REDUCING THE ENERGY CONSUMPTION OF SYSTEMS WITH THE INTEGRATED CIRCUIT TI 430FR2433

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Abstract: The Texas Instruments microcontrollers in the MSP 430 series offer four ways to save power in operation in such a way as to allow for consistent reduction of the electricity consumed. Code Composer Studio programming environment also provides support in making low-power applications. In addition to these, the MSP430FR2433 microcontroller with ferroelectric RAM allows data to be stored even in the absence of power voltage. In view of these properties of the microcontroller, a data logger application has been developed to monitor the quality of the environment in a building. Given that the MSP430FR2433 microcontroller can process both analog and numerical signals, the device monitors the temperature, humidity, carbon dioxide concentration and amount of light present in the enclosure. Thanks to energy-saving mechanisms and the possibility of keeping information for an indefinite period without the need for energy consumption, the ambient quality monitoring device can operate for a long time in places without energy resources. The device has also been tested with good results for autonomous operation using solar energy and has also been used to determine the energy performance of buildings.

Keywords: msp430 microcontroller, energy consumption, data recorder, ultra-low power, ferroelectric ram, power management, disruption management

1. INTRODUCTION

The notion of Low Power Microcontroller is closely related to the application in which we want to use this device [1]. Currently there are many firms that produce energy-consuming microcontrollers for simpler or more complex applications. For example, Cortex-M0+ from NXP or Freescale are considered to be the most energy-efficient microcontrollers. However, for simple, general-purpose applications, one of the acclaimed microcontrollers is the MSP430 Texas Instruments microcontroller [2]. Due to the advantages of low energy consumption and due to the mechanisms made available to the designer, shown below, for the application presented in this work was chosen the MSP430FR2433 microcontroller.

The MSP430FR2433 microcontroller from Texas Instruments is a Mixed-Signal Microcontroller with the following princely features: 16-Bit RISC Architecture, Clock Supports Frequencies up to 16 MHz, Optimized Ultra-Low-Power Mods (Active Mode: 126 µA/MHz Typical, Standby: <1 µA with VLO, LPM3.5 Real-Time Clock (RTC) With Counter, 32768-Hz Crystal: 730 nA Typical, Shutdown LPM4.5: 16 nA Typical), 8-Channel 10-Bit Analog-to-Digital Converter (ADC), Sample-and-Hold 200 ksps, Enhanced Serial Communications, Low-Power Ferroelectric RAM (FRAM): Up to 15.5 KB of Nonvolatile Memory. These features were presented to show the tools available to reduce energy consumption and achieve an Ultra-Low-Power regime [3].

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The central unit MSP430FR2433 is programmed to ensure the low-energy operation of applications ensuring that the following requirements are met low power, ensuring data speed and flow, reducing the current consumption of individual peripherals. Low Power Mode (LPM) is ensured the deactivation/reactivation of peripherals and component modules of the microcontroller, as needed, to reduce energy consumption. The central unit also returns to scheduled operation mode by stacking the current state.

FRAM memory also allows content to be preserved in the absence of power voltage under the conditions of a virtually unlimited reading cycle. The system control module (SYS) through the different reset and initialization modes determines the writing of FRAM memory, thus protecting its contents [4-5].

Several principles are specified for low-power applications: use of the device's clock system, use of interrupts for reactivation and program flow control, startup of peripherals only, when necessary, use of low-power integrated peripheral modules instead of software sequences, use of tables instead of long software calculations, avoidance of frequent calls of subroutines and functions, for long subroutines, registers of a single-cycle central network should be used.

Software development using the Code Composer Studio de la Texas Instrument environment also enables the use of the Ultra-Low Power (ULP) Advisor module that provides guidance on how to configure the program to reduce the energy consumption of that application [6].

The paper describes a long-term, low-energy environmental data recording application with the MSP430FR2433 microcontroller and developed in CCS 9.3.0 [7-8].

2. EXPERIMENTAL SETUP

2.1. Physical structure

Figure 1 shows the block scheme of the environmental data recording application. The sensors used for this application are all analog output sensors. These sensors connect to the digital analogue converter via a multiplexer that allows to connect eight inputs.

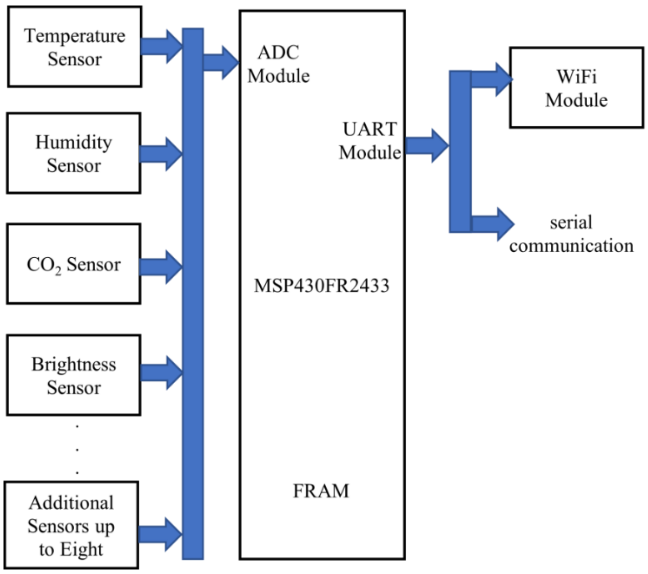

Fig. 1. The block schema of the data recorder.

Information stored in FRAM memory is distributed to Wi-Fi for local verification, or remote via the serial interface.

As shown, the analog-to-digital converter can acquire up to two hundred thousand samples per second, samples with a size of ten bits, performance that ensures the acquisition of data with high precision.

The ferro ram memory has a size of 15 kB of which 4KB are occupied by the software, 1 kB is required for the system and 10 kB remains for data storage. Since registration is made at the event i.e., when one of the parameters changes above the required limit, this amount of memory is sufficient from a few days to a few weeks.

2.2. The software structures

The written program for the data recorder is based on Utilities for MSP430 FRAM Microcontrollers provided by Texas Instruments [9]. They are a collection of utilities that allow power control and FRAM memory usage.

The nvs.h library from the same utility collection was used for permanent data storage, a library that allows data control to power loss and asynchronous power outages in such a way as to ensure the security of stored data. The structure of the stored data is complex, and a ring container is used that allows infinite storage of the data. Data storage and recovery uses the microcontroller's interrupt system (LPM3.5 interrupt) to save energy and ensure record accuracy [10]. The data structure and startup information are stored in memory so that the data can be retrieved even after the microcontroller's initialization (RESET).

Figure 2 shows the flowchart of the software for recording environmental parameters. To save power the system works in interrupt. In the interrupt all the element that remains functional is the real-time clock (RTC). The time constant can be set when the program is started in the hardware configuration phase. The default time constant value is 5 seconds. At the end of the time, the real-time clock generates an interrupt that triggers the output of the central unit from the low-energy state and the size condition is tested. The size condition is the comparison between the variation in the measured size and the maximum accepted variation. The quantity of maximum variation is established at the launch or initialization of the program in the section of the software. If the quantity of the maximum variation of the accepted is exceeded then it is stored in memory: date, time, channel symbol measured and current value.

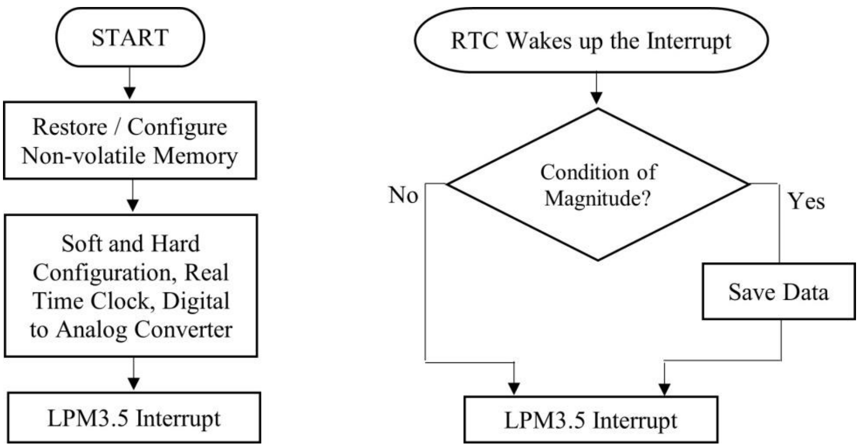

Fig. 2. The flowchart of the application.

In case of power outage or system initialization, stored data is not lost. When restarting, the memory structure that has been stored in the non-volatile data range is loaded, the data storage and recovery mode is restored so that there is access to the data already stored. This is recommended that time information be provided by a battery system in such a way that this information is kept accurate even in the conditions of power outage [11].

3. RESULTS AND DISCUSSION

The main reason the system saves a serious energy is the work in the beginning. The system works at maximum energy during the period of satisfaction between the break and then enters in economic mode. For this reason, the amount of energy saved can be adjusted from the time constant of the real-time clock.

The data storage algorithm allows data to be stored only if the change in the value of this data is significant. In this way a fine adjustment can be made to the amount of data stored in relation to the amount of non-volatile memory available. Thanks to the mechanism in the data memory ring, the latest stored data is always available.

Using non-volatile FRAM memory eliminates the need to power memory to keep stored data. This ensures an important energy saving and, at the same time, ensures the safety of stored data.

The system has been used with particularly good results in monitoring environmental parameters in isolated areas where there are no energy sources. Remote data retrieval raises some complications because an additional power source is required. The data was transmitted remotely via a radio modem. Locally the data can be retrieved via the serial cable or via the Wi-Fi module activated only when the data retrieval is needed.

4. CONCLUSIONS

The environmental parameter monitoring system has proven to be a safe and economical tool in operation. Under average conditions of use, with a time constant of 5 seconds and four parameters monitored, the average consumption was 0.1 mA. Consumption can be further reduced by adjusting the parameters of the process accordingly. Thanks to this, the system can be powered by batteries ensuring a long running time. When the power supply is lost, the latest acquired data remains stored.

Due to the low consumption, the monitoring system of the environmental parameters can be powered by a solar cell equipped with a battery. If the battery provides enough power for a few days, then the system can operate year-round without the need for another power source. This allows the monitoring system of environmental parameters to be used even in inaccessible areas.

Such a system can also monitor both analog and digital parameters. For this reason, the system can be used to record the most diverse parameters. Due to the small volume and energy consumed in small quantities, the system can also be used on mobile or overhead systems to record various parameters.

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