I/O pins to charge and discharge the capacitor, the comparator and a timer operating in

Capture Mode activated by the comparator's edge. Each I/O is set to output high to charge capacitor, is reset to discharge and is switched to high-impedance input when is not in use.

- The outputs charges and discharges the capacitor via Rref, R_{HOT}, R_{AIR}.
- The comparator's + terminal is connected to the positive terminal of the capacitor and the – terminal is connected to a reference level, 0.25 x VCC.
- The comparator output is used to gate Timer, which capture the capacitor discharge time.

The sensor measurement is based on a ratio metric conversion principle. The ratio of two capacitor discharge times is calculated as in (1).

$$\frac{N_{meas}}{N_{ref}} = \frac{-R_{meas} * C * \ln \frac{V_{ref}}{V_{CC}}}{-R_{ref} * C * \ln \frac{V_{ref}}{V_{CC}}} \quad R_{meas} = R_{ref} * \frac{N_{meas}}{N_{ref}} \qquad (1)$$

The V_{CC} voltage and the capacitor value should remain constant during the conversion, but are not critical since they cancel in the ratio. The temperature sensors used, PT500, is linear and they have a 1.996 Ω/°C resolution. For this application was used a 47 µF capacitor that assures a discharging time of tens of milliseconds for the sensors that varies round 500 Ω value. We intended to obtain an optimal result between the determination error of the discharging time and the consumed time for the measurement.

3.3. Data concentrator's structure

The data concentrator unit was bulit around a MSP430F449 microcontroller and also contains the following blocks – see figure 4:

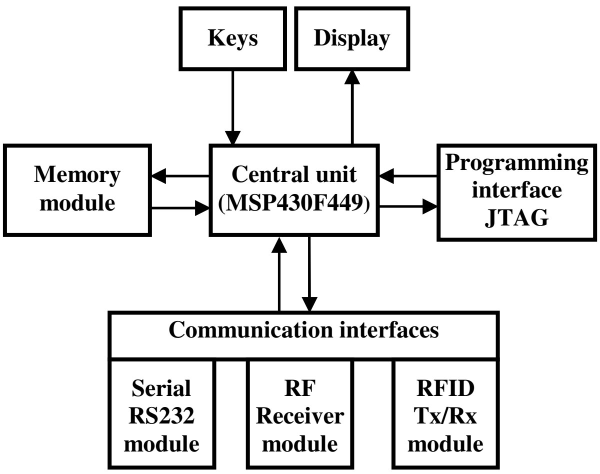


Figure 4 – The structure of data concentrator unit

- LCD display and four keys for user interface
- The EEPROM memory module for storing downloaded data
- the communications modules including:
  - RF receiver, realized with TH71111 FM/FSK/ASK integrated circuit, for collecting data transmitted from allocators at predetermined time interval;
  - Rx/Tx RFID module for configuring and checking the allocation units;
  - serial RS232 interface for downloading information into the PC hosted data base and synchronizing the data concentrator with the central processing unit

3.4 Communication interface – coding solution

The communication interface includes a radio transmitter based on Melexis TH72032 and a RFID module accomplished with discrete components. The radio transmitter was implemented according to the optimal configuration specified by the supplier, presented in [4].

The TH72032 ASK transmitter IC is designed for applications in the European 868 MHz industrial-scientific-medical (ISM) band. It can also be used for any other system with carrier frequencies ranging from 850 MHz to 930 MHz. The transmitter's carrier frequency f_c is determined by the frequency of the reference crystal f_{ref}. The integrated PLL synthesizer ensures that carrier frequencies, ranging from 850 MHz to 930 MHz, can be achieved. This is done by using a crystal with a reference frequency according to: $f_{ref} = f_c/N$, where N = 32 is the PLL feedback divider ratio – figure 5

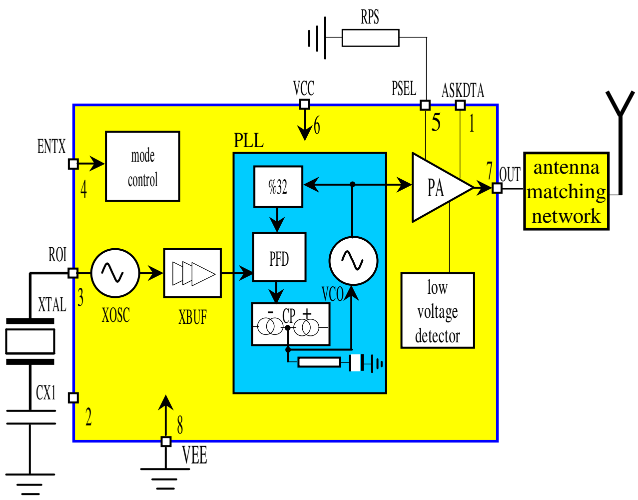


Figure 5 TH72032 ASK transmitter

The PLL transmitter can be ASK-modulated by applying a data stream directly at the pin ASKDTA. This turns the internal current sources of the power amplifier on and off and therefore leads to an ASK signal at the output.

The RFID communication is based on two modules that communicate on the master-slave principle: the master module is installed on the data concentrator and the slave module operates on the costs allocator.

The sequence of information exchange is:

- The data concentrator transmits a command to the costs allocator
- At the end of the command the carrier remains active, un-modulated, expecting the allocator's reply
- The answer of the allocator, reflected in a transistor's switching, is detected by the master's through a modification of the carrier voltage level
- The voltage evaluation is made differential and finally the useful information is re-established.

The slave module is built using a minimal number of discrete components for lower power consumption – see figure 6.

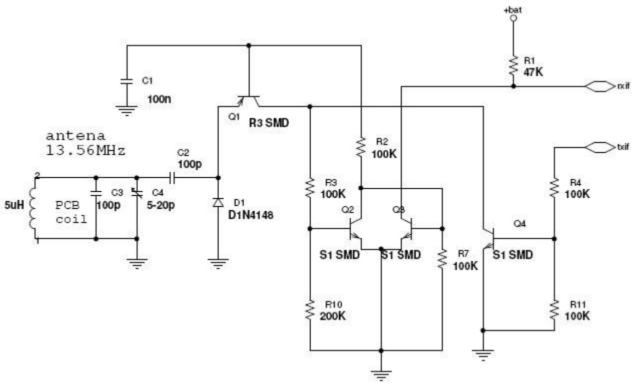


Figure 6 – The RFID – slave module

The "PCB coil" component was made on the printed circuit board. This coil with C3 and C4 capacitors represents a resonant circuit on the 13.56 MHz frequency having the role of an emission-reception antenna. The radio-frequency signal induced in the circuit is applied to the detector circuit formed with D1 and Q1. Q1 transistor has the role of a common base amplifier. C2 condenser with D1 diode and Q1 transistor realize a detecting circuit with voltage duplication.

The capacitor C1 is charged with a voltage proportional to average value of the radio-frequency signal. C1's voltage is used to supply the circuit and also as the reference voltage for the comparator. The hysteresis comparator, formed by transistors Q2 and Q3, has the role to reconstruct the modulation signal. The transistor Q3 also realizes the level adaptation for the microcontroller's input. When no voltage is induced in the antenna, the transistor Q3 is blocked and the consumption from the allocator's battery is null.

When a message is transmitted from the allocator to the concentrator module, the transistor Q4 is turned on depending of the sent bits and determines the periodical deterioration of the circuit's quality factor. This fact will be felt in the concentrator like an amplitude modulation of a very low grade (mV/tens of V).

The two types of communication that exist between the allocator and the concentrator are based on the same protocol. At binary level, when a transmission is realized, the synchronization problem of the communicating modules appears. This problem can be solved by using an efficient coding.

UART communication is not appropriate because is performed an on/off amplitude modulation that makes the low active bits not be represented of the carrier signal. This represents the disadvantage that at large sequences of low active bits, the receptor stays too long without carrier. So, is necessary a carrier codification also for low active bits.

The usable solution was a PWM signal that has a positive front at the beginning of each bit and a 25% space factor for the low active bits, a 75% space factor for the high active bits, [3]. This codification allows a bit level synchronization that makes this communication protocol very robust. The receiving bit's effective value is read at 50% from that bit period, fact that assures sufficient time for the signal stabilization.

In figure 7 is presented the codification that is used in radio communication and in transponder. The transmitted signal (**Tx**) is represented by the exemplification of the bit sequence "010". **te** represents the period that is allocated for a bit and **th** is the tine duration for which the signal is on high state. For the "0" bit, the duty cycle is 25% and for the "1" bit, the duty cycle is 75%.

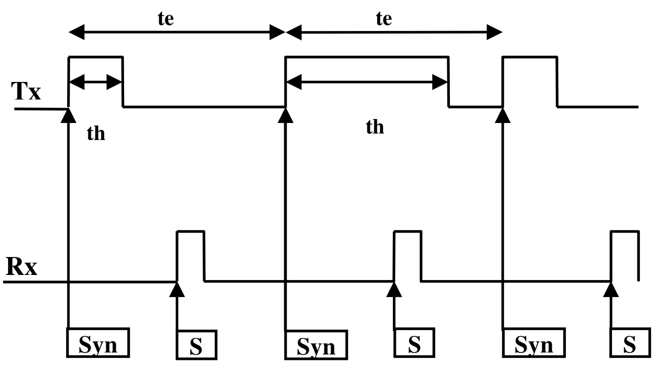


Figure 7 – PWM encoding

At the reception (**Rx**) the synchronization is made at the each bit period beginning, the operation being supported by the fact that every bit begins with an increasing front. The moment of the synchronization was represented by the **Syn** block. At the half of each bit allocated period is figured in the **S** block the moment in which is made the bit value registration.

Bit packet transmission always begins with a preamble that is a synchronization key that brings the receptor in the operation mode. For this preamble was selected the 0xCCCCH value that offers safety because this bit sequent can't accidental appear because of the noise.

4 Software application specifications

The software application must accomplish the following system's functions:

1. The individual consumption determination for a time unit through instantaneous temperature measurement with a pre-established frequency.
2. The reading of the data collected by the cost's allocators without the physical access in a private area by the implementation of a unidirectional radio communication between cost's allocator's modules and the concentrator.
3. The allocator's configuration and synchronization with the data concentrator through the bidirectional implementation of a RFID communication.
4. Data concentrator's synchronization with the afferent PC through the serial line.
5. Information storage in the data base on the PC.

4.1. User interface

At the cost's allocator level the user interface is minimal and is implemented by a LCD display. The 7 available segments are used for the alternative display for the next information:

- Accumulated energy consumption
- Hour and date
- Radiator's instantaneous temperature
- Air's instantaneous temperature
- Possible functional errors

Displayed information on the available LCD display from the data concentrator's level are more elaborated because of the presence of four buttons that permit the options selection from the menu.

Navigation buttons are:

- OK – selected command confirmation;
- ESC – cancel;
- ↑ ↓ – scroll up/down;

The user interface at the PC level designated for downloading the data from concentrator module to the database program is shown in fig. 8

- The buttons Kopplen, Stop, Konfiguration refer to the serial communication between the PC program and the concentrator module. By pressing the "Konfiguration" button a dialogue window appears for the communication parameters initialization at the start of the work session:

- "Test Handheld" offers the possibility of sending various commands to the concentrator module for testing a proper operation. By testing we assume to command the concentrator's display to show a number which is taken from the user by a text box.

- The concentrator synchronization is done with a "Set Time" command which opens a dialog window

- The "UpDate Time" button performs the information initialization by reading the system date and current hour and by displaying them. For actually sending this information to the data concentrator module it is necessary to press the "Set" button to send a message which contains the displayed hour and date.

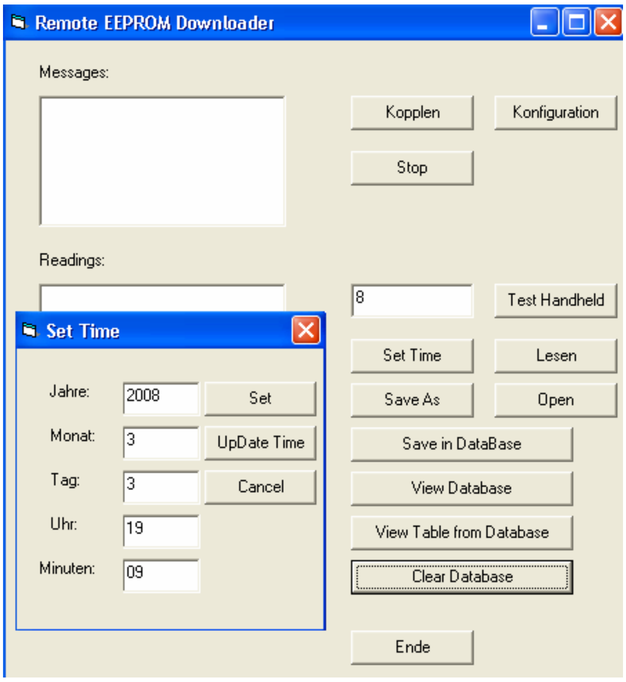


Figure 8 – The user interface at the PC level

For taking the information from the concentrator module EEPROM memory it is necessary to press the "Lesen" button. Messages and data are displayed in the two interface text windows. Further the information can be saved in the data base. The data base can be accessed during a work session without previous discharging data from the concentrator module, in which case the information correspond to some previous module memory readings. For data base visualization a window which contains all the stored records and fields is displayed - fig.9.

The information can be viewed in a tabular format with the option "View Table from Database" which displays a data base table. The data base entries can be removed by using the "Clear Database" option.

The data base necessary for storing the taken information from the concentrator module may contain all the entries from all modules or, optional, may have one table for each concentrator.

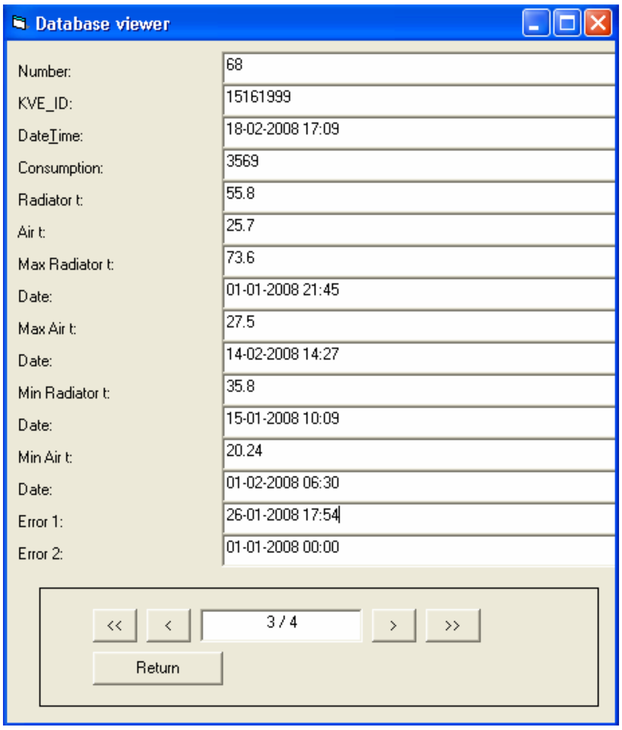


Figure 9 – The Database viewer

Regardless at the number of the necessary tables the structure of one table it is shown in the table 1.

Table 1

Field name	**Type**	**Description**
NR	*AutoNumber*	*Entry number*
ID	*Text*	*Module ID*
Hour and date	*Text*	*The hour and date of the data storing*
Current consumption	*Numeric*	*Registered energy consumption*
Radiator temperature	*Numeric*	*Measured element instantaneous temperature*
Air temperature	*Numeric*	*Air instantaneous temperature*
T_max_radiator	*Numeric*	*Radiator maximum temperature registered during the considered time interval*
Data_max_radiator	*Text*	*The date when this maxim was registered*
T_max_air	*Numeric*	*Air maximum temperature registered during the considered time interval*
Data_max_air	*Text*	*The date when this maxim was registered*
T_min_radiator	*Numeric*	*Radiator minimum temperature registered during the considered time interval*
Data_min_radiator	*Text*	*The date when this minimum was registered*
T_min_aer	*Numeric*	*Air minimum temperature registered during the considered time interval*
Data_min_aer	*Text*	*The date when this minimum was registered*
Date_error1	*Text*	*The date when this error was registered*
Date_error2	*Text*	*The date when this error was registered*
Other information	*Memo*	*Field available for other information*

4.2. System intercommunication

Radio communication is unidirectional, initiated by the allocator module depending on a preset program temporization. The cost allocator sends a message for a preset number of times to avoid the eventual reception errors or data collision. The concentrator module has to be during the data transmission period in his “listening” state.

The allocator always transmits all data package which begins whit a synchronization key. In his “listening” state the concentrator is testing each received bit until the received bit sequence matches the synchronization key. After the synchronization key data bytes are sent followed by check sum and the package end character. After receiving all data we are testing their validity by the check sum evaluation.

In the current work module it is decided a 30 sec period of a 24 hour interval, period in which the concentrator enters in the “listening” state. The 30 sec are sufficient for the allocator to initiate 3 data transmissions, so increasing the possibility that one of the 3 messages is received by the data concentrator.

Transponder communication is bidirectional and is always initiated by the data concentrator. By this type of communication the concentrator can send to the allocator 3 different commands by selecting the menu option:

- reading all the available data from the allocator;
- testing allocator LCD display (all segments on);
- synchronizing the allocator to the concentrator;

The allocator answer to those 3 commands is:

- a data package with a preset number of bytes;
- a confirmation package for display testing;
- a time updating confirmation message.

After sending one command the concentrator is waiting (1.8 sec) for the reply. If an answer is not received (or if the answer has errors) the concentrator sends one more time that command. If the answer is wrong after 3 consecutive commands the concentrator displays an error message and the process is stopped. To resume the communication it is necessary to resend the command.

Serial communication is bidirectional, and takes place between the PC and the concentrator and is the only one which requires a direct cable connection between the two modules. Before any other operation it is necessary to start the communication by port allocation and by setting the proper parameters.

The communication is always initiated by the PC level, from which 3 commands can be initiated:

- concentrator time updating;
- concentrator LCD display testing;
- data reading from the concentrator memory.

The data concentrator reply at those commands is similar with the one in transponder communication.

4.3. Communication protocol

For all the sent messages in all 3 communication types it will be used the same internal structure. The messages will have o set length for a preset command known by the both communication partners. The length of a message modifies from one command to another depending on the command characteristics. In bidirectional communications the reply messages include in the command field the same command that they represent. A message structure is shown below:

START	*COM*	*DATA*	*SUM*	*STOP*
1B	*1B*	*4B/261B*	*1B/2B*	*1B*

The table 2 presents the characteristics of the message fields:

Table 2

Byte	*Field name*	*Values (hex/char)*	*Mnemonic*	*Observations*
#1	*Start character*	*A0*	*START*	*Start Data package.*
#2	*Command*	*a,b,c*	*COM*	*Transmitted command*
#3 ... #n	*Data*	*0..000 – F..FFF*	*DATA*	*Transmitted data, in a BCD format.*
#n+1	*Check sum*	*0000 - FFFF*	*SUM*	*Checking the validity.*
#n+2	*Stop character*	*0A*	*STOP*	*Data package end.*

The command within the message depends of communication context. The possible values of this field are in the table 3 below:

Table 3

Comm	*Values (char/hex)*	*Context*	*Observations*
LCD test	*'a' / 61h*	*Conc -> Alloc PC -> Conc*	*LCD display functioning test.*
Data request	*'b' / 62h*	*Concentrator -> Allocator PC -> Conc*	*Requesting for an available data message.*
Time update	*'c' / 63h*	*Concentrator -> Allocator PC -> Conc*	*The receiver is synchronized with the source.*

Data included in the message depends on the command that makes the message object. Data field particularization is made depending on the previous commented command types.

LCD display testing – the request message, represented in the next figure, has 8B and it is :

0xA0h	*'a'/ 61h*	*0x08h 0xFFh 0xFFh 0xFFh*	*SUM*	*0x0Ah*
1B	*1B*	*4B*	*1B*	*1B*

The first data field byte has the 0x08h, value which must be displayed by each LCD digit. The rest of the bytes are high (0xFFh) so that whole message has an 8 bytes length. The protocol can be extended by using the 3 high bytes. In this case the request message has the same structure and represents the confirmation that the request has been received.

Data request – has a structure similar with the LCD display testing message :

0xA0h	*'a'/ 62h*	*0xFFh 0xFFh 0xFFh 0xFFh*	*SUM*	*0x0Ah*
1B	*1B*	*4B*	*1B*	*1B*

The answer to this message represents the current available data set of the message receiver module level. It is mentioned that in a radio unidirectional communication the message sent by the allocator is identical with a data request answer.

0xA0h	*'a'/ 62h*	*DATA*	*SUM*	*0x0Ah*
1B	*1B*	*4B*	*1B*	*1B*

Data field information are indicated in the table and are in a packed BCD format for not mixing them whit other message fields.

Time updating – current date and hour is sent in the message data field :

0xA0 h	*'a'/ 62h*	*year month day hour minute*	*SUM*	*0x0A h*
1B	*1B*	*5B*	*1B*	*1B*

The request answer is a confirmation of the time updating:

0xA0h	*'a'/ 63h*	*0xFFh 0xFFh 0xFFh 0xFFh*	*SUM*	*0x0Ah*
1B	*1B*	*4B*	*1B*	*1B*

5 Experimental verifications

In our experiments we used a MSP430F417 based allocators with a radio transmitter – Fig. 10, and a concentrator module build around a MSP430449 device – Fig. 11.

There were three experiments. The first experiment was set out to check the communication between Allocator and Data concentrator through transponder and the user interface functionality. All the imposed requirements were found working proper.

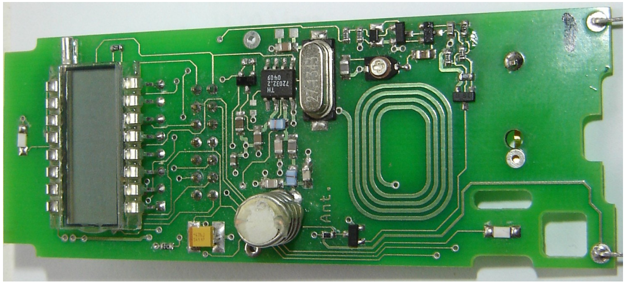


Figure 10 –Allocator with radio transmitter and RFID

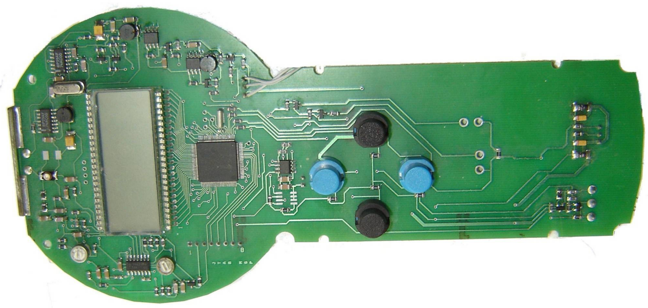
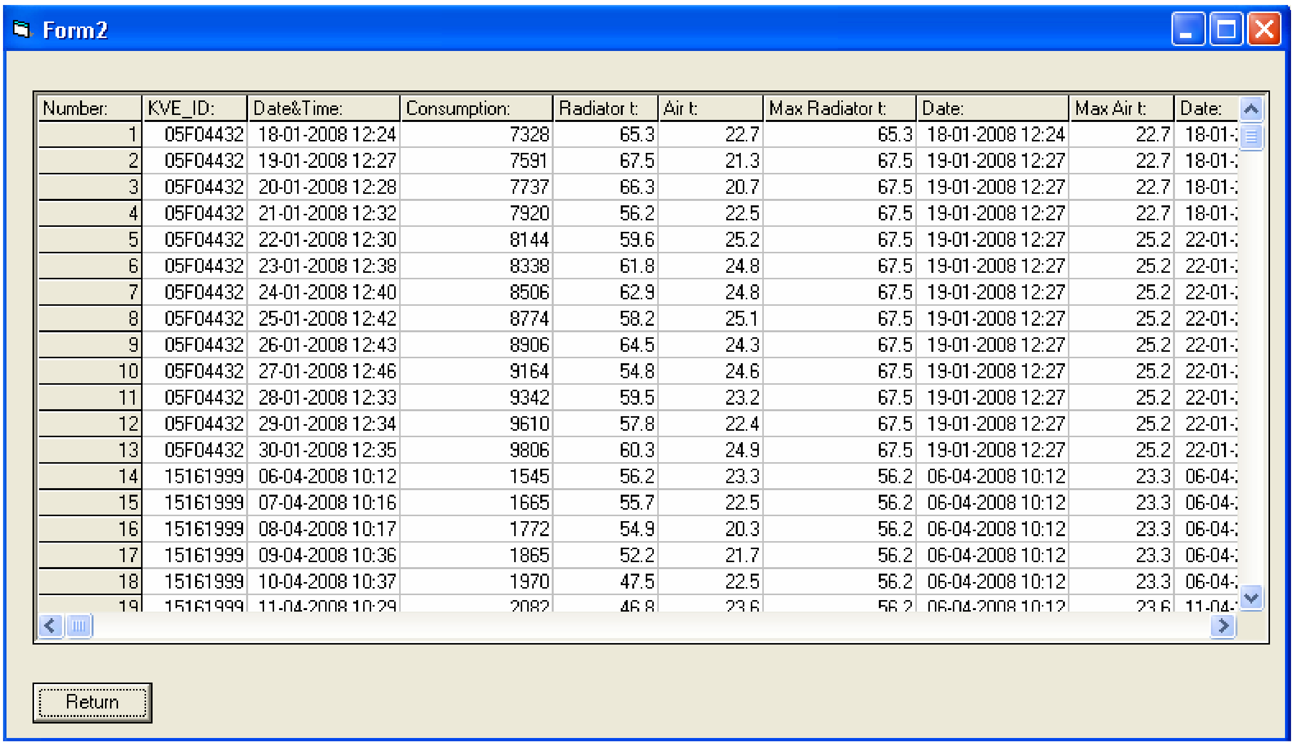


Figure 11 – Data concentrator module

In the second experiment we tried to find out the effective range of the radio connection, using the PWM encoding on our RF radio hardware. In the first experiment we set the transmitter to use the PWM encoding and to regularly send a data package containing 6 bytes of effective data plus the extra data required by our communication protocol. We started out with the transmitter close to the receiver and incremented the distance between the transmitter and the receiver by one meter once a data package was sent. On the receiver side we checked to see if the receiver got the data with no errors. Once the receiver started presenting systematic errors we stopped moving the transmitter and measured the distance between the two. Our experiment was done inside the building and we came up with a range of around 25 meters in this configuration using the Melexis RF modules and the PWM encoding.

A third experiment was set to verify the correct operation of data download procedure and the synchronization of the system's modules through RFID interface and serial line. All the imposed requirements were found working proper. A sample from the visualization table downloaded is shown in figure 12. The data corresponding to each allocator can be extracted for editing in a desired format and/or for other processing operations.



Form2

Number:	KVE_ID:	Date&Time:	Consumption:	Radiator t:	Air t:	Max Radiator t:	Date:	Max Air t:	Date:
1	05F04432	18-01-2008 12:24	7328	65.3	22.7	65.3	18-01-2008 12:24	22.7	18-01-
2	05F04432	19-01-2008 12:27	7591	67.5	21.3	67.5	19-01-2008 12:27	22.7	18-01-
3	05F04432	20-01-2008 12:28	7737	66.3	20.7	67.5	19-01-2008 12:27	22.7	18-01-
4	05F04432	21-01-2008 12:32	7920	56.2	22.5	67.5	19-01-2008 12:27	22.7	18-01-
5	05F04432	22-01-2008 12:30	8144	59.6	25.2	67.5	19-01-2008 12:27	25.2	22-01-
6	05F04432	23-01-2008 12:38	8338	61.8	24.8	67.5	19-01-2008 12:27	25.2	22-01-
7	05F04432	24-01-2008 12:40	8506	62.9	24.8	67.5	19-01-2008 12:27	25.2	22-01-
8	05F04432	25-01-2008 12:42	8774	58.2	25.1	67.5	19-01-2008 12:27	25.2	22-01-
9	05F04432	26-01-2008 12:43	8906	64.5	24.3	67.5	19-01-2008 12:27	25.2	22-01-
10	05F04432	27-01-2008 12:46	9164	54.8	24.6	67.5	19-01-2008 12:27	25.2	22-01-
11	05F04432	28-01-2008 12:33	9342	59.5	23.2	67.5	19-01-2008 12:27	25.2	22-01-
12	05F04432	29-01-2008 12:34	9610	57.8	22.4	67.5	19-01-2008 12:27	25.2	22-01-
13	05F04432	30-01-2008 12:35	9806	60.3	24.9	67.5	19-01-2008 12:27	25.2	22-01-
14	15161999	06-04-2008 10:12	1545	56.2	23.3	56.2	06-04-2008 10:12	23.3	06-04-
15	15161999	07-04-2008 10:16	1665	55.7	22.5	56.2	06-04-2008 10:12	23.3	06-04-
16	15161999	08-04-2008 10:17	1772	54.9	20.3	56.2	06-04-2008 10:12	23.3	06-04-
17	15161999	09-04-2008 10:36	1865	52.2	21.7	56.2	06-04-2008 10:12	23.3	06-04-
18	15161999	10-04-2008 10:37	1970	47.5	22.5	56.2	06-04-2008 10:12	23.3	06-04-
19	15161999	11-04-2008 10:29	2082	46.8	23.6	56.2	06-04-2008 10:12	23.6	11-04-

Return

Figure 12 – A sample from data base visualization table

6 Conclusion

An acquisition and management data system, designated for energy costs allocation was designated and tested. For each level of the system was defined the requirements and the hardware/software implementation solutions.

The main aim was to verify the performances of the in system communication solutions, the proper operation of the user interfaces and the data download procedure to the PC hosted data base.

A PWM data encoding was proposed as an alternative encoding for wireless communication to be used in low cost and low power sensors. The main advantage of this encoding is the ability to implement the transmitter and the receiver without much hardware support and of being less sensitive to timing errors. The system has a RFID module facilitating remote programming and diagnostic procedures. The system can be adapted for water meters, gas meters and electric meters. In the case of water and gas meters, an internal lithium battery provides an operational life of up to ten years. In the case of the electric meter, power is tapped directly from the electric service.

References:

[1] Heat Cost Allocators for the Detection of the Consumption of Radiators. Appliances with Electrical Energy Supply, EN 834.

[2] I. Csoknyai, Methods of Heat Cost Allocation, *Periodica Polytechnica* Ser. Mech. Eng. Vol. 44, No. 2, 2000, pp. 227–236.

[3] nAN400-07, "nRF™ Radio protocol guidelines", *Nordic VLSI ASA application note*, December 2002.

[4] Melexis GmbH, TH72032 868/915MHz ASK Transmitter, Datasheet rev. 08, June 2007, www.melexis.com

[5] Melexis GmbH, TH71111 868/915MHz FSK/FM/ASK Receiver, Datasheet rev. 013, June 2007, www.melexis.com

[6] A. Mainwaring, J. Polastre, "Wireless Sensor Networks for Habitat Monitoring", *ACM International Workshop on Wireless Sensor Networks and Applications - WSNA'02,* September 28, 2002, Atlanta, Georgia, USA.

[7] P. Oksa, M. Soini, J. Nummela, L. Sydänheimo, M. Kivikoski, "Making AMR Systems More Reliable", *WSEAS Transactions on Communications*, ISSN 1109-2742, Issue 2, volume 5, February 2006, pp. 161-167.

[8] S. Srinivasan, A. Aggarwal, A. Kuma, "RFID Security and Privacy Concerns", *WSEAS Transactions on Communications*, ISSN 1109-2742, Issue 2, volume 5, February 2006, pp 296-301.

[9] T. Tammet, J. Vain, A. Kuusik, "Using RFID Tags for Robot Swarm Cooperation", *WSEAS Transactions on Systems*, ISSN 1109-2777, Issue 5, volume 5, May 2006, pp. 1121-1128.

[10] M.-S. Jina, K. Shiuh Y. and C.-L. Lee, "Modular RFID Parking Management System based on Existed Gate System Integration", *WSEAS Transactions on Systems*, ISSN 1109-2777, Issue 6, volume 7, June 2008, pp. 706-716.

[11] W. Stallings, *Data and Computer Communications (7th ed.).* Prentice Hall, pp. 137-138. ISBN 0-13-100681-9, 2004.

[12] S. K. An; S. I. Park; S. B. Jun; C. J. Lee; K. M. Byun; J. H. Sung, "Design for a Simplified Cochlear Implant System", *IEEE Transactions on Biomedical Engineering,* Volume 54, Issue 6, June 2007 Page(s): 973 – 982.

[13] M. Varchola, M. Drutarovský, "Zigbee Based Home Automation Wireless Sensor Network" *Acta Electrotechnica et Informatica*, No. 4, Vol. 7, 2007, ISSN 1335-8243, Technical University of Košice, Slovak Republic

[14] L. Youbok, Microchip Technology Inc."CRC Algorithm for MCRF45X Read/Write Device" *http://ww1.microchip.com/downloads/en/AppNotes/00752a.pdf*

[15] J. L. Hill, "System Architecture for Wireless Sensor Networks" *PhD Disertation*, Univerisy of California, Berkeley, 2003.

[16] K. Whitehouse, "The design of calamari: an ad-hoc localization system for sensor networks." *Masters Report*, University of California at Berkeley, 2003.

[17] A. Cerpa et al., "Habitat monitoring: Application driver for wireless communications technology". *ACM SIGCOMM Workshop on Data Communications in Latin America and the Caribbean*, 2001.

[18] A. Woo, D. Culler, "Evaluation of Efficient Link Reliability Estimators for Low-Power Wireless Networks.", *Technical Report*, UC Berkeley, 2002.

[19] Y. Xu, , J. Heidemann, and D. Estrin, "Geography-informed energy conservation for Ad Hoc routing." 2001, *ACM Press: SIGMOBILE: ACM Special Interest Group on Mobility of Systems, Users, Data and Computing*. pp. 70 - 84.

[20] Texas Instruments, MSP 430 Family, *User's Guide*, slau056c, 2003