Design of the image scanning system based on low power processor MSP430

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Abstract. The aim of this document was used and demonstrated low power modes of processor MSP430 by Texas Instruments. To illustrate the low power application the target was to create energy harvesting power supply, which provides an appropriate amount energy for the camera application. The camera was controlled via PC application. This thesis includes the knowledge of the energy harvesting application, a wireless communication between hardware modules, recording image files into SD card and creating simply GUI application.

Keywords: MSP430F5529, energy harvesting, solar cell, camera, SD card, RF communication.

1 Introduction

At present according to the development of electronics increases the number of daily used electrical and electronic equipment. This trend has resulted in increased consumption of electricity.

With the growing market demand for electronic mobile devices, developers were forced to use batteries as a source of electrical energy, which has reduced the amount of energy that could in device consume. For this reason, the development of low-power consumption components for the electronics industry has become the object of interest for many companies in this branch. The development of new technologies and components was prolonged working hours per battery charge.

However, this was still not sufficient for devices that should be located in areas or locations without the possibility of recharging. For these devices it was necessary to develop a system to recharge the battery, respectively, to supply power to the device itself. The most appropriate method was the use of renewable energy sources such as solar, wind, thermal or mechanical energy. This was achieved energy independence systems that can operate for decades. [1][2]

2 The low-power device for image scanning

Requirements for the device:

- Energy independence
- The possibility of wireless control
- The possibility of wireless transmission of captured photos
- Saving a photo to the storage medium
- Angle change of the camera

According to requirements we created the solution as shown in Figure 1.

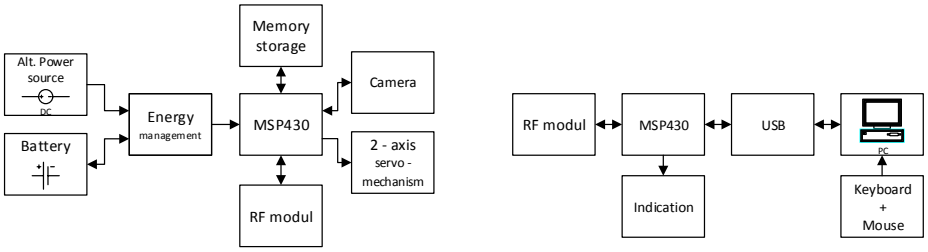

Fig. 1: Block diagram of image scanning system

In the figure we can see that the system consists of two parts. These parts can communicate with one another in master slave mode.

2.1 Sensor device module

This part of the device used to take photos and was designed with a low power microprocessor MSP430. This part is supplied by the block energy management. Energy Management manages the flow of energy from the battery or in the case of sufficient free energy available from the energy harvesting source module is supplied by this module. This part of the device contains a storage medium that allows you to store photos. Another part is the 2-axis servo mechanism, which changes the angle of camera. It also includes a camera module and wireless communication module, which receives control signals and transfers the image.

2.2 Control module

A control module creates a communication transfer bridge. It means that the module sends control commands and receives data from the sensing device module. This module is also based on low-power MSP430 devices. Control commands are received from the computer via USB and then transmitted. LED indicates the status of operations. We have created a simple GUI because of simplify the control.

3 Power supply module part of the sensing device

The basic idea is to create conditions for independent energy system which will be able to supply energy to the whole module. To achieve this goal was elected energy harvesting circuit, LTC3331 by Linear Technology. Its function is to supply the module from the battery or alternative energy sources and charging the battery.

We chose the solar cell as a source of alternative energy. It will provide enough power for the operation of the circuit, as well as energy storage in the battery. This type of battery Li-Pol provides voltage 3.7 V and its capacity is 780 mAh. For customization and debugging application was developed PCB which is described below. [8]

3.1 LTC 3331

Integrated circuit LTC3331 by Linear Technology is one of the most modern circuit of this firm. LTC3331 involves solving multiple problems. It integrates high-voltage energy harvesting module with buck-boost DC/DC inverter powered by rechargeable battery. LTC 3331 provides one output voltage, whose size can be changed through logical levels on defined terminals marked from OUT0 to OUT 2.

Another feature is the integrated module for charging batteries. Besides the charging it controls a voltage on the cell and in case of low battery is disconnected and thus protected. Parameters of threshold level can be set with pins LBSEL, FLOAT0, FLOAT1. This circuit also has an integrated power source prioritizer. Control of threshold voltage level can be set with pins from UV0 to UV3. Supercapacitor balancer is also implemented in LTC3331. [3]

3.2 Power Supplies

For the application has been selected the solar cell with a nominal value of datasheet: Uoc=5 V and Isc=50 mA. Due to increase the voltage was created the source by series connection of two solar cells. This led to achieve the theoretical parameters U_{oc}=10 V and I_{sc}=50 mA.

As the primary source has been selected LiPol battery. Its primary function is to supply energy in the case of absence of solar energy. Nominal cell voltage is typically 3.7 V and typical capacity is 780 mAh. One of the advantages is a temperature range from -20 to +60°C. [4]

3.3 Power Supply module

This universal board LTC3331 is used to adapt the connected sources. In this case is the LiPol battery and the solar cell. The whole power module was created in Altium designer 10 (scheme, PCB, 3D model) on 2 layer PCB. It is designed with plenty of adjustment short jumpers and measuring pins. This module can be customized for any voltage source. It is also possible to set the required output voltage (in this case 3,3V),

connect the supercapacitor and monitor the activities of this module using diagnostic functions. We see in figure 2 created and connected module. [8]

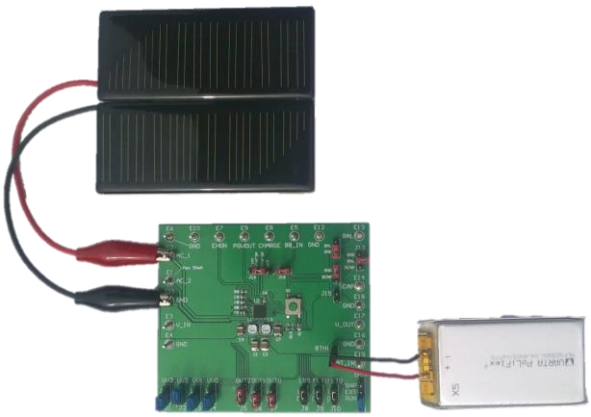

Fig. 2: Created an connected power supply module

4 Sensor device module

Sensor device module is the most important part of the whole application. It was created on a MSP430F5529 Experimenter's Board from Texas Instruments that is fitted with a low power 16-bit processor MSP430F5529. Peripheral device were connected to this board

4.1 MSP430F5529 Experimenter's Board

Experimenter's Board is based on a processor MSP430F5529 that has many built-in peripherals (i.e. full speed USB 2.0, ADC, Timers, RTC. Max. Frequency – 25 MHz etc.). This board makes the tuning of the application faster and easier. The reason behind this are many peripheral devices such as LCD display, SD card holder, capacitive buttons, LED, GPIO, analog signal, USB port etc. Also it has a built-in emulator and JTAG. [7]

4.2 Peripheral modules

Meeting the before-mentioned requirements was accomplished thanks to the peripheral modules. SD card was used as a memory medium, camera module was used for taking photographs, 2-axis servo was used for the sensor angle change and RF module was used for the communication

Camera module. This module has been acquired from the original Siemens S55 accessory. It allows the user to take Low res photos (160x120 px) and High res photos (640x480 px). Also it has a Xenon flash light which is an advantage during the night. This module takes photographs and converts them automatically into JPEG. This module can be controlled with UART.

Micro SD card. A Micro SD card has been chosen as a memory medium. It has been chosen because it is supported on the experimenter's board and its control was simplified. SPI was a communication that was used with it and there has been used a FAT file system. Also it has been chosen because of the small dimensions, big memory capacity and communication interface.

2-axis servo mechanism. Camera module's rotation is handled by a 2-axis servo mechanism. It consists of 2 model servomotors SG-90 and plastic structural parts. Each servomotor is controlled with a PWM signal and the rotation angle is set from -90° to 90°. This enables us to set an angle in the space of 2π sr.

RF module. For the wireless communication, there has been chosen a RF modul NRF24L01+. This modul is a 2.4 GHz transceiver with an implemented module Enhanced ShockBurst™. It is suitable for the low power applications. Manufacturer appointed 26 μA consumption in Standby. This module is designed to function only with a small number of external components. Communication with a microcontroller is SPI (max. 10 Mbps). With this module, we can establish a Single Master – Multi Slave communication (1 master and max. 6 slaves in star topology). It contains three 32bit Rx and Tx registers of FIFO type. Supply voltage is in a range of 1.9 to 3.3 V. This module enables channel frequency setting (2.4 to 2.4835 GHz), transmission power setting (0, -6, -12 and 18 dBm), receiver sensitivity setting (-82 dBm for 2Mbps, -85 dBm for 1 Mbps and -94 dBm for 250 kbps) and transmission speed setting (250 kbps, 1 and 2 Mbps). Module uses GFSK radio transmission modulation (Gaussian frequency-shift keying). This module has been chosen because of the sufficient range (open outside space cca 50m - measured), small number of external components and small size.

4.3 Program for MSP430F5529

Source code for MSP430F5529 was created in a C programming language in a CCS6 development workspace from Texas Instruments. This program contained each device according to the requirements and it was always trying to set the processor into the lowest power consumption mode. We used a Low frequency clock source 32,768 Hz and used PLL with the frequency of 8 or 12 MHZ. Created program acquired data from the RF communication and executed the received orders. The program could be made to:

- Charge the flash
- Low res photo without flash
- Low res photo with flash

- High res photo without flash
- High res photo with flash
- Low res photo without flash with a retroactive photo sending
- Low res photo with flash with a retroactive photo sending
- Photo saving into the SD card
- Setting of the desired servomechanism's position

Photo saving is done automatically after the photo creation. A name of the saved file consists of the date and time of the photo creation. During idle state, when there is no communication, the MSP430F5529 processor is set to the LPM4 mode. LPM4 (low power mode) lowers the processor's consumption. This state is active until the RF module receives new data. IRQ is set then and the processor is in active mode.

4.4 Current consumption measurement

After the program creation and testing of the sensor device module functionality, there has been measured a current consumption of both modules. We found out that the current consumption of the MSP430F5529 processor was in an active mode 3.785 mA and with use of LPM4 it was 244 µA (fig.3).

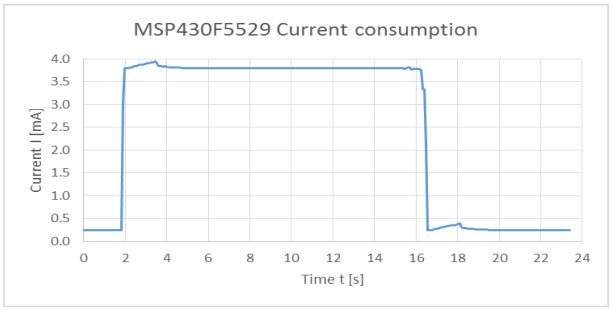

Fig. 3: MSP430F5529 current consumption

Idle current consumption of a servo motor is 5.778 mA. With the use of the mechanism, it would be in an idle state 11.556 mA. If we add to it a camera module consumption (435 µA), the resulting consumption would be almost 12 mA. The current consumption of a servomechanism is displayed in the figure 4.

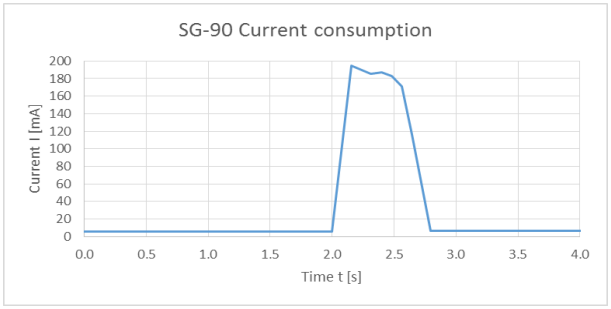

Fig. 4: SG-90 current consumption

Lowering of the consumption in the idle state was accomplished with use of a simple electronic circuit that disconnects the power supply of a servomechanism and camera module. (Fig. 5) This circuit was controlled by a MSP 430 processor.[8]

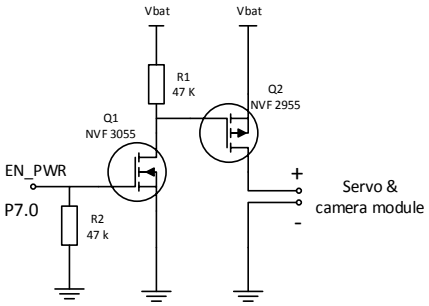

Fig. 5: Electronic modules reducing consumption

This simple electronic module reduced the power consumption from 12 mA to 78 µA. Fig. 6 shows a disconnection of 1 servo from the supply voltage with help of a module.

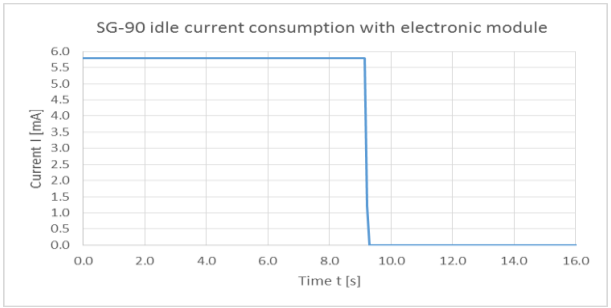

Fig. 6: SG-90 Current consumption with electronic module

5 Control module

It is a simple module that creates a communication bridge between a PC and sensor device module.

It is based on an experimenter's board MSP430F5529 LP that has a MSP430F5529 processor. RF module NRF24L01 is connected to the experimenter's board (same as in the sensor device module). Program was created to receive the orders from PC via USB and then to transmit them with a help of a RF module. Activity state is indicated with the led diodes. This module could use a LPM0 mode because of the use of an USB module. It doesn't matter because this module isn't powered from the battery and it is power consumption isn't important. Because of this we paid attention to the functionality mainly. The whole module is displayed in the fig. 7. [6][8]

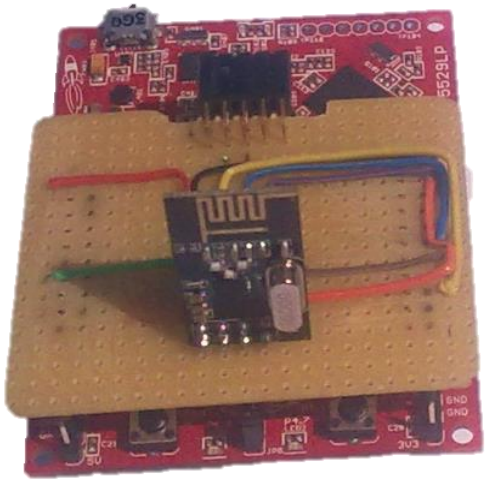

Fig. 7: Control module

6 GUI

GUI was created for easier control of designed device. This application communicates with the connected control module and sending it commands. This application contains automatic detection of connected devices, setup and take a photo, servomechanism control and display photos. GUI is shown in Fig. 8.

Fig. 8: GUI

7 Summary

The final version of device (Fig.9) consists of two HW parts and 1 SW application. The whole device is able to takes photos, communicates wirelessly, transmits pictures, changes the angle and saves created photo. The aim of sensor device was to reach Low Power consumption. This was achieved with MSP430F5529 processor in LPM4 and electronic module for disconnect the power supply. Sensing device is battery-powered. A secondary source of power is solar cell, which supplies battery power if there is enough solar energy. The proposed device is possible use with lower power consumption and energy harvesting supply module placed in locations without a power supply or hard to reach places, where required a long battery life on a single charge for different operation.

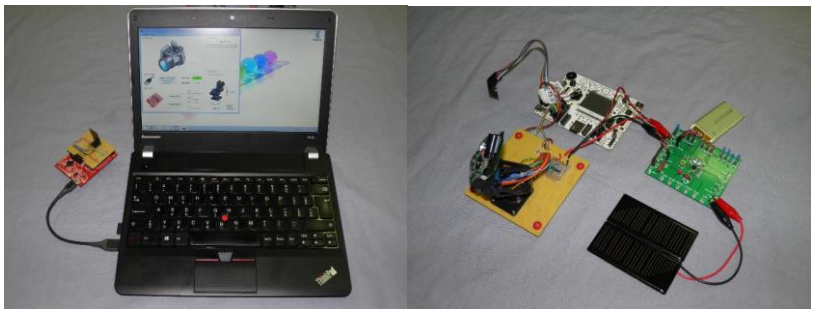

Fig. 9: Complete device

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