

# MKM14 Pressure Sensor with Current Loop (4-20ma) Output

by: Petr Gargulak

## 1 Introduction

This application note explains the example of how to use MKM14 device in non-electric metering application. In this case, the MKM14 device is used in simple small pressure sensing application with industry standard current loop output 4-20 mA. The benefit of MKM14 is precise Analog Front-End (AFE) is used for reading the pressure sensor with small span of differential voltage output. The next benefit of MKM14 is good computing power on low-power device. This enables implement compensation technique, which is required for low-cost uncompensated pressure sensor devices (like MPX53 series), used in this application.

## Contents

1	Introduction .....	1
2	Board hardware.....	2
2.1	Power source.....	3
2.2	Board current measuring.....	4
2.3	Output current load circuit.....	4
2.4	Sensor connection.....	4
2.5	Current management.....	4
2.6	Bill of material.....	5
2.7	The board schematic .....	7
3	Software.....	9
3.1	Main loop.....	9
3.2	Pressure sensor read interrupt routine.....	10
3.3	Output current shunt resistor read interrupt routine	11
4	Conclusion .....	12
5	Revision history .....	12

## 2 Board hardware

Due to the limitation of maximum current as 4 mA for the whole design, this application cannot be used with any standard Kinetis M series development kit. The circuit is designed like a real application with small layout and minimal number of parts to reflect actual requirements of final application, like low-cost, small layout, robustness, and precision. The complete hardware is designed to support two different types of pressure sensors:

- Uncompensated – with 3.3 V power supply and small output voltage span  $\leq 60$  mV, CASE 344B-01, for example is used MPX53DP
- Fully compensated – with 5 V power supply and big output voltage span  $\sim 5$  V, CASE 482A precise

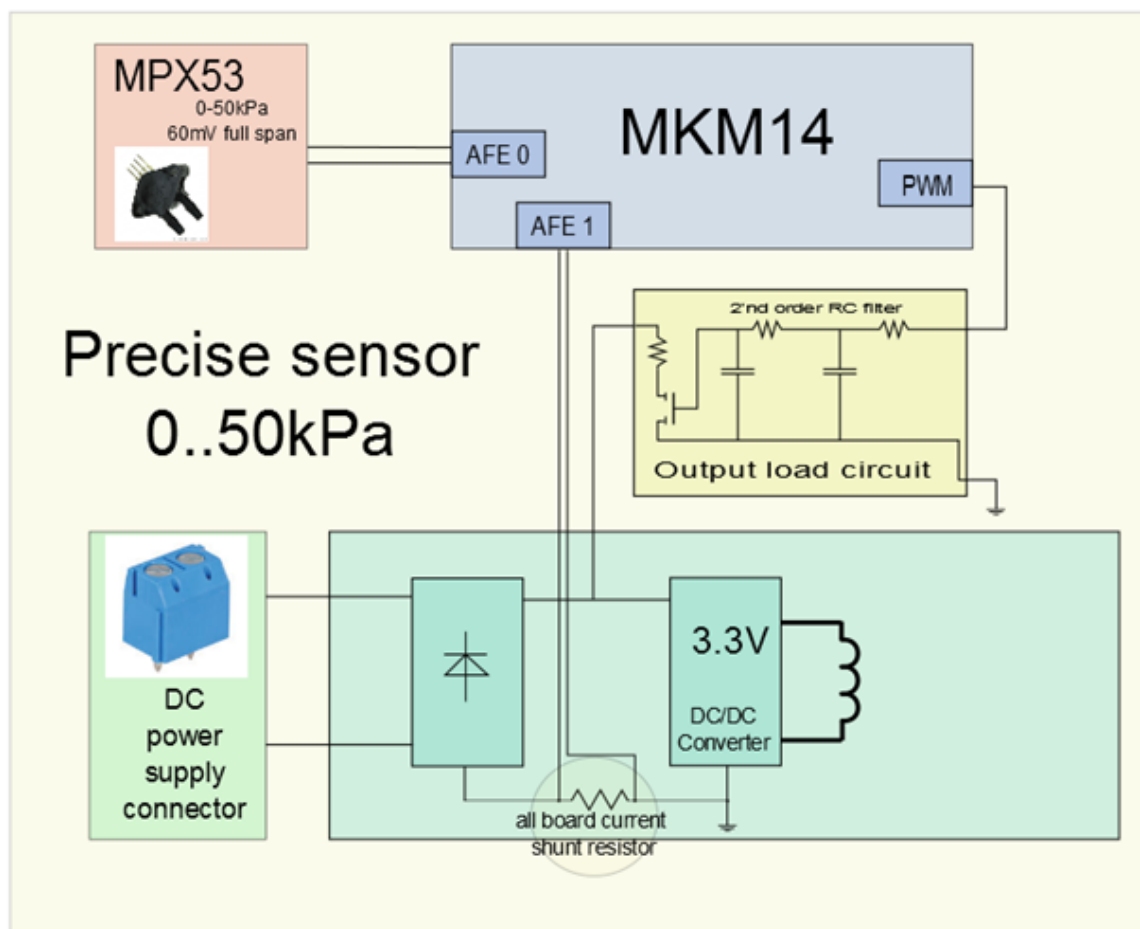


Figure 1. Hardware block diagram of MPX53DP

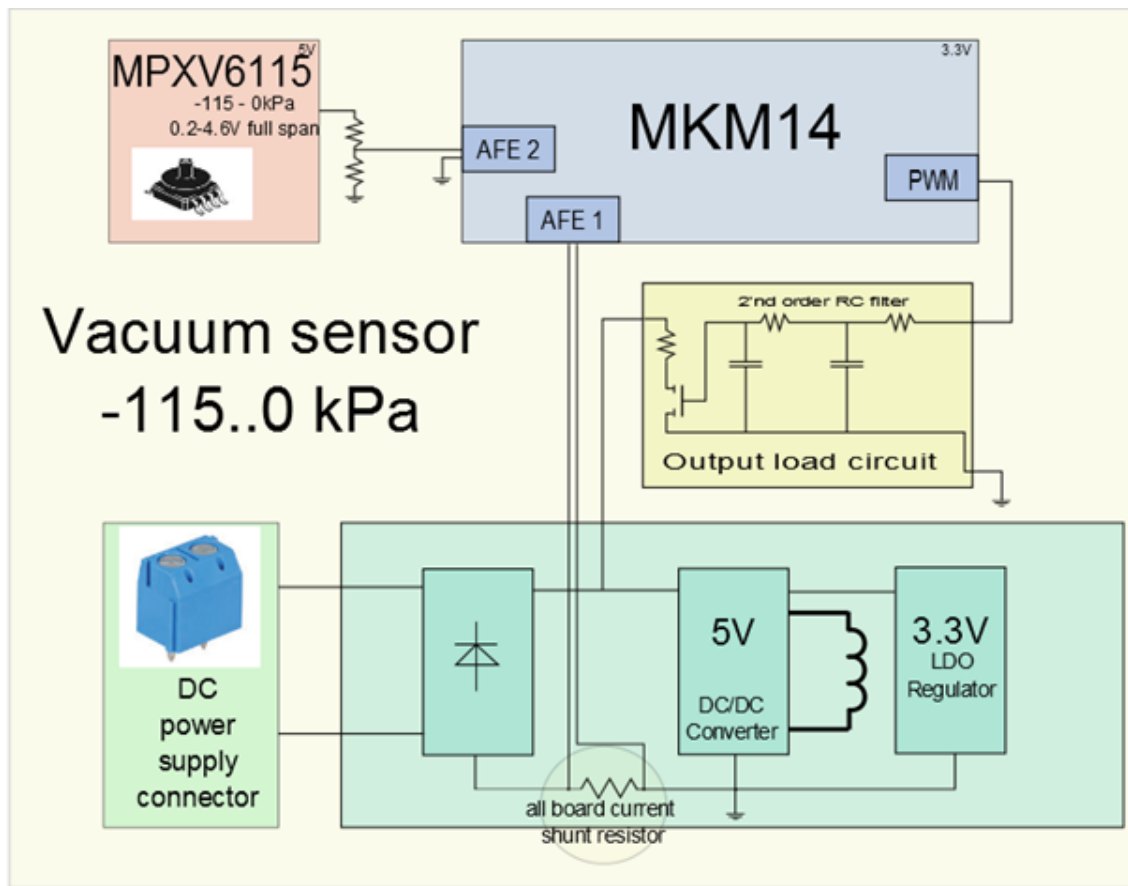


Figure 2. Hardware block diagram of MPXV6115

## 2.1 Power source

The input voltage is unipolar due to use Diode Bridge that handles possible reverse of input voltage polarity. Because the input voltage range is pretty wide (15-35 V), after diode bridge is connect switching power supply with 5 V or 3.3 V output it depends on current configuration of sensors. The reason to use switching power supply is current harvesting as the whole board is consuming more than 4mA specified in current loop standard. So for the switching power source LTC3632 chip is selected which is directly recommended for current loop sensors application. The board is running (due to MKM14) at 3.3 V, so if the 5 V pressure sensor is selected then the additional 3 V LDO will be used to supply the MCU. For more information see [The board schematic](#).

Also there is additional filter for analog voltage to supply MKM14 Analog Front End and uncompensated sensor that is run also on 3.3 V.

## 2.2 Board current measuring

Because the design is constructed with a 4-20 mA current loop output, the close loop regulation of output current is selected to provide accurate current output. The signal for feedback correction of close current loop is generated through the shunt resistor on the ground signal connected directly to MCU AFE to allow precise measurement of overall board current consumption.

## 2.3 Output current load circuit

To generate accurate board current consumption, circuit is used to generate additional current consumption based on sensor value. The output current load circuit is build by small MOSFET transistor with load resistor and the gate of MOSFET is connected through the second order RC filter to PWM output of microcontroller. With this simple circuit, the MCU by generated PWM can generate additional current consumption of whole board.

## 2.4 Sensor connection

The design can be assembled with two different types of sensors:

- MPX53 – This sensor is 3.3 V device with differential uncompensated small span output. This sensor is connected to filtered analog power supply and the differential output is connected directly to AFE0 (analog front end 0) of microcontroller without any filtering.
- MPXV6115 – This sensor is 5 V device with single-ended high-range compensated output. The sensor output is connected to AFE1 of microcontroller in single-ended configuration and due to high-range of sensor, the output is divided by voltage divider to fit the AFE input range.

## 2.5 Current management

For design with current loop, it is important keep overall board consumption output under 4mA, in order to achieve full scale of 4-20 mA output. And because the parts (sensor, MCU, and power converter) takes about 14 mA at 3.3 V so voltage regulator is used in design switching power converter with high efficiency that convert low input current to higher on 3.3 V side. So this allows to use parts in design with consumption of about 15 mA without any problem.

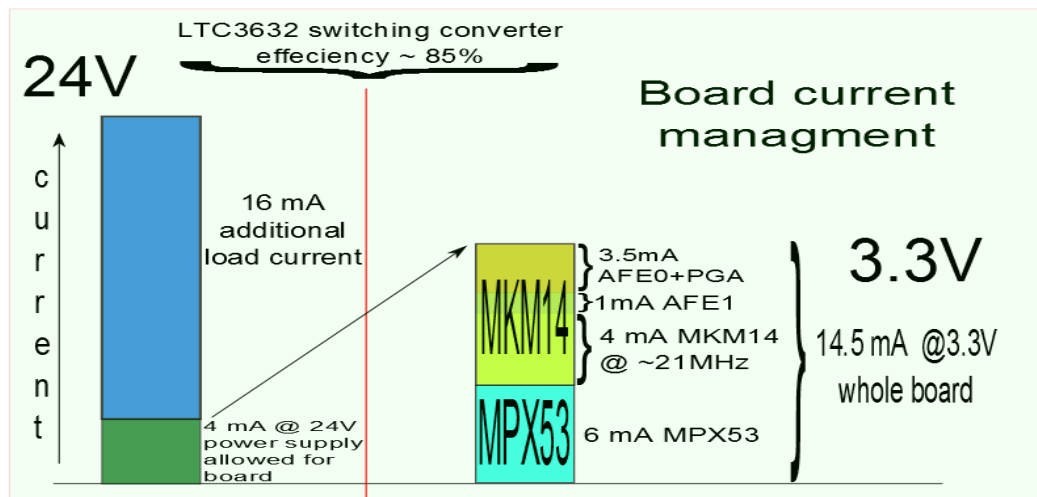


Figure 3. Current consumption block scheme

## 2.6 Bill of material

### 2.6.1 MPX53 version

MPX53 version					
Part Reference	Value	Quantity	MFG_PN01	MFG_NAME01	Note
C2 C3 C6 C7 C10 C11	0.1uF	6	capacitor 100nF / 50V, 0603	—	—
C5	1uF	1	capacitor 1uF / 10V, 0603	—	—
C8	0.01uF	1	capacitor 10nF / 50V, 0603	—	—
C9	0.047uF	1	capacitor 47nF / 50V, 0603	—	—
C12	10uF	1	C1608X5R0G106M	TDK	—
D1 D2	BAV99	2	BAV99	Fairchild	—
J1	HDR 2X5	1	FTSH-105-02-F-D	SAMTEC	—
J2	CON TB 2	1	MC000048	MULTICOMP	—
L1	1000uH	1	LPS6235-105ML	Coilcraft	—
L2	100 OHM@100MHZ	1	BLM18EG101TN1D	MURATA	—
Q1	NTS4001NT1G	1	NTS4001NT1G	ON SEMICONDUCTOR	—
R1 R4	300	2	resistor 300R / 100mW, 1206	—	—
R2	330K	1	resistor 330K / 100mW, 0603	—	—
R3	5.1	1	resistor 5R1 / 100mW, 0603	—	—

R5	120K	1	resistor 120K / 100mW, 0603	—	—
R6	200	1	resistor 200R / 100mW, 0603	—	—
R7	1.0K	1	resistor 1K / 100mW, 0603	—	—
R10, R11	10.0K	2	resistor 10K 1% / 100mW, 0603	—	—
R12, R13	6.8K	2	resistor 6K8 1% / 100mW, 0603	—	—
SH1	0	1	LAYOUT ELEMENT ONLY	—	Must be shorted on board
U1	MKM14Z128CHH5	1	MKM14Z128CHH5	FREESCALE SEMICONDUCTOR	—
U2	MPX53DP	1	MPX53DP	FREESCALE SEMICONDUCTOR	—
U4	LTC3632	1	LTC3632EDD#PBF	LINEAR TECHNOLOGY	—

## 2.6.2 MPXV6115 version

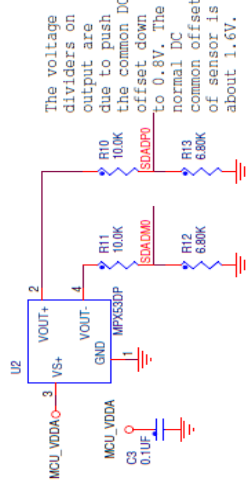
MPXV6115 version					
Part Reference	Value	Quantity	MFG_PN01	MFG_NAME01	Note
C2 C4 C6 C7 C10 C11	0.1UF	6	capacitor 100nF / 50V, 0603	—	—
C5	1uF	1	capacitor 1uF / 10V, 0603	—	—
C8	0.01UF	1	capacitor 10nF / 50V, 0603	—	—
C9	0.047UF	1	capacitor 47nF / 50V, 0603	—	—
C12	10UF	1	C1608X5R0G106M	TDK	—
D1 D2	BAV99	2	BAV99	Fairchild	—
J1	HDR 2X5	1	FTSH-105-02-F-D	SAMTEC	—
J2	CON TB 2	1	MC000048	MULTICOMP	—
L1	1000uH	1	LPS6235-105ML	Coilcraft	—
L2	100 OHM@100MHZ	1	BLM18EG101TN1D	MURATA	—
Q1	NTS4001NT1G	1	NTS4001NT1G	ON SEMICONDUCTOR	—
R1 R4	300	2	resistor 300R / 100mW, 1206	—	—
R2	4.3M	1	resistor 4M3 / 100mW, 0603	—	—
R3	5.1	1	resistor 5R1 / 100mW, 0603	—	—
R5	820.0K	1	resistor 820K / 100mW, 0603	—	—
R6	200	1	resistor 200R / 100mW, 0603	—	—

R7	1.0K	1	resistor 1K / 100mW, 0603	—	—
R8	24K	1	resistor 24K / 100mW, 0603	—	—
R9	150.0K	1	resistor 150K / 100mW, 0603	—	—
U1	MKM14Z128CHH5	1	MKM14Z128CHH5	FREESCALE SEMICONDUCTOR	—
U3	MPXV6115VC6U	1	MPXV6115VC6U	FREESCALE SEMICONDUCTOR	—
U4	LTC3632	1	LTC3632EDD#PBF	LINEAR TECHNOLOGY	—
U5	NCP563SQ33T1G	1	NCP563SQ33T1G	ON SEMICONDUCTOR	—

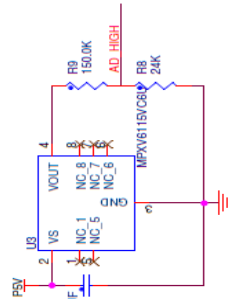
## 2.7 The board schematic

## SENSORS

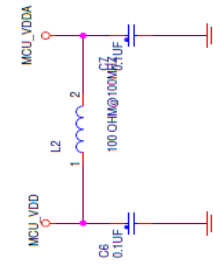
50 kPa Uncompensated Silicon Pressure Sensors



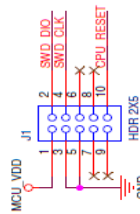
OR  
TC PRESSURE SENSOR -115-0 KPA 0.2-4.6V 4.75-5.25V SOP8



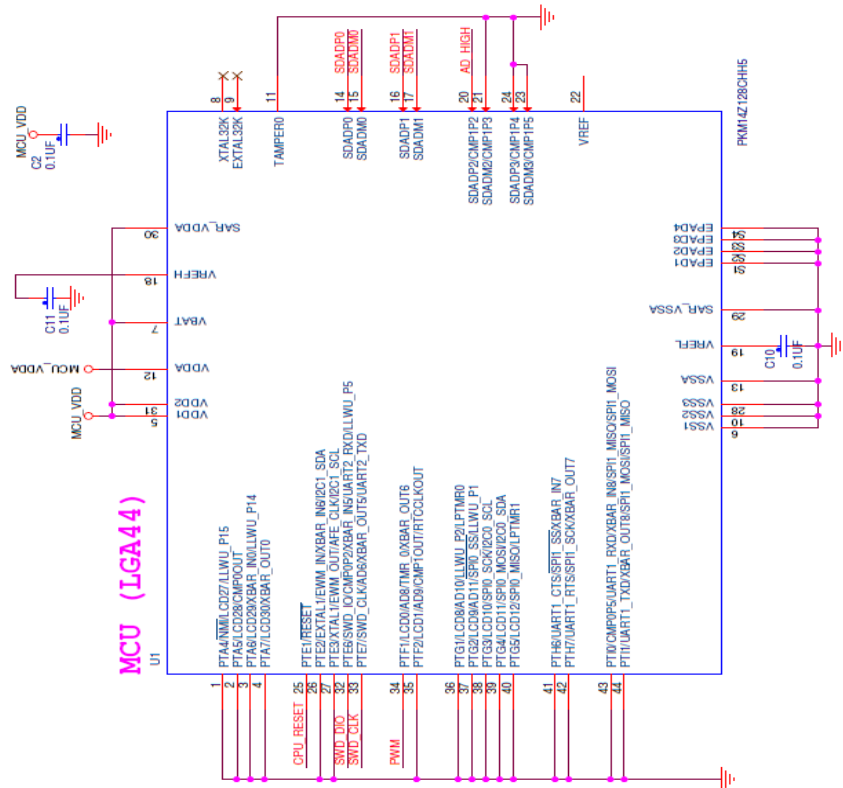
## ANALOG POWER SOURCE



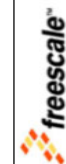
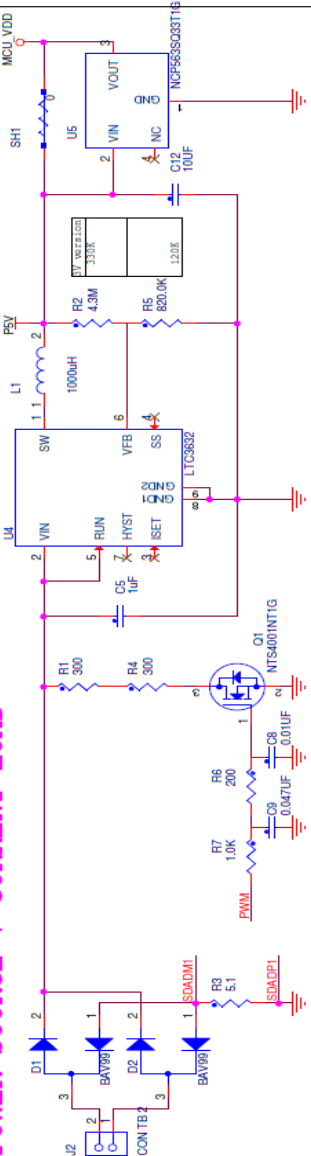
## JTAG / SWD CONNECTOR



## MCU (LGA44)



## POWER SOURCE + CURRENT LOAD



**Automotive, Industrial & Multi-market Solutions Group**  
6501 William Cannon Drive West  
Austin, TX 78735-8988

This document contains information proprietary to Freescale and shall not be used for engineering design, procurement or manufacture in whole or in part without the express written permission of Freescale.

Designer: Petr Gargulak	Drawing Title: X-PTN-PRSR_SNSR	FCP: FUD:
Drawn by: Petr Gargulak	Page Title: Photon pressure sensor 4-20mA	PUB: X
Approved: L. Vackulak & M. Mensel	Document Number: SCH-28068 PDF: SPF-28068	Rev: B
Date: Wednesday, October 02, 2013	Sheet: 2	of: 2



### 3 Software

The software of this pressure sensor has interrupt driven concept, it executes two tasks, checks AFE reading from pressure sensor and shunt resistor of output current. Based on results of these readings is updated PWM output to generate accurate board current depends on measured pressure by pressure sensor.

In main function is just setup MCU peripherals like input clock source and initializing the AFE and TMR peripherals.

The code structure is divided into following three independent parts:

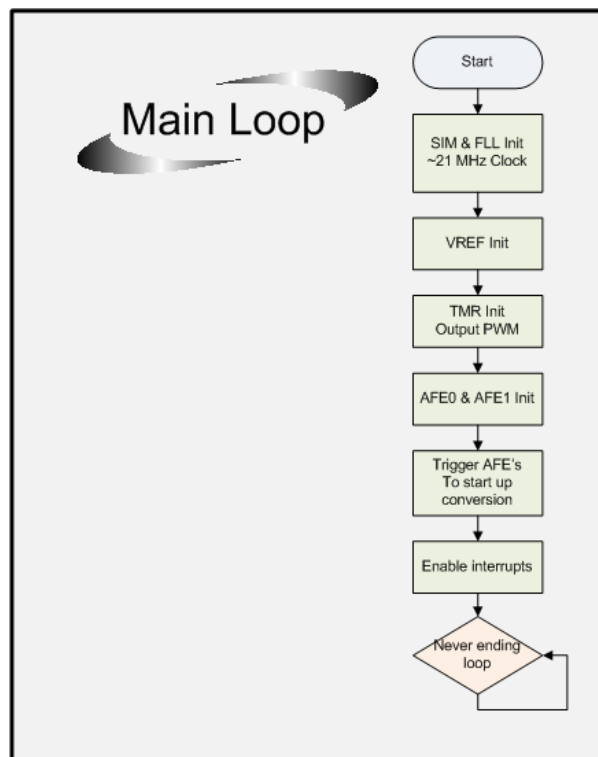
- Main function - initial code is defined.
- Interrupt of reading pressure sensor - this small piece of code is generating requested value for output current regulator.
- Interrupt of reading of shunt resistor - code is running the simple proportional regulator to keep current of the board on the required value.

#### 3.1 Main loop

The main loop is used for complete initialization of the required peripherals on the chip, enable interrupts to startup interrupt driven part of code and lock the main function in never ending loop.

The used and initialized peripherals are as follows:

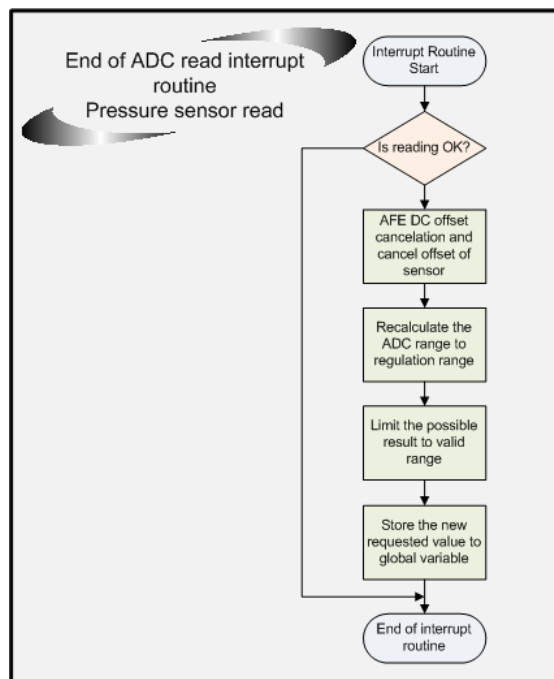
- FLL – start FLL to generate system clock at ~21 MHz, this is an approximate value because it takes from non-trimmed internal clock source.
- VREF – voltage reference that is needed to run AFE correctly.
- TMR – Quad timer peripheral is used to generate output PWM signal.
- AFE – Analog front end is used to measure pressure sensor and output current shunt resistor.



**Figure 4. Main loop**

### 3.2 Pressure sensor read interrupt routine

The first interrupt routine is based on the end of AFE conversion measuring event of output voltage of pressure sensor. This interrupt routine is comprised of few lines of code to AFE DC offset cancelation and mainly recalculate the input value of AFE (24-bit size of signed output) to choose internal range of 1024 steps of required value. Also, there is mechanism to limit calculated value in output valid range 0-1024. The computed result value, which is required for the PWM output regulator, is stored at global volatile variable.



**Figure 5. Pressure sensor read interrupt routine**

### 3.3 Output current shunt resistor read interrupt routine

The second interrupt routine is based on the end of AFE measuring event of board current shunt resistor. This interrupt routine is comprised of few lines of code to AFE DC offset cancelation and mainly proportional regulator of output current in range 4-20 mA based on the required value that is generated by pressure sensor interrupt routine. This proportional regulator secures feedback regulation of all board current, which keep the current value that reflects the sensor output value.

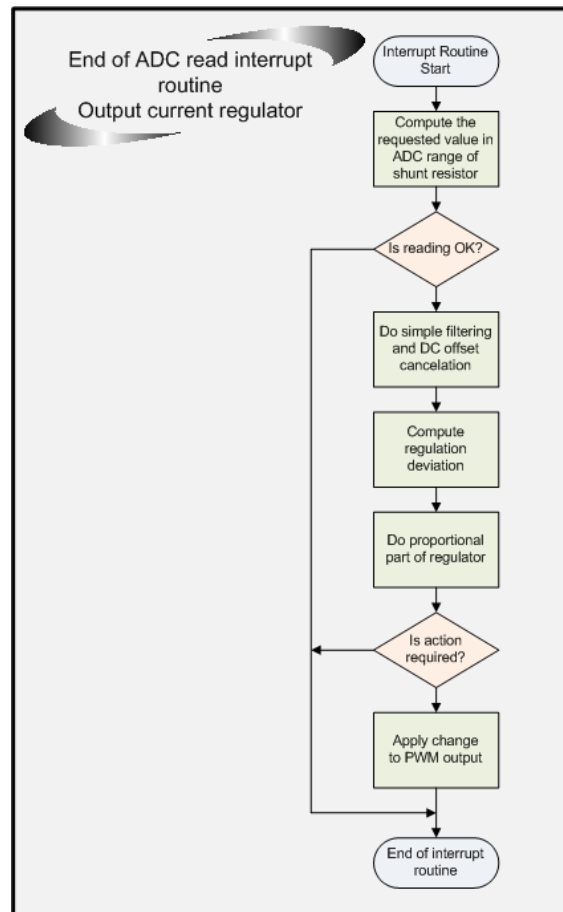


Figure 6. Proportional output current regulator interrupt routine

## 4 Conclusion

This application note shows the Kinetis M family (metering) in non-electric metering application where the application profits from the precise AFE and low-power of MCU. The precise AFE is needed due to weak pressure sensor output and cost of final board to avoid use of operational amplifier to gain sensor output for standard SAR ADC. And low-power is needed to meet specification of current loop output 4-20 mA.

## 5 Revision history

The following table summarizes revisions history of this document:

Table 1. Revision history

Revision number	Date	Change description
0	01/2014	Initial release

**How to Reach Us:****Home Page:**[freescale.com](http://freescale.com)**Web Support:**[freescale.com/support](http://freescale.com/support)

Information in this document is provided solely to enable system and software implementers to use Freescale products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits based on the information in this document.

Freescale reserves the right to make changes without further notice to any products herein. Freescale makes no warranty, representation, or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters that may be provided in Freescale data sheets and/or specifications can and do vary in different applications, and actual performance may vary over time. All operating parameters, including "typicals," must be validated for each customer application by customer's technical experts. Freescale does not convey any license under its patent rights nor the rights of others. Freescale sells products pursuant to standard terms and conditions of sale, which can be found at the following address: [freescale.com/SalesTermsandConditions](http://freescale.com/SalesTermsandConditions).

Freescale and the Freescale are trademarks of Freescale Semiconductor, Inc., Reg. U.S. Pat. & Tm. Off. All other product or service names are the property of their respective owners. The ARM Powered Logo is a trademark of ARM Limited.

© 2014 Freescale Semiconductor, Inc. All rights reserved.

Document Number: AN4853

Rev. 0

01/2014

