WEB Based Electronic Energy Meter suitable for Energy Efficiency Analysis

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This paper presents an WEB based electronic power metering system using the MCP3905 energy metering chip from Microchip® together with the microcontroller PIC18F67J60 for the data processing. The purpose of the system is to monitor active power consumption of domestic electric devices like air conditioners, stoves, lights, hot plates, etc. The system provides RJ45 interface for connecting to the Internet to logging the data into a backend or controlling the monitored device (data logger or host system).

Keywords – **Power Consumption, Energy meter, WEB based, TCP/IP stack, Home Automation**

I. Introduction

It is important for us to know exactly how much power consume our electronic devices. This is especially true for cooling/heating (HVAC) devices. A look over the measurements and statistics can show any problems in high cost monthly bills; also it will show the energy efficiency. Now the energy efficiency analysis is the top priority policy in European Union [4]. This paper describes a solution for a cheap WEB based high-precision measurement system suitable to use for energy analysis.

The system is based on two basic modules: database system and measurement and process controllers. The communication between is done using the Internet. HVAC controller implements own internal WEB server. That allows simple real-time monitoring of the controllers' parameters, also to implement some control possibility (for example setting by the remote user which can use a simple smart phone and internal browser in the phone).

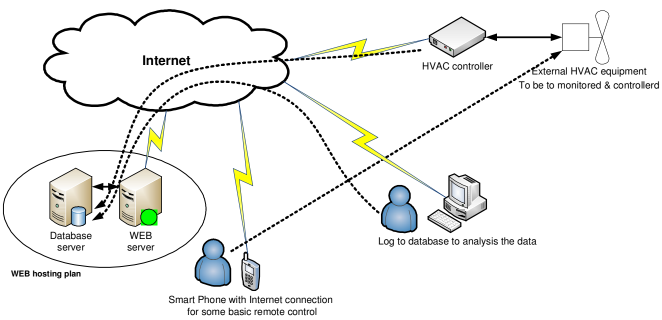

Figure 1 – High Level Schematic

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The controller periodically reports measured data to external database server. The communication with the server is based on HTTP protocol; that allows standard hosting plans to be used (WEB and database server on one machine). In our previous project we used local web hosting company. They offered PHP web server with 1GB storage space, unlimited traffic to the server and 3 databases, which is enough for the current project. Because the communication from the controllers is done by Internet,

it is good the hosting company to be a local one (the database storage server to be as close as possible to the controllers to ensure shortest data path of the communication). It will be not a problem if the HVAC controller is placed all over the word. If the connection to the Internet goes down, the controller implements own memory to store temporary data. After the connection is established again, the temporary memory is transferred to the database server automatically.

So, for the software side the requirements are for good WEB hosting, supporting PHP and databases support of MySQL. The programming uses PHP and HTML technologies. The graphics are done using own PHP script code on the WEB server. Some data analysis and calculations (for example the tabular results) also uses PHP code on the database server side. Code can be uploaded to the server remote using FTP (File transfer protocol) also the database can be managed remotely.

This device could be a part from an energy efficiency analysis system [1,2,6]. The design uses four core components listed down:

- The MCP3905A/05L/06A devices are energy-metering ICs designed to support the IEC 2053 international metering standard specification [3]. They supply a frequency output, proportional to the average active real power, as well as a higher-frequency output proportional to the instantaneous power for meter calibration. They include two 16-bit Delta-Sigma ADC for wide range input currents. There is a DSP block built into the chip for active real-power calculation. A no-load threshold block prevents any current creep measurements.
- The DS1302/07 serial real-time clock (RTC) is a low power; full binary-coded decimal (BCD) clock/calendar plus 56 bytes of non-volatile SRAM. Address and data are transferred serially trough an I^2C bi-directional bus. The clock/calendar provides seconds, minutes, hours, weekday, date, and month and year information. The chip has built-in power-sense circuit that detects power failures and automatically switches to the backup supply.
- AC204Y is 20 characters x 4 lines LCD display with integrated controller (KS0066U). The display operates on 5V power supply. It has 8-bit wide data bus (can be used in 4-bit mode) and 3 control lines. Its instruction set contains 11 commands. Its font table contains 210 factory defined characters and 16 user definable characters.

II. Functional Blocks and Working Principle

The device includes nine functional blocks (see Fig. 2). Every block is separated on the printed circuit board (Fig 3). There is isolation between the high-voltage measurement part and the low-voltage computing unit.

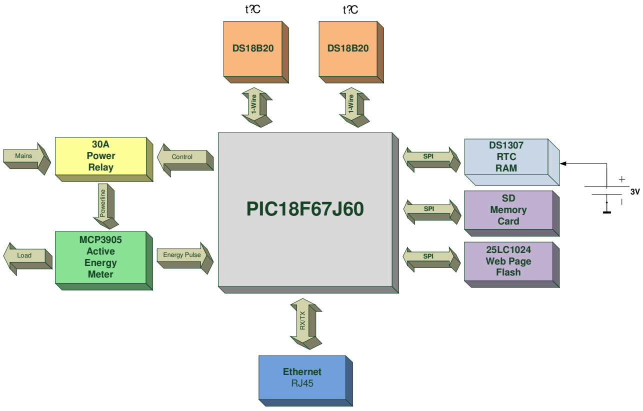

FIGURE 2 – HIGH LEVEL SCHEMATIC

The hardware of the controller is more interesting. It implements many possibilities. First it implements real time clock (RTC) to maintain the timestamp of the data samples. This real-time clock is automatically synchronized with the Internet timeservers. The RTC has build in battery to ensure correct time after the main power goes down, also the RTC has small memory to store some data parameters when the device is switched off (or main power goes down).

A SD (Secure Digital) memory card interface exists to allow some data storage and back up. This is the temporary memory if the connection to the Internet goes down.

The controller has many I/O pins some of them are analogue. It can measure up to 10 analogue voltages for sensors (temperatures, pressure, electrical power consumption etc.). Currently we do not use these analog inputs because the temperature sensors we used are digital type (1-Wire bus sensors). They are more precisely than the analog thermometers and there is no communication error from the connection cable (noise and interferences). The temperature sensors are DS18B20, manufactured by Dallas semiconductors and can be used in temperature range of –55C to +125C degrees. The powerful think of their use is that every sensor has unique custom address, allowing many sensors to work in parallel and to use single flexible bus of 3 wires and error free signals on that bus. This allows monitoring of more than 10-15 temperature parameters at the same time (time division method). The temperature conversion of the sensors is quite small – about 750nS, so if the controller measures 10 temperatures, the conversion time for both will be around 7,5mS.

If the temperature range of the used sensors is quite small (maybe the highest possible temperature of +125C will be too small), we can base a thermistor or thermocouple connected to the analog inputs instead of the digital semiconductor sensors.

Electrical energy measurement is another urgent part of the project. Currently we use a single-phase electrometer for active (real power) energy to measure consumption up to 20kW supporting IEC 62053 specification (higher part of the electronics on the picture). The used chip is MCP3905. For the highest power we can add a current transformers. For a 3 phase measurement (for the high power applications we can base another energy measurement chip – MCP3909.

Available analog inputs on the microcontroller allow other signals to be measured. For example the pressures via pressure transducers can be measured. All data can be visible also on LCD display.

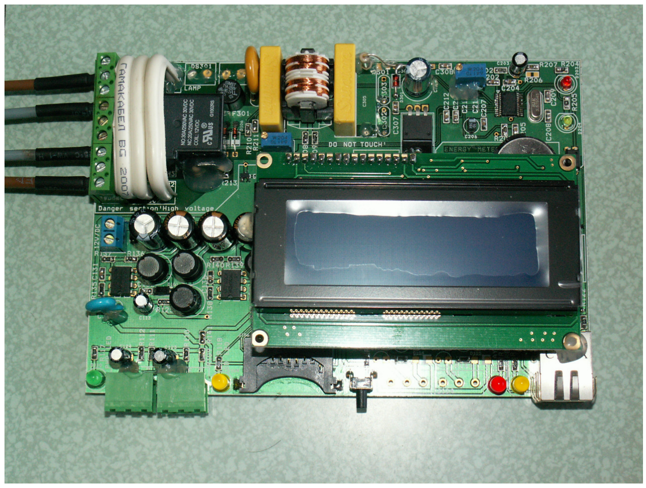

FIGURE 3 – PCB OF THE MEASUREMENT MODULE

Power supply block

Power supply for the digital devices on the board is taken from the main power network trough transformer, rectifier and stabilizer. The transformer is connected before the measuring part of the device to avoid measuring self-consumption (which is smaller than 1W). The transformer lowers the mains voltage to 12V. The lowered voltage is driven trough a diode bridge after which is connected a switching voltage stabilizers LM2575T-5.0. It outputs 5V and 3.3V for the rest of the circuit.

Measurement block

It is based on the MCP3905 chip from Microchip®. That part of the board is isolated and disconnected from the other parts of the device by transformers and optical connections. The consumption is calculated via measuring voltage and current sink from the target device. The voltage is lowered to safe range with suitable voltage divider. The current is measured by measuring voltage drop onto a shunt with fine grade precise resistance. It is calculated that so the voltage drop onto it should be in a device-safe range. These two values are driven to specified chip inputs, which are connected to an internal two-channel Sigma-Delta ADC. After conversion the values are multiplied in the hardware DSP block. The result is converted to a sequence of square pulses with proportional frequency to the active power. The range of the measurement can be defined via some configuration pins that set gain of the Channel 0 (current channel) and multiplication of the output frequency. This chip outputs two signals – one low frequency and one high frequency. In the current design the high frequency output is used. The chip has a built-in driver for controlling mechanical counters in cheaper and simpler systems.

Computing block (PIC18FJ60)

The microcontroller we used is manufactured by Microchip. It is an 8-bit RISC microcontroller with integrated Ethernet module, which allows the data communication using simple Internet connection. Programming of the microcontroller is more complex, due some low-level programming style. We used ANSI-C and C18 compiler. The programmer connects to the board using six-wire cable to an external connector. This allows the board to be programmed flexible without chip replacement or any soldering actions. After the controller board is finished (in prototyping phase), then no programming or supporting of the hardware is required. The controller only collects the data, which is processed by the WEB & Database server in the external storage analysis system. If a new statistical query to the data needs to be done, it is programmed on PHP code for the WEB server.

Real time block

It is based on the DS1302/07 single-chip clock/calendar from Dallas®. The block has its own emergency power (a 3.6V Li-Ion battery) that is used when a main power failure is detected. Uninterrupted and continuous work of the chip is needed because it is the non-volatile memory of the device. The chip provides independency of the device from any outer-board clocks that are used in the old mechanical power metering systems. The chip has square wave output pin which frequency can be software programmable.

Display block

The LCD module has its own backlight and fine contrast control, which make it comfortable for observation in different situations.

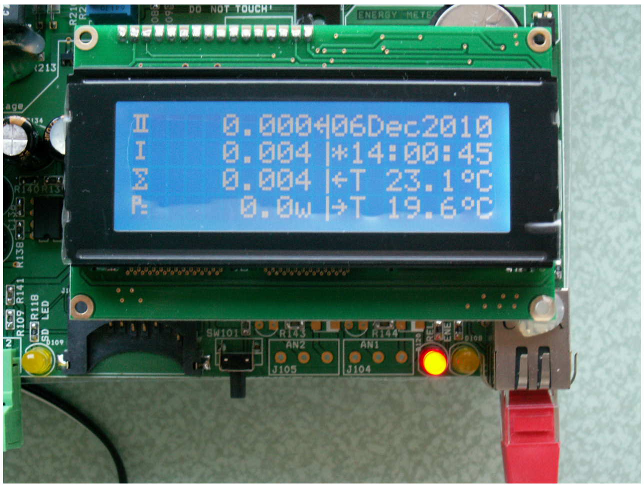

FIGURE 4 – DISPLAY INDICATIONS

It is based on AC204Y LCD from Ampire®. The module is working at 8-bit data, which is faster than 4-bit data rate. Most frequently used commands are: SET DDRAM ADDRESS (moving the cursor) and WRITE DATA TO DDRAM (putting a symbol on the display grid). The following indications are displayed (see Fig. 4): instant power (P=) [W] (5 digits, 1 decimal dot, one digit after), total power counters for day (II) and night (I) and sum (∑) rate [kWh] (5 digits, 1 decimal dot, 3 digits after) and current time (DD/MM/YY HH:MM:SS).

Communication block (Ethernet RJ45)

The controller reports all the parameters to the internal WEB server. That way the parameters can be monitored remotely using standard WEB browser, connected to the IP address of the device. The controller reports all the data automatically every one minute to the external database server. It makes connection to the server using unique ID & password and sends also a CRC code of the transmitted block. This technique is used to discard invalid data coming to the input interface of the data storage server.

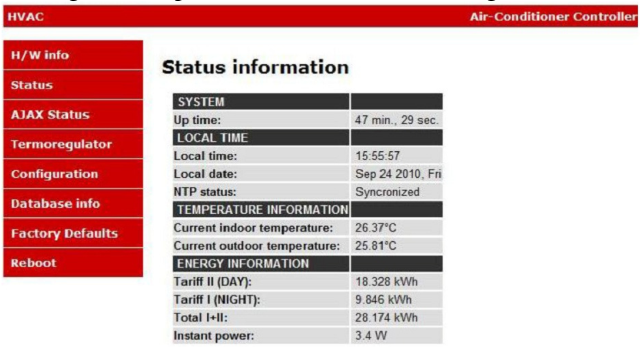

FIGURE 5 – EMBEDDED WEB INTERFACE OF THE CONTROLLER

The external server uses also accountings to make access control. Some of the monitored devices can be viewed by everyone (public devices) or to me monitored only if a user logs in using its account information. After user logs in, he can monitor all public and all private devices belongs to his account. All the graphics are done using simple drawing functions in PHP. I do not use any external graphics tool or library. That makes the system universal and it can work on most of the hosting servers.

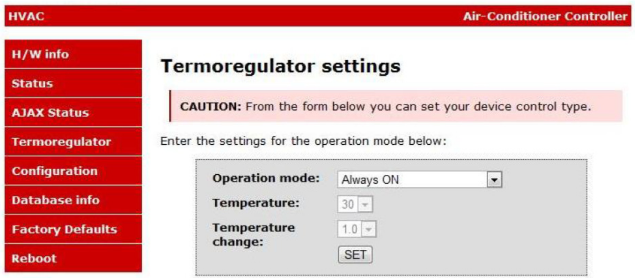

FIGURE 6 – REMOTE CONTROL USING WEB INTERFACE

III. EXPERIMENTAL RESULTS

The presented energy measurement module is used in a complex system for analysis of the energy efficiency of HVAC equipment. In this statistical experiment we investigate the efficiency of inverter air-conditioner, which is overrated [1, 2].

A graph of total consumption in time is illustrated on figure 7. The investigated model was ASY-A12LCC, developed by Fujitsu-General Limited. The nominal heating power of the model is about 4,8kW and the unit was installed in a small living room (about 14 square meters) with heating requirements about 1,8kW.

TABLE 1. AIRCONDITIONER CONSUMPTION VS TIME

Month	Tariff II (day) (kWh)	Tariff I (night) (kWh)	Total, (kWh)	Cost (day) (BGL)	Cost (night) (BGL)	Total cost, (BGL)	Consumption, Avg (W)	Avg in temp (°C)	Avg out temp. (°C)
2009-Dec	115.34	57.29	172.63	20.33	6.72	27.05	293.63	21.42	4.14
2010-Jan	159.3	77.58	236.87	28.08	9.1	37.18	318.39	21.31	1.86
2010-Feb	112.17	58.3	170.47	19.77	6.84	26.61	253.67	20.33	4.46
2010-Mar	64.75	33.2	97.95	11.41	3.89	15.31	131.84	19.15	9.11
2010-Apr	19.85	16.99	36.84	3.5	1.99	5.49	51.17	20.71	14.83
2010-May	0.12	0.05	0.17	0.02	0.01	0.03	0.23	22.96	20.33
2010-Jun	6.45	2.5	8.95	1.14	0.29	1.43	12.43	25.13	22.84
2010-Jul	27.39	7.98	35.37	4.83	0.94	5.76	47.54	25.85	25.68
2010-Aug	43.43	13.95	57.39	7.66	1.64	9.29	77.13	26.41	28.53
2010-Sep	0.29	0.14	0.43	0.05	0.02	0.07	0.59	24.82	21.93
2010-Oct	50.04	32.53	82.57	8.82	3.82	12.64	110.83	22.06	12.95
2010-Nov	30.22	21.13	51.35	5.33	2.48	7.81	71.32	22.12	14.31
2010-Dec	128.37	71	199.37	22.63	8.33	30.96	267.97	21.7	4.13
2011-Jan	125.66	70.87	196.53	22.15	8.31	30.46	264.16	22.02	3.4
2011-Feb	102.96	57.42	160.38	18.15	6.74	24.88	238.67	21.47	4.75
2011-Mar	91.99	52.1	144.08	16.22	6.11	22.33	193.92	21.69	8.97
2011-Apr	46.03	39.77	85.8	8.11	4.66	12.78	119.18	21.48	13.39
2011-May	14.14	12.05	26.18	2.49	1.41	3.91	39.56	22.38	18.53

The graph on figure 7 starts from 1st-JUN-2010. The results from the measurements show that the required electrical energy for heating is 4,9 times higher than the energy in cooling mode. The heating mode continues 6 months, while the cooling continues only 3.

The result from the measurement show that the efficiency of the inverter air-conditioner increase, when the air conditioner works below its nominal power (measured Heating Seasonal Power Factor is 5,07). The HSPF factor, listed in the specifications for this model, when it is used around 4,8kW is about 3,40.

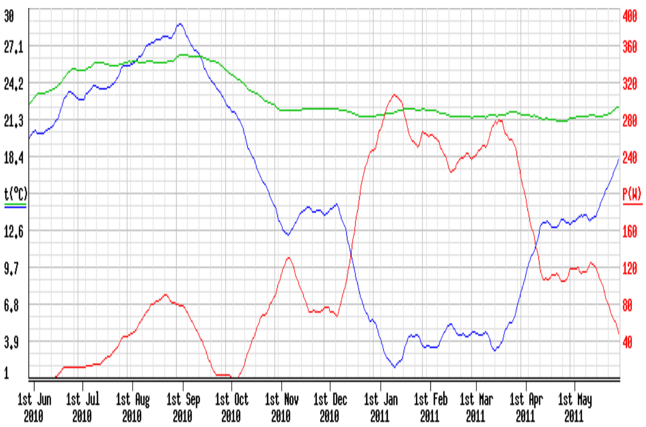

FIGURE 7 – CONSUMPTION OF DOMESTIC AIR-CONDITIONER

The electronic power meter is compared with the industry ones, installed by the energy companies on their customers. In the comparison we used ACE2000 type 290, manufactured by Actaris [5]. The Itron ACE2000 type 290 meter with internal real-time clock is a compact meter offering cost-effective, complex tariff functionality with enhanced features. EVN Bulgaria EAD installs it on its customers. The comparison shows difference of 0.3% in the total measurements using both on same complex load.

IV. CONCLUSIONS

The presented device is a suitable solution for monitoring power usage by domestic electric devices. It has a communication capabilities and this allows the device to be used as an embedded power-metering module in complex systems. Also additional features can be built in, because most of the computing power of the MCU is idle. The precision of the RTC is enough for the purpose of the device - one second difference for 3 days means about one minute difference per year. The maximal electrical load power that can be measured is about 20kW. The presented measurement module also displays the instant power and it is easy to calibrate.

A new hardware is planned. It uses PLC modem chips (ARM7 based AMIS-49587 which are compliant to IEC1334-5-1 IEC 1334-4-32 / EN50065). A one Internet gateway will collect data from multiple controllers via existing power line.

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