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1. Executive Summary

According to RFS issued by Sierra Instrumentation, we performed Suitability analysis of MKL25Z128VLK4 for vortex flow meter application. The FRDM-KL25Z development board was used to evaluate MKL25Z128VLK4 controller. MKL25Z128VLK4 is interfaced with digital interfaces, analog sensors and user interface devices to test its hardware capabilities. The software performance was tested on the basis of responsiveness, mathematical operations, and accuracy. This performance is also compared with simulation tool MATLAB.

The critical test results and findings of the evaluation of MKL25Z128VLK4 for flow meter application are listed below-

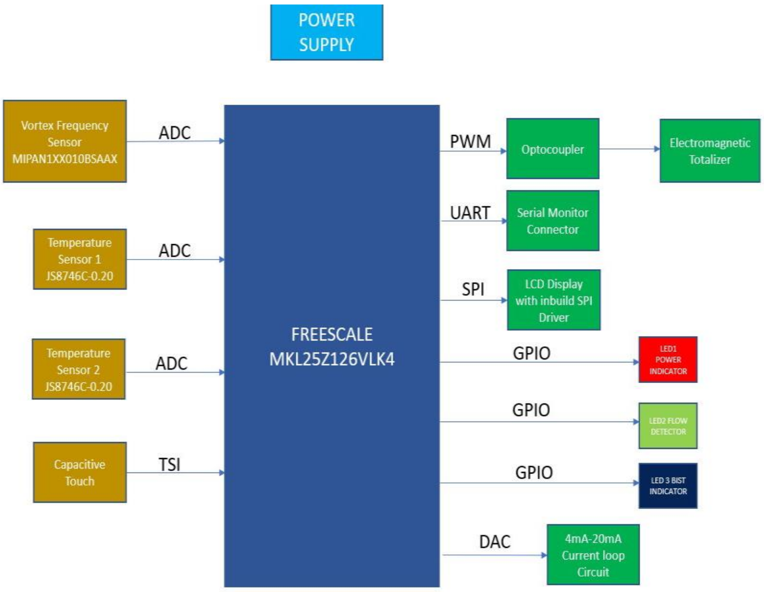
- MKL25Z128VLK4 able to communicate serially with terminal. This gives remote access to critical data. This can be used as to see real time values of frequency, flow, and temperature. This is very useful and simple for debugging too.
- MKL25Z128VLK4 is able to provide 39 DMIPS which is very closer to requirements for the flow meter application.
- MKL25Z128VLK4 has internal capacitive touch sensing peripheral which we tested for human inputs. It provided good response to external human inputs. Capacitive touch sensing is more reliable and cheaper compared mechanical counterparts for the harsh industrial environment.
- MKL25Z128VLK4 has internal timer peripheral which we used for scheduling the different tasks. This helps to improves responsiveness to the different tasks.
- MKL25Z128VLK4 has internal 16-bit ADC peripheral which we used to interface temperature sensor. This was able to provide satisfactory temperature data points for the calculation of the fluid flow.
- Estimated cost of MKL25Z128VLK4 based flow meter solution is USD 180.556 which is lower than RFS cost requirement.
- Estimated power consumption of MKL25Z128VLK4 based flow meter solution is 65.34 mW in the full load situation which is lower than RFS power requirement.

Based on the observations and test results, the design evaluation team came to conclusion that solution with MKL25Z128VLK4 can satisfactorily meet all the functional as well as performance requirements present in RFS of vortex flow meter. Therefore, we give a strong go to MKL25Z128VLK4 based solution.

2. Problem Statement and Objectives

- Perform software and hardware evaluation of MKL25Z128VLK4 for vortex flow meter application by performing series of the given tests on FRDM-KL25Z development board.
- Perform simulation of vortex flow meter algorithm and replicate it on the MKL25Z128VLK4 controller.
- Estimate performance parameter (DMIPS), power consumption, and cost of the proposed MKL25Z128VLK4 controller-based vortex flow meter solution.
- Provide GO/NOGO recommendations for the solution chosen for vortex flow meter.

3. Approach and methodology of evaluation



Block Diagram

Evaluation of Hardware Peripheral –

- Hardware evaluation based on regulatory and testing standards -
    1. Passive components, connectors to sensor integrated circuits used in proposed solutions adhere to ROHS requirement. Additionally, components are also accordance with UL, FSA, and FM standards. We need to make assembly of the components following the design guidelines to pass EMC and FCC standard testing.
- Hardware evaluation based on availability of hardware peripherals (Required/Available) -
    1. GPIO – 3/36
    2. UART- 1/3
    3. TIMER-1/2
    4. ADC- 3/16
    5. DAC- 1/2
    6. PWM-1/6
    7. TSI- 1/16
    8. SPI – 1/2
- Suggestion for interfacing sensor and user interface with MKL25Z126VLK4 –
    1. Use 3 16-bit ADC channels to interface 2 temperature sensors and frequency.
    2. Use 1 SPI interface to interface LCD display.
    3. Use 1 DAC to provide inputs to current loop.
    4. Use 1 timer to scheduling of tasks.
    5. Use 1 PWM channel to drive totalizer.
    6. Use 1 TSI channel for touch slider interface.
    7. Use 1 UART for remote real time data access for debugging and monitoring.
- Hardware evaluation based on cost constraint-
    1. Proposed solution costing is USD 180 which is less than requirement in RFS. This includes costing of components, connectors, PCB manufacturing and assembly, and cables. Cost of components are taken from Octopart.
- Hardware evaluation based on power constraint-

  Proposed solutions power consumption is 63.34 mW which is less than RFS requirement.

Evaluation of software –

- Evaluation of software is done by modular basis. There are 4 modules which are intended to test specific functions.
    1. Module 1- Designed square root function using mixed programming for evaluating computation capability of the controller.
    2. Module 2 - Implemented interface with accelerometer and TSI slider to test peripheral capability of the controller. Additionally, used timer peripheral of the controller to schedule the task.
    3. Module 3 - Designed remote monitor to display real time data on the terminal. This will help to improve debugging capability of the device.
    4. Module 4 – Developed flow calculation algorithm and matched the output with simulated result.

4. Module Test Results

- Module 1

Finding the square root of a number

1. In this module, we find a square root of 16 bit number. To calculate the square root we have used bisection method which in mathematics applies to continuous functions. This methods bisects the interval which is defined and checks if the functions changes the sign to determine the exact or close result value. We have developed the code such a way that it mixes C program with assembly. In C program we call a function to calculate the square root. This function is developed in assembly language. It uses Thumb instruction and handles non perfect numbers as well to calculate the nearest integer square root value. The advantage of using mix coding technique is to perform the execution faster and optimize the code.
2. The CPU cycle required for the execution of number 121 is 94

- Module 2

Getting hands on with Touch slider and accelerometer.

1. In this module, we first interface the touch slider to get values on user input. With those input values we control the brightness of green led as shown in the video. FRDM-KL25Z have an in build MMA accelerometer sensor which uses I2C communication protocol with the processor. We read the respective axis values X,Y and Z. Depending on those values, we changed the color of RGB LED’s
2. CPU cycle for Touch slider is 6835000. (Considering 20nsec CPU cycle)
3. CPU cycle for Accelerometer is 8375000. (Considering 20nsec CPU cycle)

- Module 3

Serial Port Debugger

In this module, we have used serial port to display values like temperature, flow and frequency using UART commands. Serial terminal software named Tera Term was used to make the serial commands interactive. The system developed is bidirectional system which means the Host computer sends some commands to FRDM board and in return board executes the commands. Some of the commands are DEBUG, NORMAL, SEN, etc.

1. The counter value shown in timer0 ISR is 43542
2. Debug Monitor results screenshot is attached and we were able to get the values of all registers. We observed that the commands runs in infinite loop by calling the timer which is called every 100us. Even with switch case break the debug monitor prints continuously.
3. Some new commands added are REG (Display register contents) and SEN

(Display sensor values – Touch slider and Accelerometer)
4. The GPIO pin driver high at beginning of ISR and low at the end of the ISR will generate a square wave which will have one period (ON until the ISR is complete and then OFF0
5. CPU cycle = 20. (100 millisecond operating cycle)
6. DMIPS for MKL25Z128VLK4 is 39 DMIPS as per drystone benchmark.

- Module 4
  1. Vortex Flow meter analysis

Frequency as per the given sample data is 250 Hz

Estimated flow from the inputs given is 802.85 gallons/minute

2. Temperature range varied from 21 - 26 degree Celsius
3. Power consumption of the system is for normal operation – 65.34mW.
   For low power operation – 19.47Mw.

5. List of Project Deliverables

All code files and Doxygen output files are upload on git profile with report, simulation screenshot, block diagram and readme.

6. Recommendations

- MKL25Z128VLK4 is evaluated with respect to RFS for the vortex flow meter for both software and hardware requirement.
- Hardware evaluation of MKL25Z128VLK4 performed for peripheral capability, power requirements and cost requirements. MKL25Z128VLK4 has sufficient hardware peripherals to meet RFS requirements. Additionally, its' power consumptions and costing are less than RFS requirements.
- MKL25Z128VLK4 also meets regulatory and environmental standards listed in RFS.
- MKL25Z128VLK4 provides 39 DMIPS as per drystone benchmark which is very closer RFS requirement.
- MKL25Z128VLK4 provided sufficient math computation power which can easily produce satisfactory results for flow calculations.
- MKL25Z128VLK4 has sufficient ADC, DAC, UART and timer peripherals to interfaces sensors and schedule tasks related to them and provide satisfactory outcomes as per RFS.
- MKL25Z128VLK4 has both open source as well as easy to use development environment. IDE supports debugging and easy to maneuver. It also has good code base which can accelerate development.
- Hardware design as well as software library is also available which reduce development time. Additionally, open-sda hardware and firmware is available which can be used to develop debugging interface.
- Hence, this project is feasible within time as well as cost specified in RFS. Therefore, recommendation for the use of MKL25Z128VLK4 in Vortex Flowmeter product design is a straight-GO.

7. References

1. Project 1 Guide, Request for Services and Report guidelines from canvas
2. Getting Started with ARM using mbed
3. Freescale Kinetis KL25Z Temperature AN3031 manual
4. AN3570 – Temperature Compensation document
5. Freescale Kinetis KL25Z Reference Manual
6. Freescale FRDM-KL25Z Platform User's Guide
7. Embedded Systems Fundamentals with ARM Cortex-M Based Microcontrollers: A Practical Approach by Dean Alexander - Chapter 6 (ADC Bare metal coding)
8. Code guide for Module 1-4

9. Project Staffing

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