ECEN 5803 MASTERING EMBEDDED SYSTEMS ARCHITECTURE

Project 1

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Executive summary:

The report presents a brief overview of various tests carried out on FRDMKL25Z128 to determine its suitability for designing vortex flowmeter. The FRDMKL25Z has number of peripherals like UART, ADC, SPI that makes it very useful to design vortex flowmeter. Moreover, the price of FRDM board is about 13 dollars that makes it perfectly suitable for keeping the budget within constraint. The FRDM board can support all the requirements which are laid down by Sierra instrumentation, and one of the interesting feature being its small package size that allows the flowmeter to be as compact as possible. Another advantage of FRDM board been it is easy to program due to availability of all libraries of each of the peripherals present on board. Hence, the programmer doesn't have to worry about details of every component that facilitates the software development and debugging process. The abstraction of each component in terms of libraries makes the FRDM board an excellent choice for the design of vortex flowmeter.

Based on the and requirements laid out by Sierra instrumentation, various test have been performed which proves the feasibility of FRDM board to be used in vortex flowmeter. The on-chip ARM m0+ processor architecture makes it easy to support the arithmetic operations like performing squarerroot operation, handling the vibration sensor and accelerometer, controlling ADC, SPI with very great accuracy. Also, the FRDM board has low power consumption which is marks it as a good embedded system. Considering the ease of implementation due to wide availability of libraries, the development time that is required to make this product is also less, and hence satisfies the schedule within which the product must be developed.

Though the implementation looks to be nearly perfect in its initial stage, there are few optimizations regarding hardware and software which are yet to be done to make the product follow the triple point constraint of budget vs performance vs schedule. To conclude, the FRDM board seems to be a viable alternative to implement the vortex flowmeter, the justification and details are presented in the detailed report below.

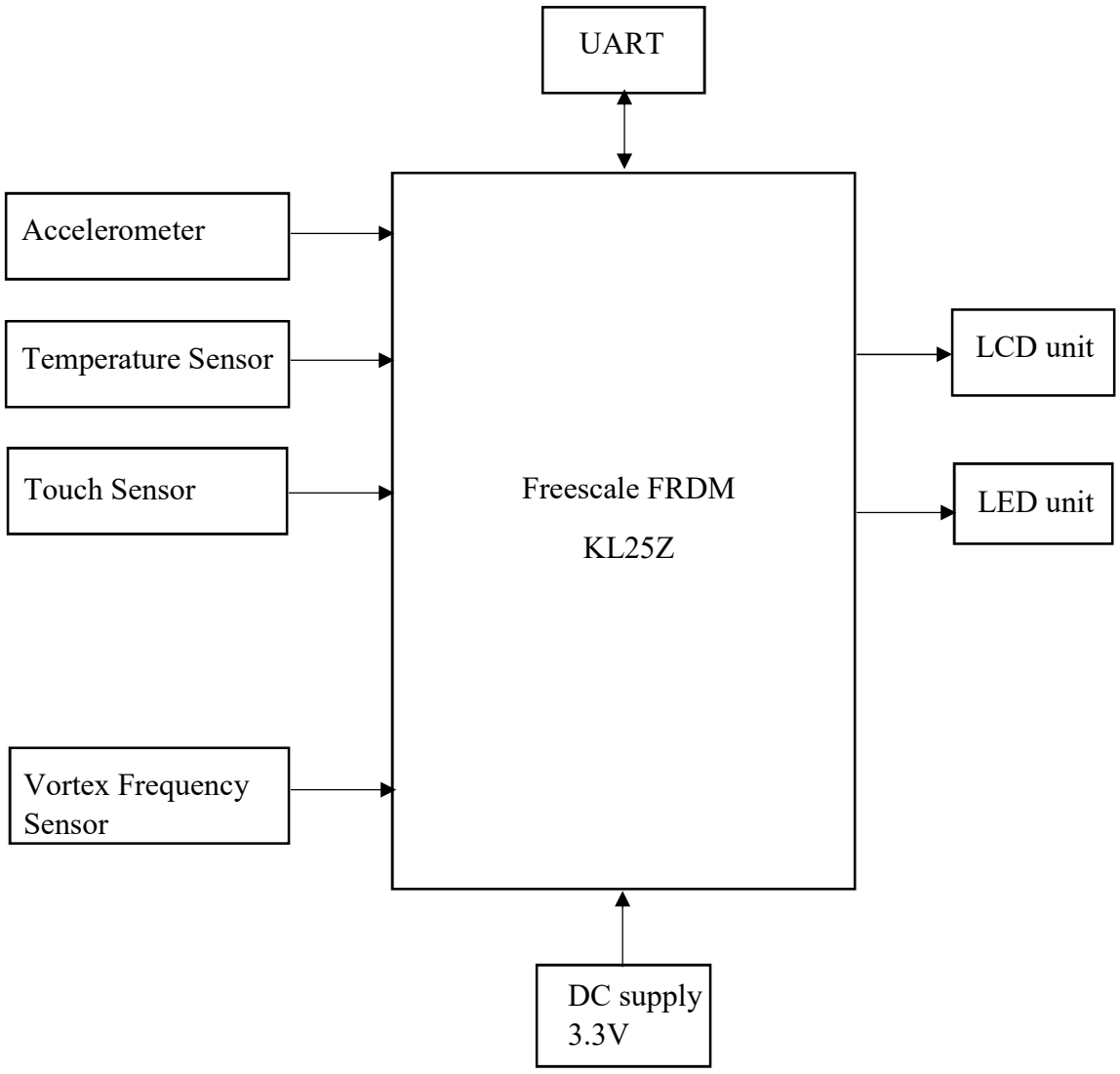
Problem Statement:

To make an embedded system design as per the requirements of Volumetric Vortex Meter by using Cortex M0+ based microcontroller FRDM KL25Z.

Objective:

To test the Freedom board for the functionality as per the requirements and improve the solution by developing new parameters to design the embedded system.

Block Diagram:



Hardware Evaluation:

Hardware evaluation is done based in availability of the peripherals required to implement the Vortex flowmeter.

Result: As per the given requirements, FRDM KL25Z can support all the features required for the development of this product. The feature required are GPIO, UART, ADC and PWM.

Requirements:
Input Requirements:

1. Vortex Frequency sensor:
   A 16-bit ADC is present in FRDM KL25Z board, that gives up to 12-bit mode operation with the conversion rate of 20 ksps. Using the timer interrupts in KDS, the conversion rate can be scaled down to 10 ksps by using a delay function.

2. Temperature Sensors:
   Temperature sensor is not provided in the board, which is why we must use an external temperature sensor. External sensor is easy to implement with the 16-bit ADC provided on the KL25Z board.

3. Touch Keypad:
   A Touch Sensing Software(TSS) is implemented on KL25Z which is used to implement a capacitive touch slider. Library component for TSS needs to be included to make the module work. External touch keypad can also be implemented using I2C interface.

4. 3-Axis Accelerometer:
   A Freescale MMA8451Q low-power, three-axis accelerometer is interfaced through an I2C bus and two GPIO signals. By default, the I2C address is 0x1D (SA0 pulled high)

Output Requirements:

1. LEDs:
   Three PWM-capable signals are connected to a red, green, blue LED. To interface three LEDs on this board, we use PTB18, PTB19 and PTD1 ports.

2. Serial Port:
   KL25Z board has one low-power UART and two standard UART module which is configured as serial port for communication and to perform monitor function and display data.

3. 4-20 current loop (PWM or DAC output):
   PWM helps to implement an accurate current-loop transmitter. One 6-channel PWM and two 2-channel PWM modules are provided in the board that can be configured to meet the given requirements. FRDM KL25z board has a 12-bit DAC support which can be configured to implement a 4-20 current loop.

4. Pulse output for totalizer:
   FRDM KL25Z board has two 2-channel Timer/PWM modules, edge-aligned PWM mode and motor control functions which satisfies this requirement.

5. Average Power consumption:
   As per the requirement, the average power consumption is expected to be less than 100 mW.

Further Hardware evaluation is done considering the processor's capability.
Requirements: 40 DMIPS
Result:

Hardware evaluation for the cost of the product is performed. Please refer "Cost Estimation" in the documents and screenshots folder for the cost of individual components.

Result: The implementation of the product using FRDM KL25Z satisfies the given budget of $200. The system is implemented in $128.72.

Module test results:

There were four modules that were implemented to test the functionality of vortex flowmeter. The description and output of modules is as follows.

Module 1:

1. Finding the square root of number

In this, bisection method was used to determine the square root of any number which is 32 bits. The program utilized assembly function call to implement the square root function. One of the reason to use mix of assembly and C language was that use of assembly language made the processing of instruction faster and optimized the code. The bisection method was implemented to take care of number for which perfect root didn't exist. For e.g.., if the number whose square root to be obtained is 65, then bisection method is designed in such a way that it would perform iterations which may not cross 20 counts. The number which is obtained after 20 counts was somewhat closer to the original root but is truncated.

Module 2:

1. Feel the vibrations

In this, the on-chip accelerometer MMA was used to sense the vibrations. Based upon the value of x axis, y axis and z axis component, the color of RGB led was changed. Also, the capacitive touch interface used to increase/decrease the intensity of LED.

Module 3:

1. Serial port Debug monitor

In this, the values of flow, temperature and frequency were made to display on monitor. A software named Tera Term was used to display the constants and all data passed via microcontroller aka FRDM board. The host machine communicated with FRDM board with help of UART module, the code for which is written on mbed. Three modes were used namely: DEBUG, NORMAL and QUIET. The values from FRDM board were displayed on monitor using the debug mode.

2. Test each command. Explain something which you did not expect.

Answer: When timer0 function is called every 100us, it goes into an infinite loop and the time is too short to execute the functions after the timer0.

3. What is the new command you added to debug. Explain its usage?

Answer: Register (REG), Sensor (SEN) and Memory (MEM). REG is used to display the values from the registers (R0-R15). MEM is used to display the value in specified memory location

4. A GPIO pin was driven high during start of timer isr and was made low at the end. What purpose did it served?

Answer: It will generate the square wave as the timer is invoked after 100us.

5. What is the DMIPS of KL25Z?

Answer: 57.82 DMIPS

Module 4:

1. Bare metal flowmeter simulation

In this, there were various peripherals like ADC, SPI and PWM which were used to sense the temperature and frequency. An inexpensive LCD was interfaced using SPI bus. An algorithm was developed with various formula pertaining to physics of Vortex flowmeter

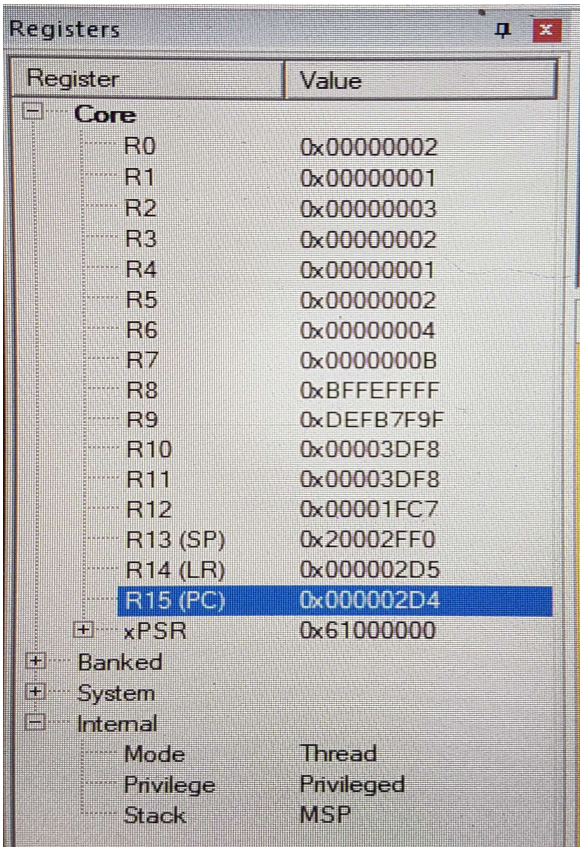
List of Project Deliverables.

Doxygen output files and mbed code files for each module is included in the zip file provided with the report.

Module 1:

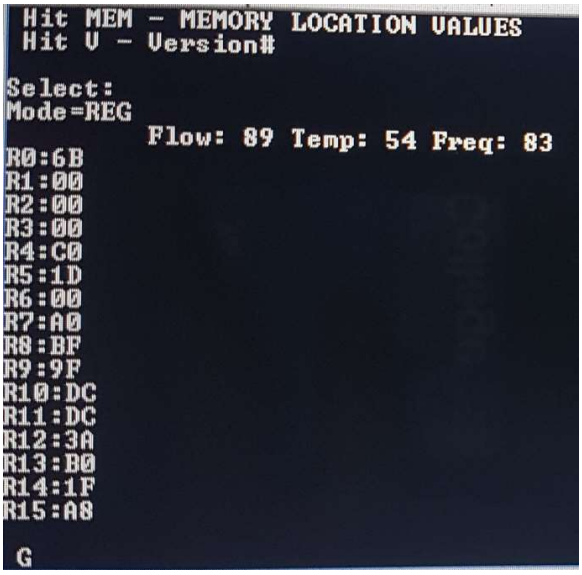
Square root of 4.

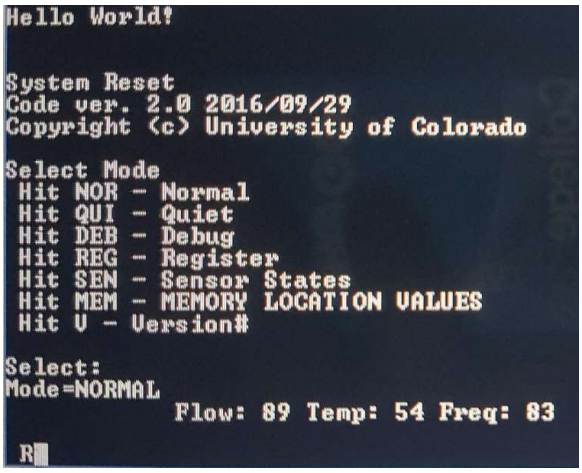
Output is stored in Register R0.



Module 3:

Debug Window





Recommendations:

The important parameters in developing Sierra vortex flowmeter is performance, quality and cost efficiency. FRDM KL25Z board does an excellent job to satisfy these parameters. After the evaluation and testing of the board for the given requirements, we can conclude that FRDM KL25Z is capable to handle the functions required by Sierra vortex flowmeter. Programming of components, peripheral buses and case of debugging is quite easy on KL25Z. This makes the project feasible in given time and budget. Hence the recommendation for the use of FRDM KL25Z in the Sierra Vortex Flowmeter product has been given a straight GO.

References:

1. Project 1 Guide
2. Request for Services
3. Getting Started with ARM using mbed
4. Freescale Kinetis KL25Z Datasheet
5. Freescale Kinetis KL25Z Reference Manual
6. Freescale FRDM-KL25Z Platform User's Guide
7. Module User's Guides for Modules 1-4.

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