Microcontrollers/ TI MSP430F5438A

ECE 480 senior Design

Team 3

Application Note

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Abstract
Microcontrollers are key components on today’s modern world. These devices have the ability to perform numerous numerical operations that result on the automation of almost every device used on today’s modern world, from cars to elevators to cellphones. Microcontrollers have all the same basic structure: A CPU, a ROM and RAM memory and I/O ports, but other components like A/D converter, clocks and number ports, just to mention a few, vary from manufacturer to manufacturer. In the following document the family of the MSP430xx5xx manufactured by TI will specifically explored.
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**Introduction**

Before microcontrollers appeared, devices called Vacuum tubes consisting of sealed glass or metal-ceramic enclosure were used to amplify weak currents, rectification of AC current among others, but these devices were incredible big making the invention of easy-to-carry devices almost impossible, but then the invention of the transistor came to substitute vacuum tubes. Transistor are small, usually three pins (Emitter, Base, and Collector) devices that, as vacuum tubes, are able to amplify weak signal, but this newly invented device was not only able to amplify weak signals but also to function as ON/OFF switch, depending on the voltage applied to one of its pins (Base). With the invention of this new device, the possibility of creating small scale products was open. Following the invention of the transistor, came the ICs (Integrated Circuit) which are small devices comprised of transistor. ICs are the base of Microcontroller.

Microcontrollers are electronic devices that resemble the architecture of a computer, it posses a CPU that executes all programs stored on the microcontroller’s memory. It also has a RAM (Random Access Memory) which stores all variables used on each program and a ROM (Read Only Memory) which contains the program being executed, Lastly it has a I/O ports which aids on the communication of outside world-program. The small size and versatility of these devices make them ideal for almost any automation need on today’s modern world. These devices are used in industries like:

Automotive (Cars, GPS ...)
Household appliances (Microwaves, refrigerators ...)
Telecommunication (Cellphones)

The MSP430F5438 is a 100 pin microcontroller fabricated by TI. It belongs to the Ultralow-Power Consumption family, with the ability to work on 4 different modes: Active mode, standby mode, off mode, and shutdown mode, to achieve extended battery life on portable applications. This microcontroller features a 16-bit RISC CPU, 16-bit registers and a digitally controlled oscillator (DCO) which allows the device to wake up from low-power modes to active mode in approximately 3.5µs. It also has three 16-bit timers, a high performance 12-bit analog-to-digital converter (ADC), up to four universal serial communication interfaces, a real-time clock module and up to 87 I/O pins (11 general purpose digital I/O). See Figure 1 for pin out of the MSP430F5438.
Figure 1. Pin out of MSP430F5438A

**CPU**
The CPU is the brain of the microcontroller; it executes all the programs of the microcontroller. The MSP430F5438A has a 16-bit RISC architecture. All operations, other than program-flow instructions, are performed as register operations in conjunction with seven addressing modes for source operand and four addressing modes for destination operand. The CPU is integrated with 16 registers, four of the registers, R0 to R3, are dedicated as program counter (Contains the address of the instruction being executed), stack pointer (Contains the address of the last program requested), status register (Contains information about the state of the processor), and constant generator (Contains constant values generated to be used on the program being executed or to be executed, the value will remain until is changed), respectively. The remaining registers are general-purpose registers. Figure 2 shows the organization of the CPU.
The flash memory can be programmed via the JTAG port, Spy-Bi-Wire (SBW), the BSL, or in-system by the CPU. The CPU can perform single-byte, single-word, and long-word writes to the flash memory. It also has $n$ segments of main memory and four segments of information memory (A to D) of 128 bytes each. Each segment in main memory is 512 bytes in size, segments 0 to $n$ may be erased in one step, or each segment may be individually erased, segments A to D can be erased individually, and segment A can be locked separately.

**RAM**

The RAM memory is made up of $n$ sectors. Each sector can be completely powered down to save leakage, let’s keep in mind that all information in RAM memories are lost when they are power off. The RAM memory has $n$ sectors. See Table 1 for size of each sector. All sectors can be completely disabled and can automatically enter low-power retention mode when possible. For devices that contain USB memory, the USB memory can be used as normal RAM if USB is not required.
Table 1. Memory organization of the MSP430F5438A

**I/O Ports**

I/O ports provide a connection between the microcontroller and the outside world. There are 10 8-bit I/O ports (P1-P10), there is also a special port (P11) which contains three individual I/O ports. These digital ports can be set at the user's desired following these guidelines:

- Input, using the PxIn register (0: input is low, 1: input is high)
- Output, using the PxOUT (0:output is low, 1:output is high)
- Direction register (0: Port pin is set to input direction, 1: Port pin is set to output direction)
- Selection, using PxSEL (0: I/O function, 1:Peripheral mode)

This microcontroller also offers the option of enabling a pullup resistance (resistor connected between a signal and a power supply to ensure valid logic level) or pulldown resistance (resistor connected between a signal and ground to ensure valid logic level) using the PxREN register (0:disabled, 1:enabled).
Operation Modes

Operation modes on the MSP430F5438A determine which elements of the microcontroller are active and/or disable. The microcontroller has one active mode and six software selectable low-power modes of operation. Interrupts events can wake up the microcontroller from any of the low-power modes, service the request, and restore it back to the low-power. There are two different low-power modes and one active mode; these operating modes are detailed next:

- Active mode (AM)
  - All clocks are active
- Low-power mode 0 (LPM0)
  - CPU is disabled
  - ACLK and SMCLK remain active
  - MCLK is disabled
  - FLL loop control remains active
- Low-power mode 1 (LPM1)
  - CPU is disabled
  - FLL loop control is disabled
  - ACLK and SMCLK remain active
  - MCLK is disabled
- Low-power mode 2 (LPM2)
  - CPU is disabled
  - MCLK, FLL loop control, and DCOCLK are disabled
  - DCO's dc-generator remains enabled
  - ACLK remains active
- Low-power mode 3 (LPM3)
  - CPU is disabled
  - MCLK, FLL loop control, and DCOCLK are disabled
  - DCO's dc generator is disabled
  - ACLK remains active
- Low-power mode 4 (LPM4)
  - CPU is disabled
  - ACLK is disabled
  - MCLK, FLL loop control, and DCOCLK are disabled
  - Crystal oscillator is stopped
  - DCO's dc generator is disabled
  - Complete data retention
- Low-power mode 4.5 (LPM4.5)
  - Internal regulator disabled
  - No data retention
  - Wakeup from RST, digital I/O

Depending on which functions the user is most interested in using the low power mode will be selected. For example if the user is only interested to execute an action as a result of the reset button being pressed or a specific signal from one of the I/O ports, it might be a good idea to use the LPM4.5, but if the user is interested in a function to executed after certain amount of time has passed it might be a better ide to use one of the modes has the ACLK active.
Software

To edit and compose any code to the MSP430F5438 is necessary to install the Code Composer Studio. This program can be found following the link www.ti.com/ccs. Once the program has been downloaded and installed, the home a new project can be created. Clicking Under the tabs File >> New Project a new windows should appear, Figure 3 shows the new windows with the selection made for the MSP430F5438A, when clicking on Identify connection the MSP-FET430UIF programmer, see Figure 4, must be connected to the computer. Selecting Empty Project (With main.c) will immediately create a main.c file, this is only recommended for projects that are going to be started from scratch, if it is desired to modified a previously created project the project must be imported. After typing a file name and selecting finish a main.c file ready to edit should appear, see Figure 5.

Figure 3. New CSS project tab
Figure 4. the MSP-FET430UIF programmer

Figure 5. Main.c file and project created

To test the code modified, the green bug button on the top left side should be pressed, this will take the user to debugging mode where the code can be tested.
Conclusion

Microcontrollers are key devices on today’s modern world. Almost any device that processes information contains at least one microcontroller. Understanding how they work and they can be programmed and modified to fulfill any user’s needs is important for engineers, but is important to keep in mind that every microcontroller is different, they posses different amount of I/O ports, RAM and ROM sizes and CPU capabilities as well as different add-ons like ACD converter, clock frequencies etc. But what does no change from microcontroller to microcontroller and from manufacturer to manufacturer are the basic components of a microcontroller: CPU, RAM, ROM and I/O ports
Resources
http://electronics.howstuffworks.com/microcontroller1.htm
http://www.robotplatform.com/electronics/microcontroller/microcontroller.html
https://ti.tuwien.ac.at/ecs/teaching/courses/mclu/theory-material/Microcontroller.pdf
http://www.ti.com/lit/ug/slau208n/slau208n.pdf