CMPE 443 PRINCIPLES OF EMBEDDED SYSTEMS DESIGN

LAB #006

"Methods for Low Power"

Motivation

Power consumption is the most important constraint in today's embedded systems. Power consumption is directly related with energy efficiency and battery life.

In this experiment, we will reduce power consumption in an embedded system. Hence, you will be:

- practicing power-saving methods in an embedded software.
- observing the effects of low-power modes in microcontroller.

1) Problem Description

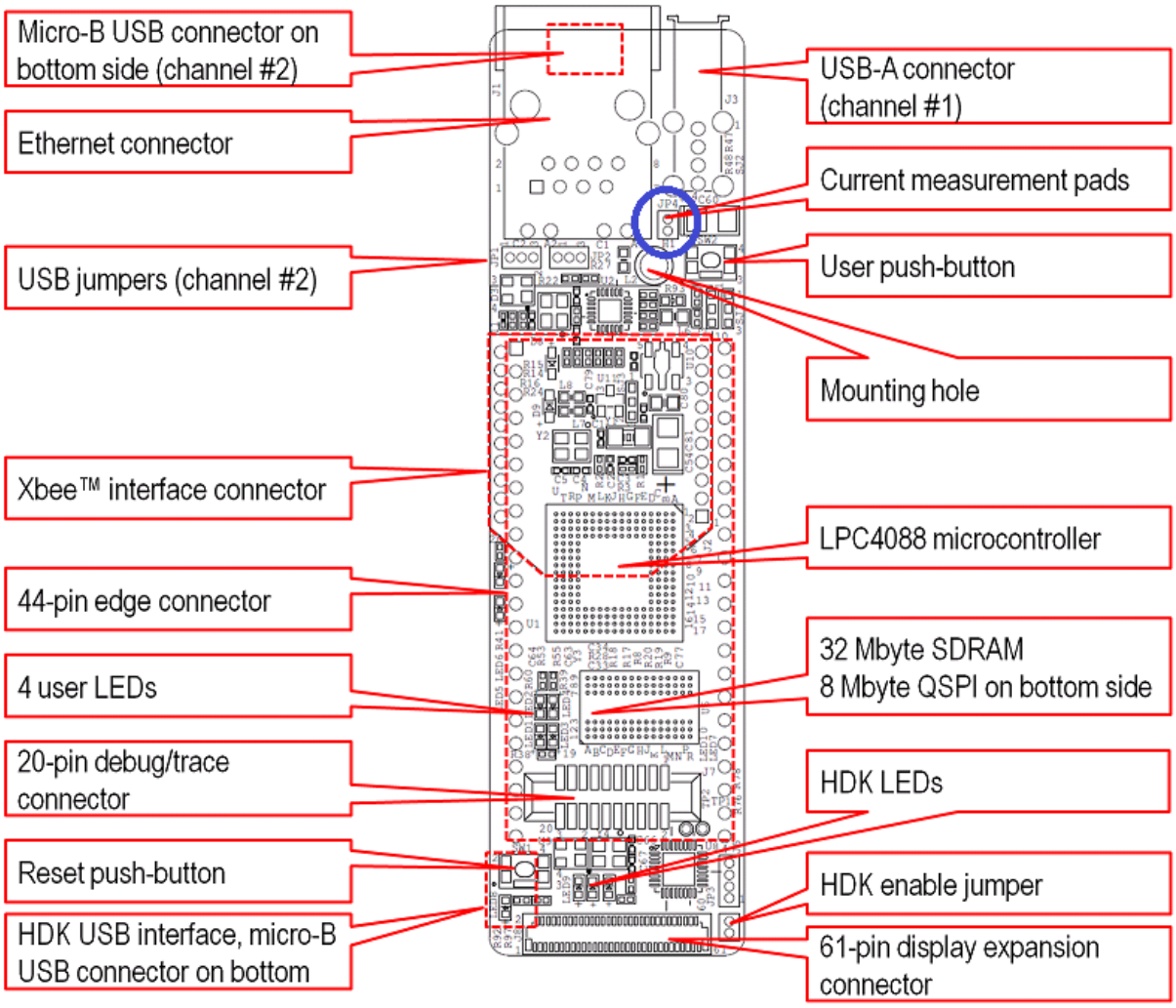
In this experiment, you will change the power modes of the board and after that, you will reduce the power consumption on the LAB_5 code by using frequency scaling.

*Note: When a question ends with **(*)** notation, that means write on the code. When a question ends with **(?)** notation, that means write on the paper. When you see **(*?)**, the answer of this question should be written on the paper and code.*

2) Energy Measurement *15 pts*

In this part, you need some additional components other than LPC4088 Quickstart Board. These are a Multimeter and two cables.

a) Current Measurement Pads



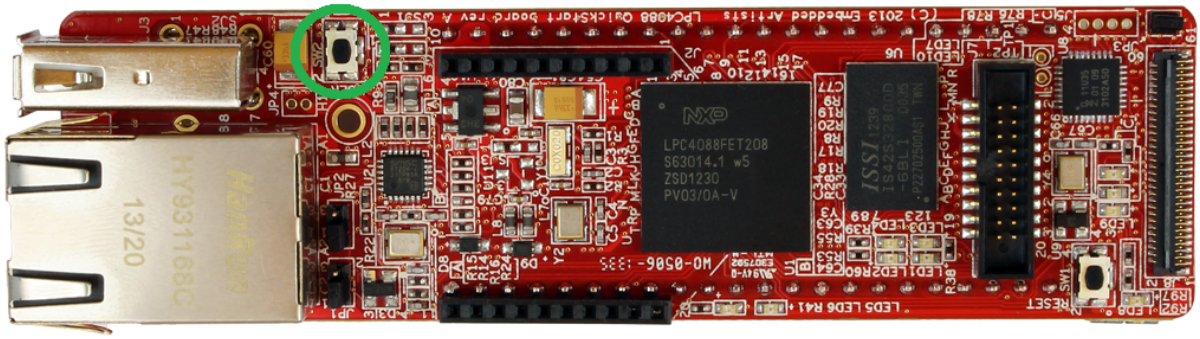
b) Calculations *2 pts*

- **Current Calculation:** JP4 is reserved for measuring current of the QuickStart Board. In LPC4088_QuickStart_Board_revB.pdf, it is written as "JP4 10mV per 100mA current" (For example: If you read 15.5 mV from Multimeter, the current will be 155 mA)
- **Power Calculation:** Power can be calculated as this formula: $P_{(W)} = V_{(V)} \times I_{(A)}$. You can find the voltage value of LPC4088 from the board's schematic. Therefore you can calculate power consumption of the board by measuring the current across pads of JP4.

- Measure Current while LED off. **(?)** _____ *0.25 pts*
- Compute Power while LED off. **(?)** _____ *0.25 pts*
- Measure Current while LED on. **(?)** _____ *0.25 pts*
- Compute Power while LED on. **(?)** _____ *0.25 pts*
- Compute the average Current. **(?)** _____ *0.5 pts*
- Compute the average Power Consumption. **(?)**_____ *0.5 pts*

c) Sleep Mode *1 pt*

In this part, you should change the LAB_6 code for entering the sleep mode. Your code should go to Sleep Mode after 5 LED Blinking. (When you pressed the push button on the LPC4088 which is shown in the figure, the **EINT0_IRQHandler** will be called and board will wake up) Firstly, uncomment **PLL_Change_Configuration** method, and fill the inside of the method from the LAB_5.



- Find Current while LED on in the Sleep Mode. **(?)** _____ 0.5 *pts*
- Find Power while LED on in the Sleep Mode. **(?)** _____ *0.5 pts*

d) Deep Sleep Mode *5 pts*

In this part, you should change the LAB_6 code for entering the deep sleep mode. Your code should go to Deep Sleep Mode after 5 LED Blinking. In order to enter Deep Sleep mode, The System Control Register should be used with PCON register. (In **SystemStructures.h** file)

- Write the address of System Control Register (SCR) **(*?)** _____ *0.5 pts*
- Write the address of PCON Register **(*?)** _____ *0.5 pts*

In order to enter the Deep Sleep Mode:

- What should be written in to SCR register **(*?)** _____ *0.5 pts*
- What should be written in to PCON register **(*?)** _____ *0.5 pts*

- Find Current while LED on in the Deep Sleep Mode. **(?)** _____ *0.5 pts*
- Find Power while LED on in the Deep Sleep Mode. **(?)** _____ *0.5 pts*

Observe the blink rate of the LED after exiting the Deep Sleep Mode:

- Is LED blink rate changes or not? If it changes, write it is increased or decreased? **(?)** _____ *0.5 pts*
- Write the cause of this change **(?)** _____ *0.5 pts*
- Write a code for eliminating this change (*?) _____ *1 pt*

e) Power-Down Mode *2 pts*

In this part, your board should enter Power Down Mode, instead of Deep Sleep Mode. In order to enter the Power Down Mode:

- What should be written in to SCR register **(*?)** _____ *0.5 pts*
- What should be written in to PCON register **(*?)** _____ *0.5 pts*

- Find Current while LED on in the Power Down Mode. **(?)** _____ *0.5 pts*
- Find Power while LED on in the Power Down Mode. **(?)** _____ *0.5 pts*

f) Deep Power-Down Mode *3 pts*

In this part, your board should enter Deep Power Down Mode, instead of Power Down Mode. In order to enter the Deep Power Down Mode:

- What should be written in to SCR register **(*?)** _____ *0.5 pts*
- What should be written in to PCON register **(*?)** _____ *0.5 pts*

- Find Current in the Deep Power Down Mode. **(?)** _____ *0.5 pts*
- Find Power in the Deep Power Down Mode. **(?)** _____ *0.5 pts*

- How can you wake up the board from the Deep Power Mode? **(?)**

_____ *1 pt*

g) Reducing Power Consumption *2 pts*

In this part, you will reduce the power consumption of the LAB_5 code while getting the same output. Explain why this method reduces the power consumption.

- Current after reducing. _____ *0.5 pts*
- Power after reducing. _____ *0.5 pts*
- Explain your method. _____ *1 pt*

(Hint: You can look at the power saving instructions in the Cortex™-M4 Instructions.)
(Bonus: The group measures the minimum power will get +5 points.)