

Flow Meter Reference Design

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Chapter 1 Introduction

1.1 Introduction to flow meter reference design

Flow meter based on MC9S08GW64 is a low-cost, low-power system. This reference design is specifically targeted for gas and fluid meters. This design fulfils the basic market requirement for the Flow meter: low-power, low-cost, able to run on battery, and with automated meter reading (AMR).

The main attraction of this design is that the flow sensing module of the MCU keeps running even when the MCU goes into low-power mode. Since the MCU is in low-power mode for most of the time, it reduces the power consumption.

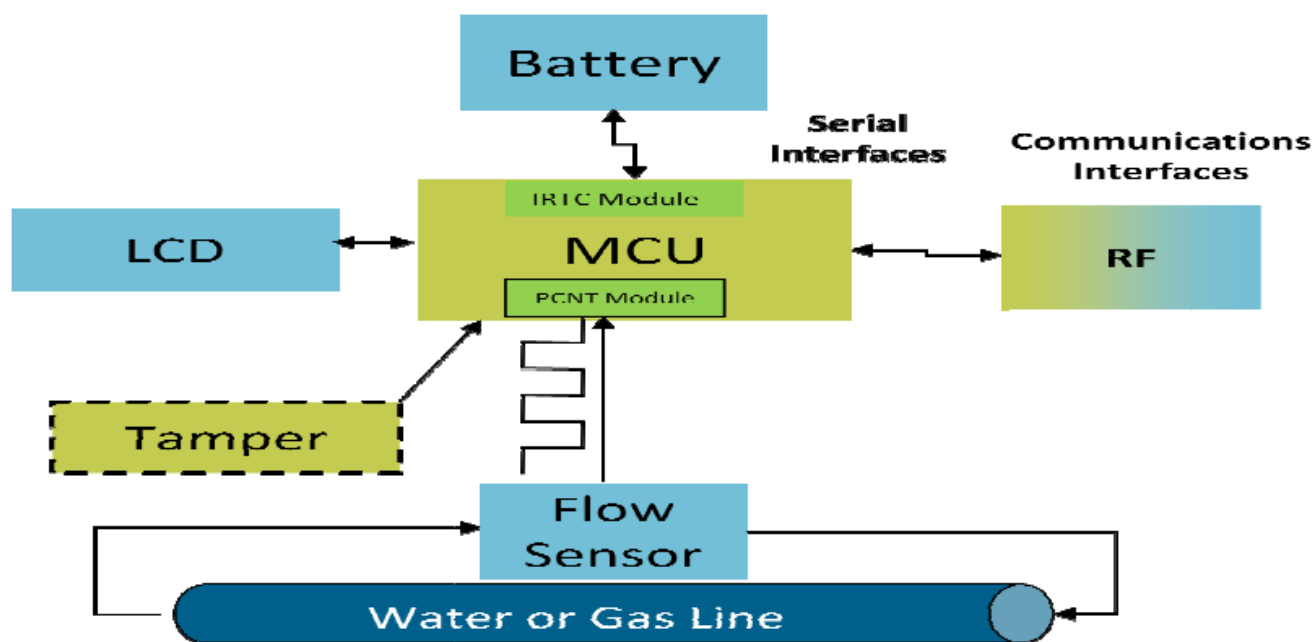


Figure 1-1. Block diagram

This meter supports a battery driven power supply and is capable of time keeping. It senses the signals from the flow sensor, calculates the flow and then accumulates it. The total flow accumulated and the monthwise profile of the flow are stored and updated in the memory. The user key available on the board can be used to display the flow accumulated in a month and the date on the LCD.

The design also supports wireless communication with another handheld device using ZigBee[®]. Thus, the device supports the AMR where a user can derive the flow readings using a handheld device from a distance.

This document describes the design of a flow meter reference design based on Freescale's MC9S08GW64 microcontroller specifically targeted for flow metering applications. This design is targeted at consumer and industrial applications.

1.2 Application features and components

The reference design is based on MC9S08GW64 microcontroller and has the following features:

- Operating voltage 3.3 V and frequency 4 MHz
- Based on Hall Effect sensor
- RF communication over ZigBee
- Battery driven power supply, capable of running more than 10 years
- Measurement and storage of the total flow accumulated as well as the monthly profile of flow
- LCD display of the flow accumulated in a month
- User switch (SW2) available on the design for the LCD display (display turns off automatically after a few seconds to save power)
- Inbuilt hardware to detect box-open tamper even in case of power failure

The following items are supplied for developing the energy meter using the MC9S08GW64 microcontroller:

- Reference energy meter
- Software—Design document, source code
- Documentation—DRM, BOM, schematics

1.3 Freescale controller: advantages and features

The advantages of using MC9S08GW64 include:

- Extremely low-power consumption since the CPU stays in low-power mode in between the calculations
- Ultra-low-power independent RTC with calendar features

- Inbuilt LCD driver
- Inbuilt position counter (PCNT) that keeps working even in the low-power mode and is used to calculate the flow and to send interrupts for MCU wakeup
- Tamper pin used as a user interface to scroll through the display options
- Standby RAM of the IRTC used to update the flow on every interrupt
- Flash used for EEPROM emulation to store the flow accumulated and other data

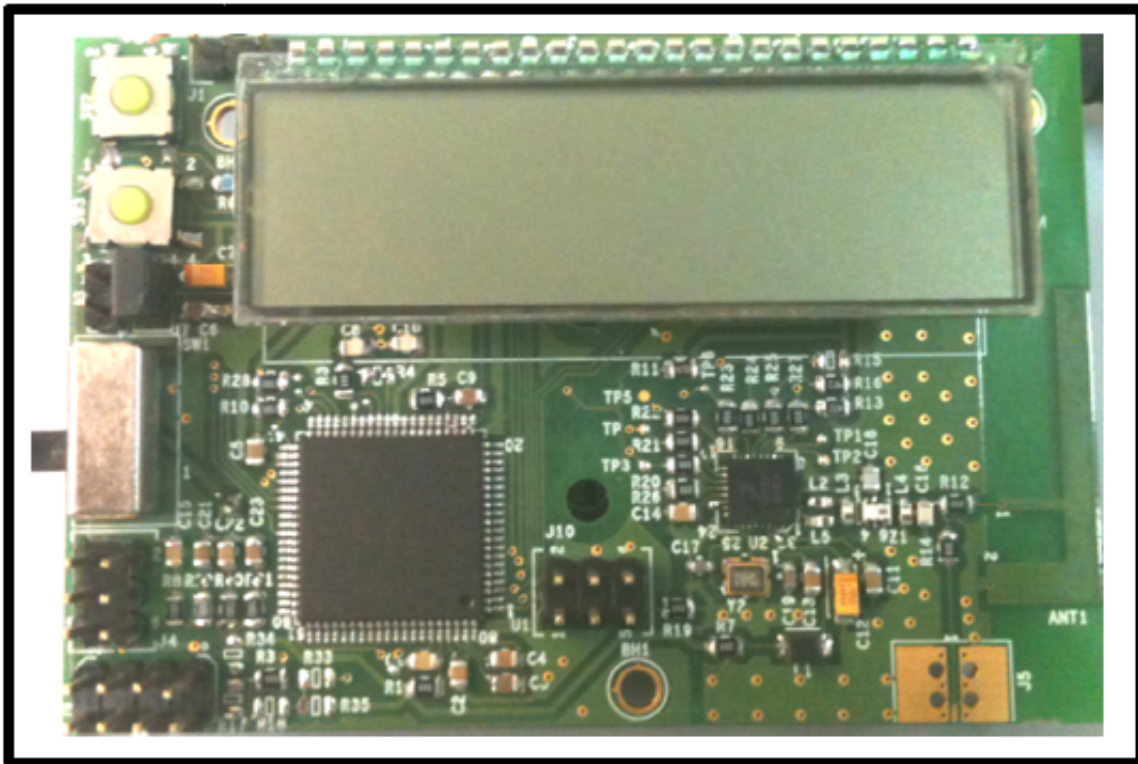


Figure 1-2. Reference design for flow meter

The features of the Freescale's MC9S08GW64 MCU include:

- 20 MHz 8-bit S08 MCU
- Up to 288 segments (1...8x43...36) of LCD and can be interfaced. Flexible frontplane/backplane pin assignments
- AMR SPI and SCI, 5 V tolerant master/slave SPI and SCI
- 2 separate tamper
- Operating temperatures: -40°C to 85°C , 80/64 pin
- Inbuilt battery operated IRTC



Chapter 2 Metering Theory and Configurations

2.1 Basics of flow meter

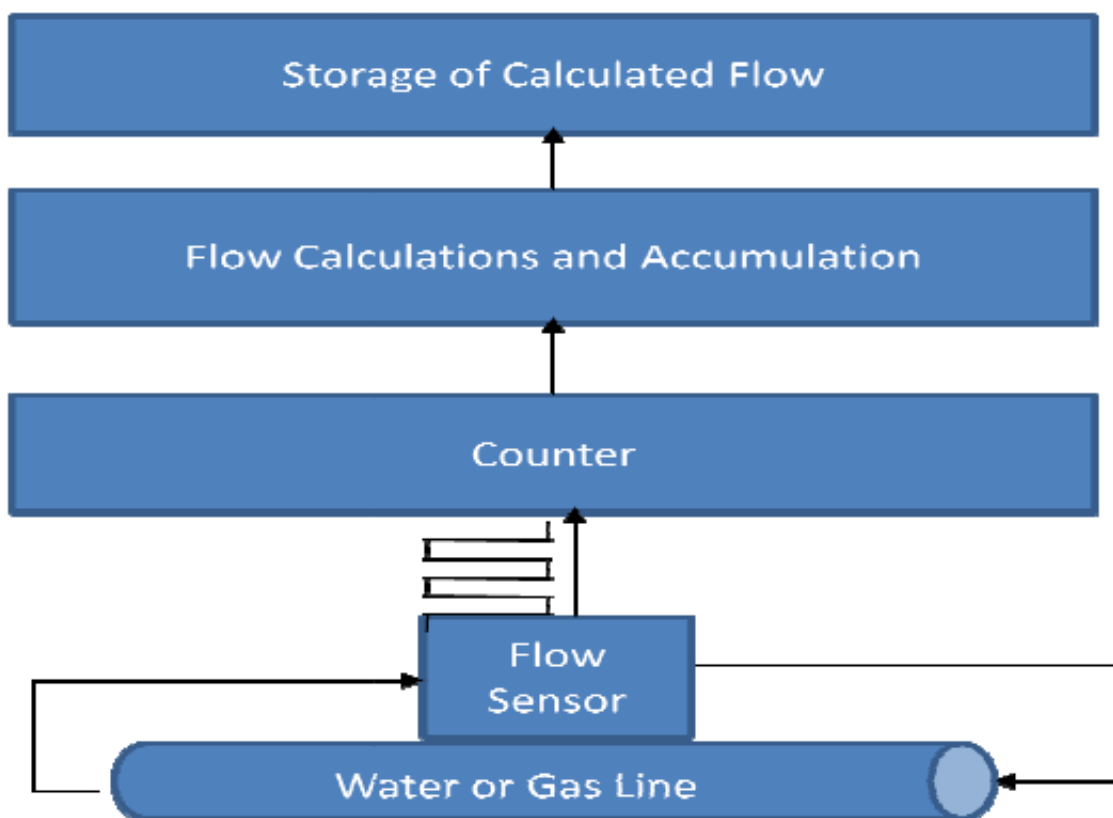


Figure 2-1. Block diagram of basic flow meter

Figure 2-1 shows the flow meter concept block diagram. The flow sensor is used to sense the flow of the gas or fluid. It generates pulses according to the flow sensed. These pulses are counted using a counter and then based on the number of pulses encountered in a particular time, the flow is calculated, accumulated, and stored.

- A flow meter is a device that measures the rate of flow and the flow accumulated over the time.

- It can be used for measuring the flow of gas or fluid supplied for residence, factory, agriculture, and so on.
- The unit for the measurement of flow is liter

2.2 Flow calculations

The flow calculation is done with the help of PCNT (position counter) module. It keeps on counting the pulses generated by the flow sensor. The overflow generates the interrupt to the MCU. The flow calculations in this reference design are done on a linear flow sensor.

Suppose the sensor generates ‘x’ pulses per second (pps) when the fluid flows at a rate of ‘y’ liters/minute. The flow is calculated as follows:

‘y’ liters/minute => ‘x’ pulses per second => ‘x’*60 pulses per minute

Thus, if ‘x’ * 60 pulses are counted then flow accumulated = ‘y’ liters Suppose ‘n’ pulses leads to the overflow of the PCNT then

Flow accumulated when due to ‘n’ pulses = {‘y’/ (60* ‘x’)}* ‘n’

Chapter 3 Hardware Design

3.1 Block diagram

The block diagram below gives the overview of flow meter based on MC9S08GW64.

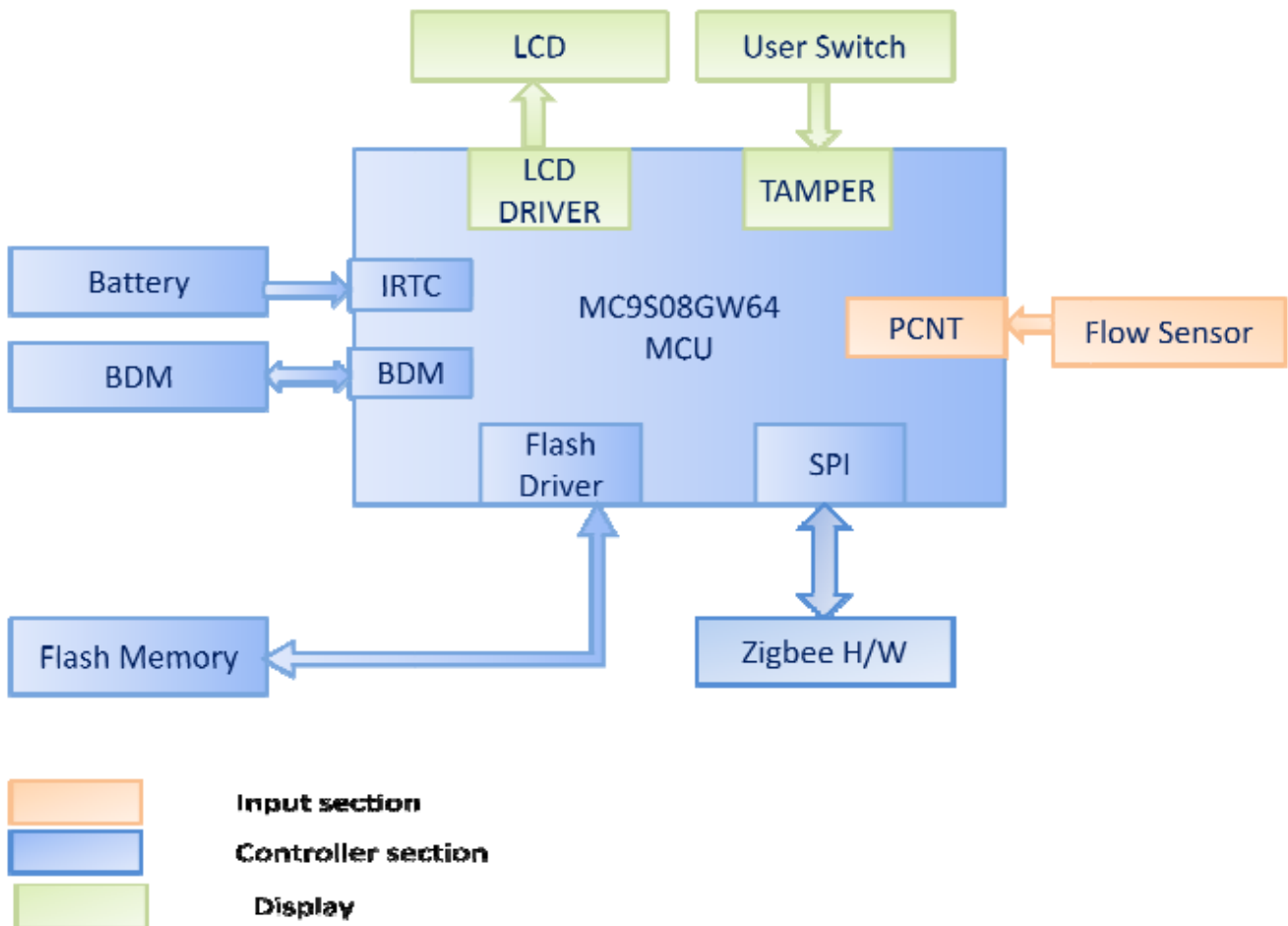


Figure 3-1. Flow meter reference design block diagram

3.2 Power supply

The power is supplied using batteries as shown in the diagram below. Using the switch (SW1) the power can be switched on or off.

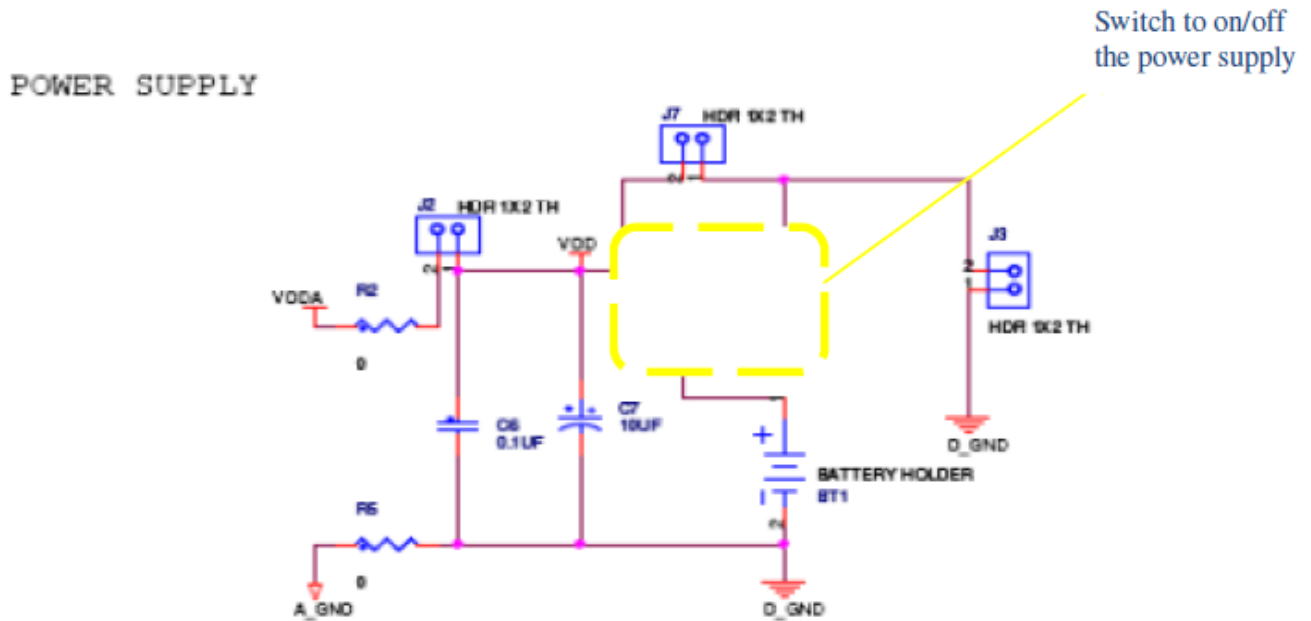


Figure 3-2. Power supply schematic

3.3 Display interface

LCD (Liquid Crystal Display)

LCD used for display is a flow meter specific as shown in the figure below:

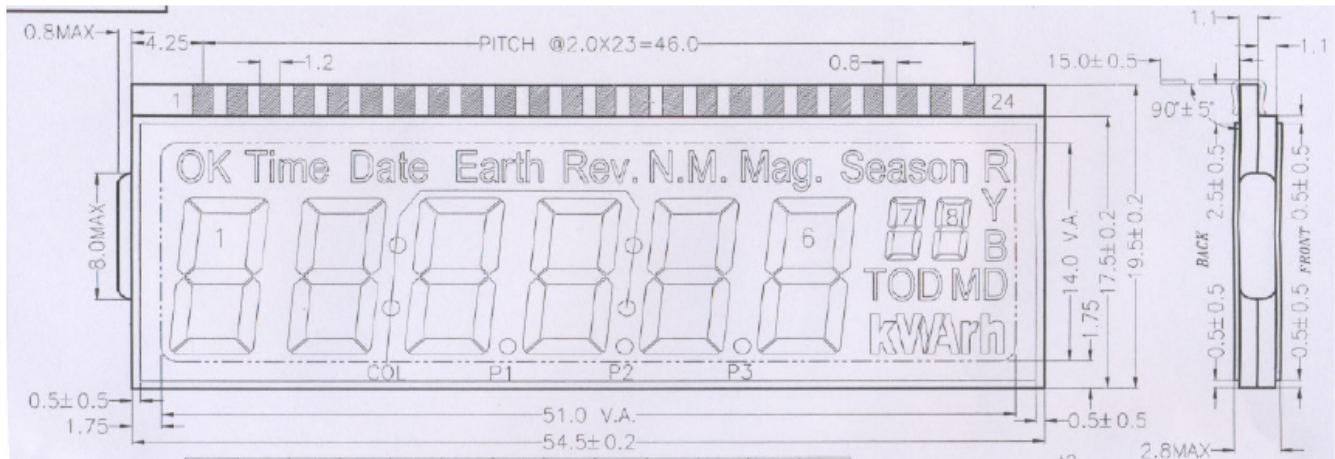


Figure 3-3. Front view of LCD

- Viewing angle — 6:00 o'clock
- Display m — positive/ reflective/ in type
- Driving voltage — 3.0 V, Duty — 1/4, Bias — 1/3
- Operating temperature — 20° C to 70° C
- Storage temperature — -25° C to 75° C
- Polarizer: Transmissive / Positive (UV)
- Display Type: TN

The glass uses four pins as backplane and 20 pins as front plane. This has 4 x 20 (80) segments in all. The flow and date can be displayed on this LCD.

3.4 Flow sensor interface

The interface between the reference meter and the flow sensor is shown in the figure below:

FLOW SENSOR

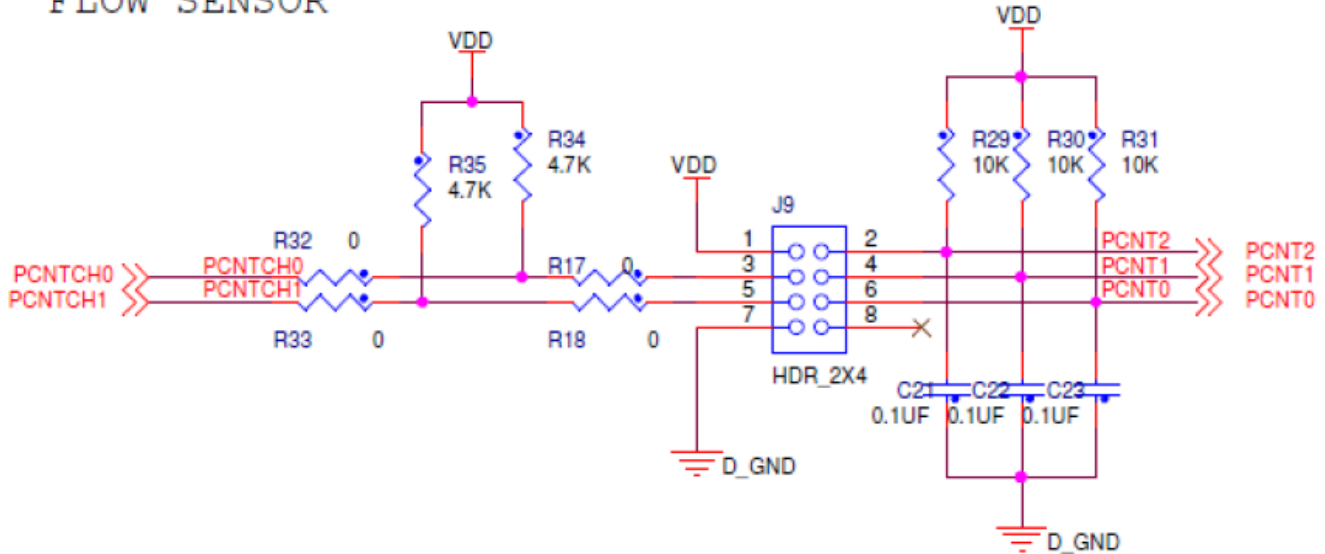


Figure 3-4. Flow sensor interface diagram

- The pulse output from the flow sensor should be connected to the "PCNT2" (PCNT0 and PCNT1 pins are not used but kept for connectivity for up to 3 bit binary or grey coded sensors).
- The power supply and ground can be provided to the flow sensor using the pins 1 and 7 of the jumper J9 as shown in [Figure 3-4](#).

3.5 User pin interface

There is one push button on the reference meter which displays the flow and date on the LCD alternatively.

3.6 Communication port

The meter can communicate with the ZigBee trans-receiver available on the reference design.

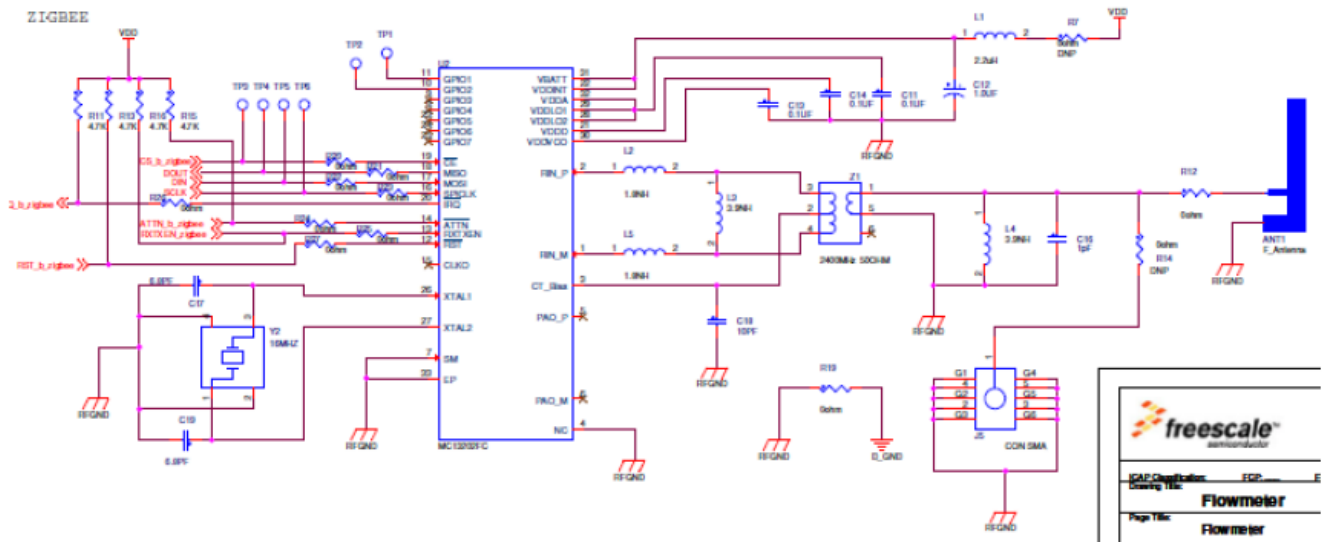


Figure 3-5. Schematic of ZigBee trans-receiver on the reference design

- Wireless (ZigBee) communication – data exchange for flow meter parameters
- ZigBee communication complied with IEEE 802.15.4 standard for data exchange

3.7 Background Debug mode (BDM)

- The BDM communication interface is used basically for programming the controller
- The non-isolated BDM port is connected directly to the controller



Figure 3-6. Photograph of PE micro USB multilink

- PE's USB multilink is a debug interface that allows a PC to access the background BDM on controller MC9S08GW64
- It connects between a USB port on a windows machine and the standard 6 pin berg debug connector on the target
- The user can take advantage of the BDM to halt normal processor execution and use a PC to control the controller
- The user can then directly control the target's execution, read/write registers and memory values, debug code on the controller, and program internal or external FLASH memory devices

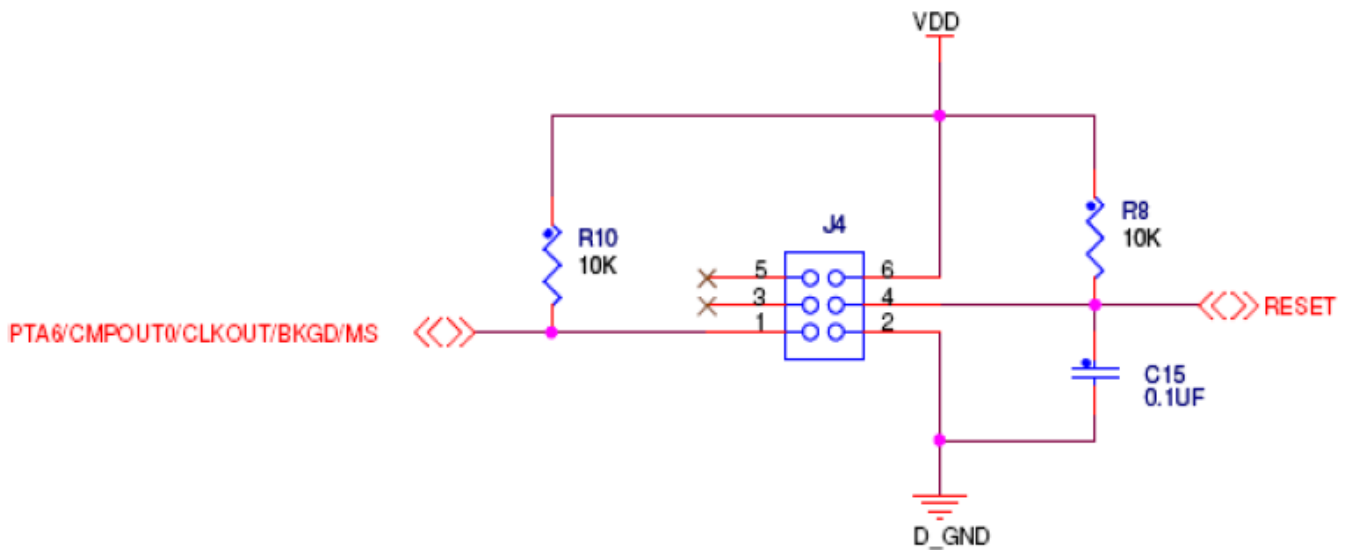


Figure 3-7. Circuit of BDM 6-pin connector

3.8 Microcontroller requirements

3.8.1 Crystal requirements

The external 32.768 kHz is a crystal used for the RTC, the same clock is multiplied by the FLL which is internal to the controller to provide clock to core, bus, and peripherals.

3.8.2 LCD requirements

The LCD driver of the controller requires three ceramic capacitors whose typical value is 0.1 μ F for LCD bias voltages and a 0.1 μ F ceramic capacitor for the LCD charge pump.

3.9 Assembled printed circuit board

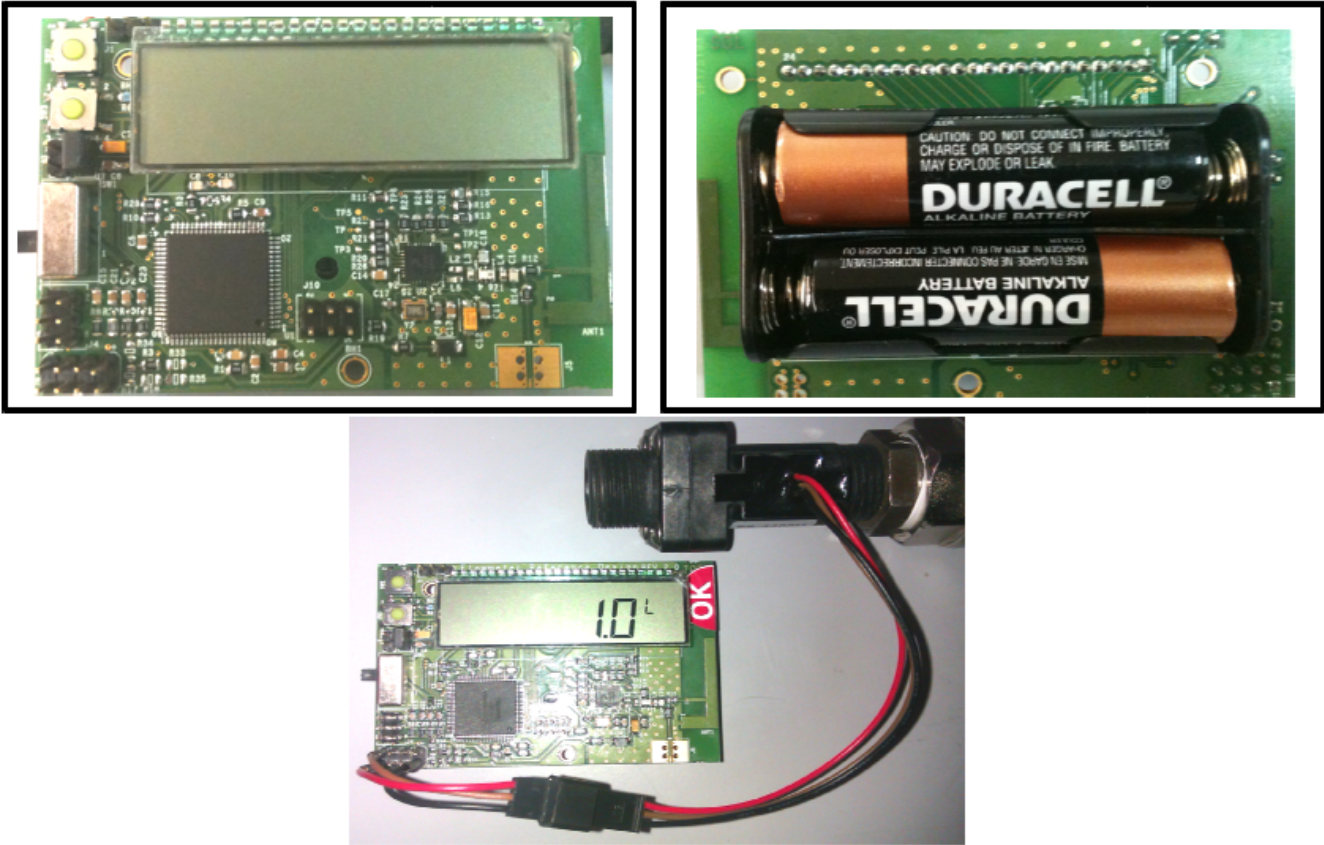


Figure 3-8. Assembled board

Chapter 4

Software Design

4.1 Introduction

This section describes the software design for the flow meter application. The software design consists mainly of the flow calculation, database, user interface, and communication modules. This chapter aims to explain the software design. The software architecture is a custom kernel running on an MC9S08GW64 controller. The controller uses the external RTC clock source and internal FLL to generate the system clock of approximately 2 MHz.

The software has following main modules:

- Flow Calculation Module
- Database Management Module
- User Interface Module
- Communication Module

4.2 Block diagram

The following figure shows the block diagram of MC9S08GW64-based flow meter software:

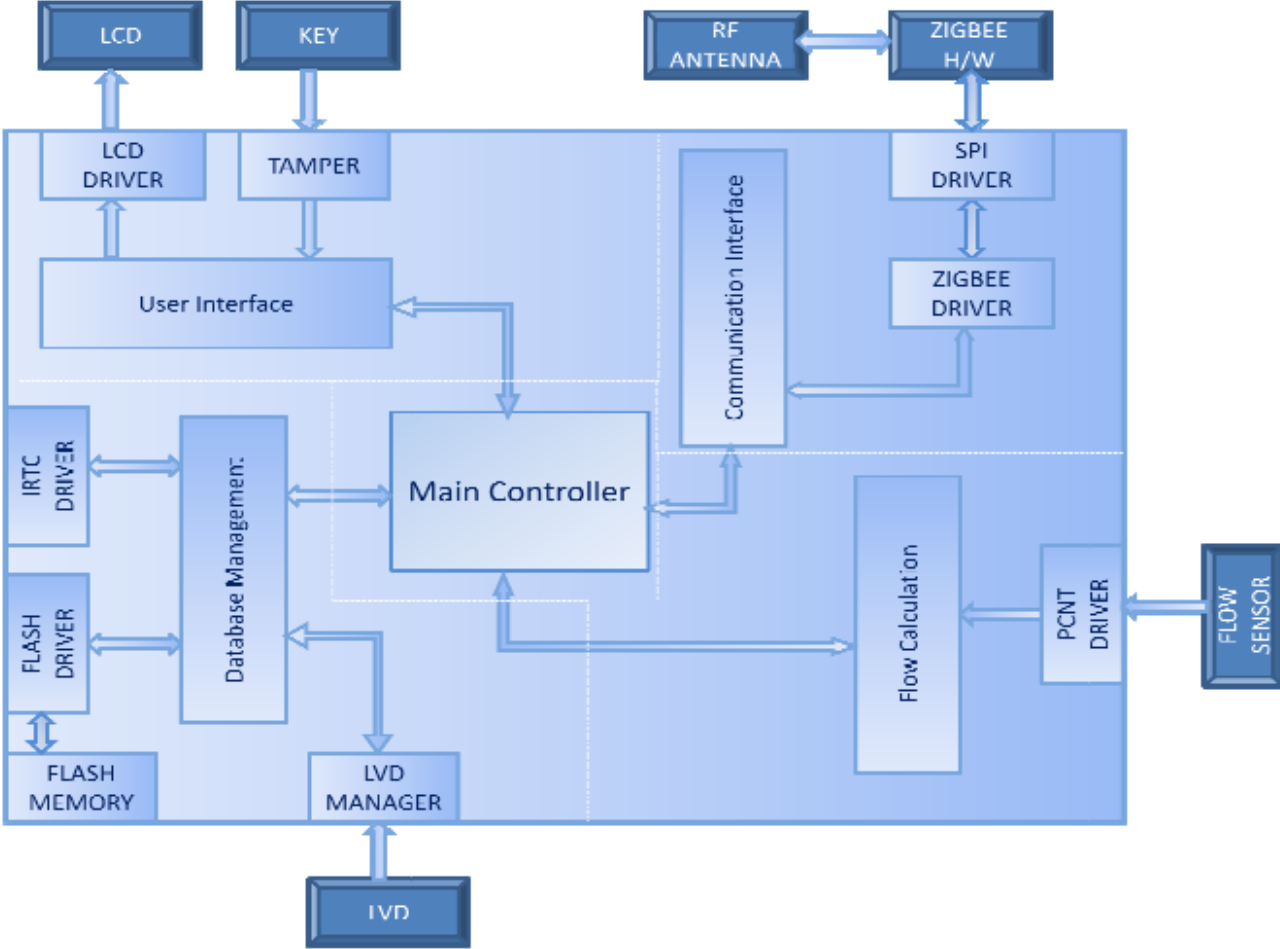


Figure 4-1. Block diagram of software architecture

4.3 Data flow diagram

The following figure shows the data flow diagram of MC9S08GW64-based flow meter software architecture

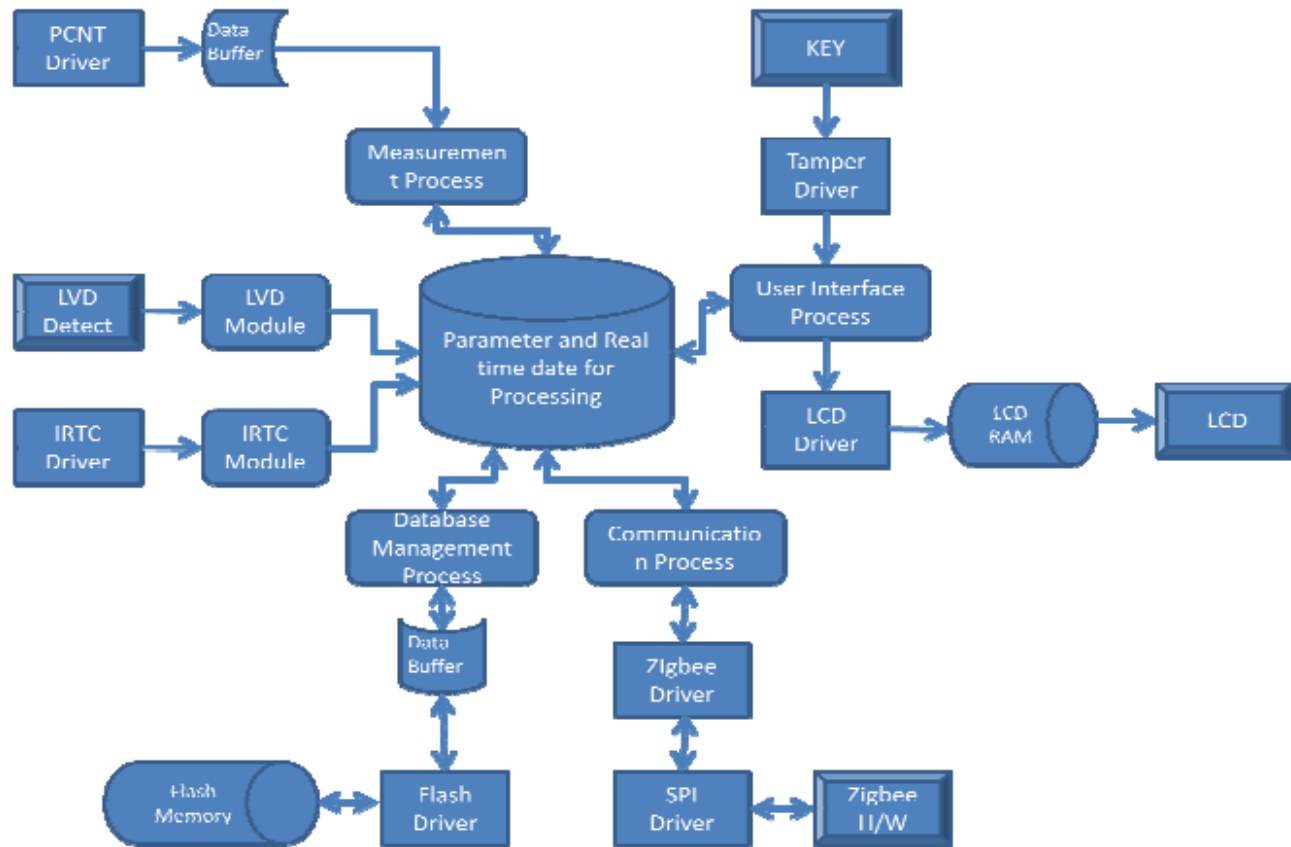


Figure 4-2. Data flow diagram

4.4 Hardware resource allocation

Table 4-1. Hardware Resource Allocation

MC9S08GW64 inbuilt block	Description
PCNT	Used to count the sensor output pulses and calculate the flow
Flash	Used to store the flow
Timer (MTIM1)	Used for interrupt generation to switch off the LCD after few seconds
LCD	Used to drive the LCD screen to display the flow on LCD screen
SPI	Used to communicate with ZigBee hardware
IRTC	Used for time keeping
Tamper	Used as a user switch

4.5 Flow Calculation

4.5.1 Overview

The Flow Calculation Module of the Freescale's Reference Flow Meter performs the following functions:

1. PCNT module counts the pulses from the flow sensor output.
2. Sends an interrupt to the MCU on PCNT overflow.
3. Computes the flow for the interval.
4. Accumulates the flow in a variable.

4.5.2 Measurement parameters

The following are the measurable parameters of MC9S08GW64-based Reference Flow Meter design.

- Accumulated flow for the entire interval when the meter is running
- Current month's flow
- Date and time

4.5.3 PCNT Module

PCNT or position counter is a low-power pulse sequence counter. Once configured, it is capable of working independent of the CPU in stop3 or stop4 modes. The PCounter accumulates the valid pulses input to it. The PCounter interfaces to various rotatory sensors that provide it with necessary pulse sequence to determine the flow direction and quantity of the flow.

4.5.3.1 Summary of key features

- Supports interfacing to one-, two- or three-pin rotatory sensor.
- Supports 180 degree, Gray and Binary Decoding mode. Two-Signal Gray mode is also called as Quadrature mode.
- Able to filter sensor signals with programmable filter width.
- Able to detect and generate interrupts on an invalid sequence.
- Generates interrupts on counter overflow.
- Generates required signaling to activate sensors.
- Generates asynchronous interrupt to wake MCU from low-power modes.

- Able to function independently in Stop mode.
- Modulus registers to interrupt CPU on specific count or full count.
- Able to function as limited capability PWM (that is, edge- or centre-aligned PWM).
- Internal counter can function as an atomic counter which increments on each IPS writes and generates an interrupt on counter overflow.

4.5.3.2 Initialization sequence

Before the PCNT module can be used to count pulses, an initialization procedure must be performed. A typical sequence is as follows:

- Enable clock to PCNT module.
- Program PCNT_PWM_MOD, PCNT_PWM_CH1_VAL and PCNT_PWM_CH2_VAL registers for proper generation of sensor activation signal and sampling signal or PWM signals.
- Program the PCNT_CTRL register with the required filter value, interrupt enablers, PWM mode, and channel selection with PCNT_EN 1'b1.
- PCNT_PWM_MOD, PCNT_PWM_CH1 and PCNT_PWM_CH2 get locked when the PCNT_EN bit of PCNT_CTRL is asserted. Users are not able to update these registers till PCNT_EN = 1'b1.

4.5.3.3 Pseudo-Code for PCNT initialization

In this example, the PCNT module is set up to perform a single 16-bit conversion at normal power with a long sample time on input channel 1, where the internal ADCK clock is derived from the bus clock divided by 1.

PCNT_CTRL = 0x2400 (0010010000000000)

Bit 15 SINVIE 0 State invalid event does not generate an interrupt.

Bit 14 RCOVFIE 0 RCounter overflow event does not generate an interrupt.

Bit 13 FCOVFIE 1 FCounter overflow event generates an interrupt.

Bit 12-11 MODE 00 PCounter operates in binary mode.

Bit 10-8 CHANNEL_SEL 100 Selects PCNT Channel 2.

Bit 7 PCNT_EN 0 PCounter is disabled.

Bit 6 DIR 0 Direction bit.

Bit 5 POL 0 Low-true pulses (set output on compare-up) on Ch1 and Ch2.

Bit 4 CPWMS 0 Ch1 and Ch2 operate as a edge-aligned PWM.

Bit 3-0 FILTER VALUE 0000 Filtering operation disabled.

PCNT_FCMOD_H = 0x00 (0 0 0 0 0 0 0 0)

PCNT_FCMOD_L = 0xFF (1 1 1 1 1 1 1 1)

The PCNT_FCMOD modulo register contains the modulo value for the FCounter. After the FCounter reaches the modulo value, it resumes counting from 0x0000, and the overflow flag FCOVF of PCNT_STATUS becomes set.

PCNT_CTRL_PCNT_EN 1 To enable the PCNT module

4.5.4 Calculation and accumulation process

The position counter keeps on counting the pulses and when the counter overflows, an interrupt is generated that wakes up the MCU and it calculates the amount of fluid that has flown in the time interval. The flow calculated in the given interval is accumulated in the variables.

4.6 Database

4.6.1 Overview

- Reference Flow Meter design has flash memory inside the MCU
- Flash memory storage parameters
 - Monthwise Accumulated Flow
 - Accumulated Flow
 - Month and Month's flow when the LVD occurs

4.6.2 Block diagram

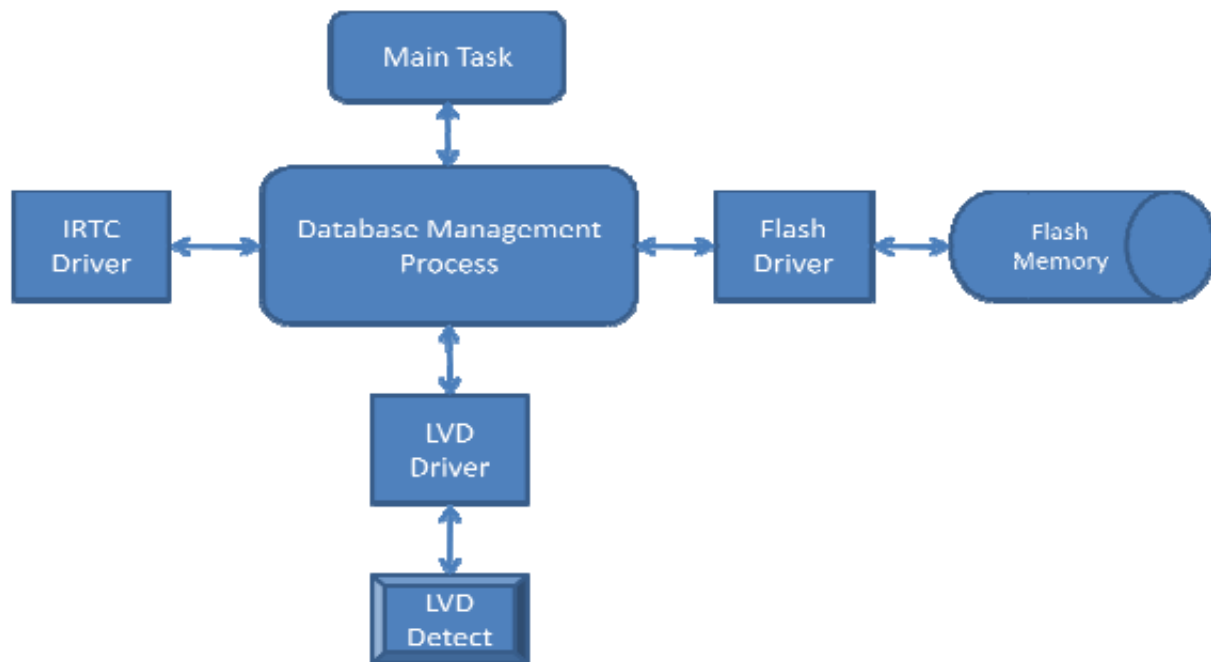


Figure 4-3. Database block diagram

4.6.3 Implementation

- IRTC is used for time keeping and it generates an interrupt when a month expires.
- As soon as a month is over, the flow accumulated in that month is updated and stored in the flash memory using the flash driver.
- The monthwise flow keeps on updating in the flash and at any time the monthwise profile of the flow can be retrieved from the flash using flash driver.
- On occurrence of LVD (Low Voltage Detect), the flash is updated with the month, flow in that month, and the flow accumulated till date.

4.7 User Interface

4.7.1 Overview

- The User Interface Module comprises LCD, User switch, and its respective drivers.
- Custom LCD specific for flow metering application
- Meter has a user key to display the date and the current month's flow

4.7.2 Block diagram

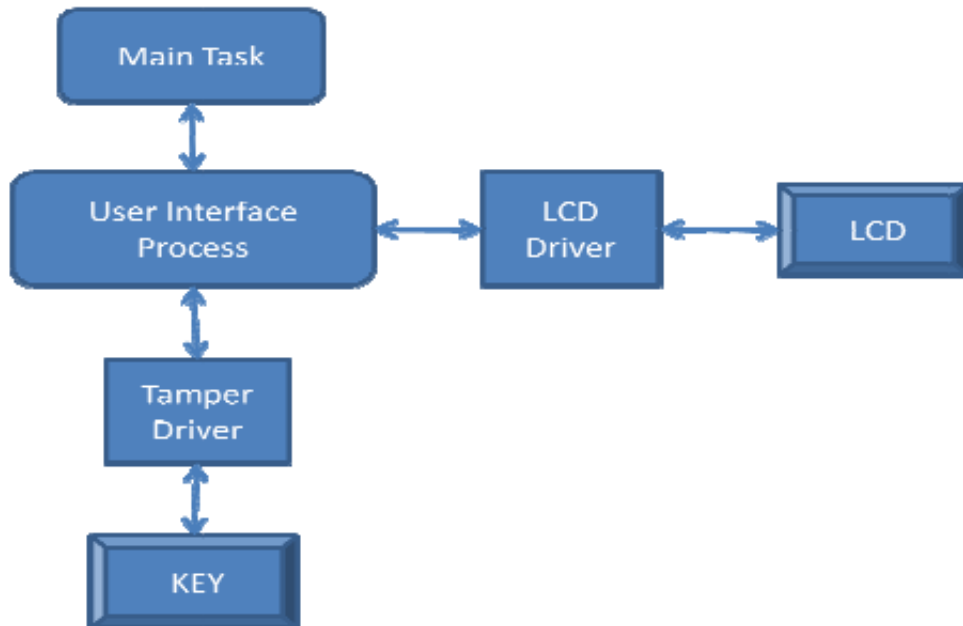


Figure 4-4. User Interface block diagram

4.7.3 Implementation

LCD

- Flow accumulated in the current month and the date are displayed alternately
- The LCD goes off after a few seconds of display
- When the LVD (Low Voltage Detect) occurs then the LCD displays “OFF” as an indicator

Key

- User key is available to enable the LCD and display the parameters (Flow and Date)

4.8 Communication

4.8.1 Overview

- Meter shall facilitate wireless communication over ZigBee with external world

- On other side, a handheld unit supporting ZigBee shall be used for communication purpose.
- Transmission and reception by interrupt method.

4.8.2 Block diagram

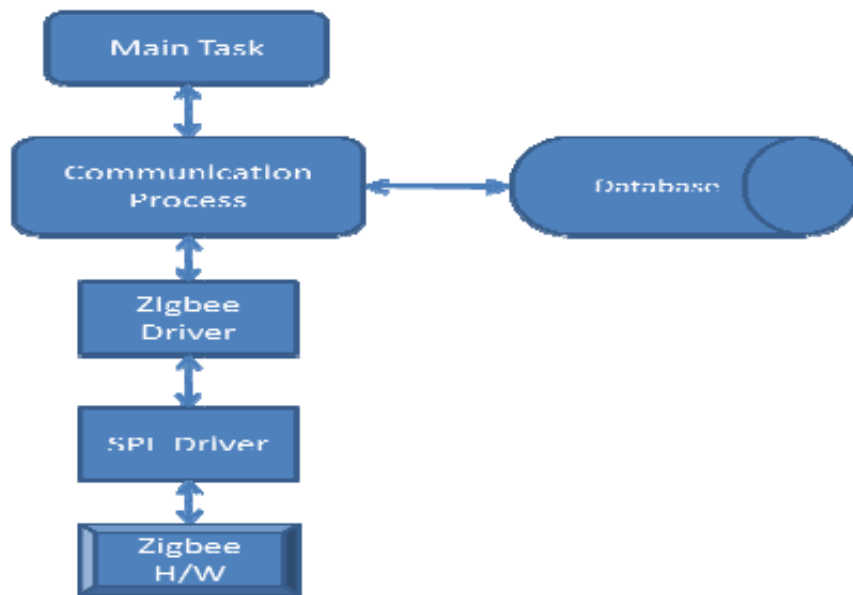


Figure 4-5. Communication block diagram

4.8.3 Implementation

ZigBee interface

- IEEE 802.15.4 standard used for data exchange
- A RF antenna is used for the interface between the meter and the handheld device connected to PC for communication
- Transmission and reception is on interrupt based. Reception is disabled until the received packet is processed.
- MCU uses SPI interface to communicate with the ZigBee hardware
- The block diagram below explains the flow of ZigBee communication

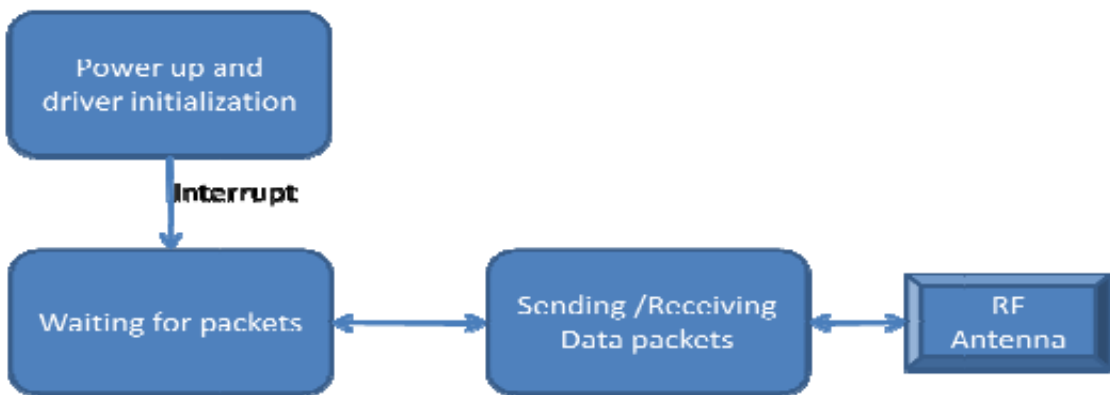


Figure 4-6. ZigBee communication diagram

Appendix A Schematic and Layout

A.1 Schematic

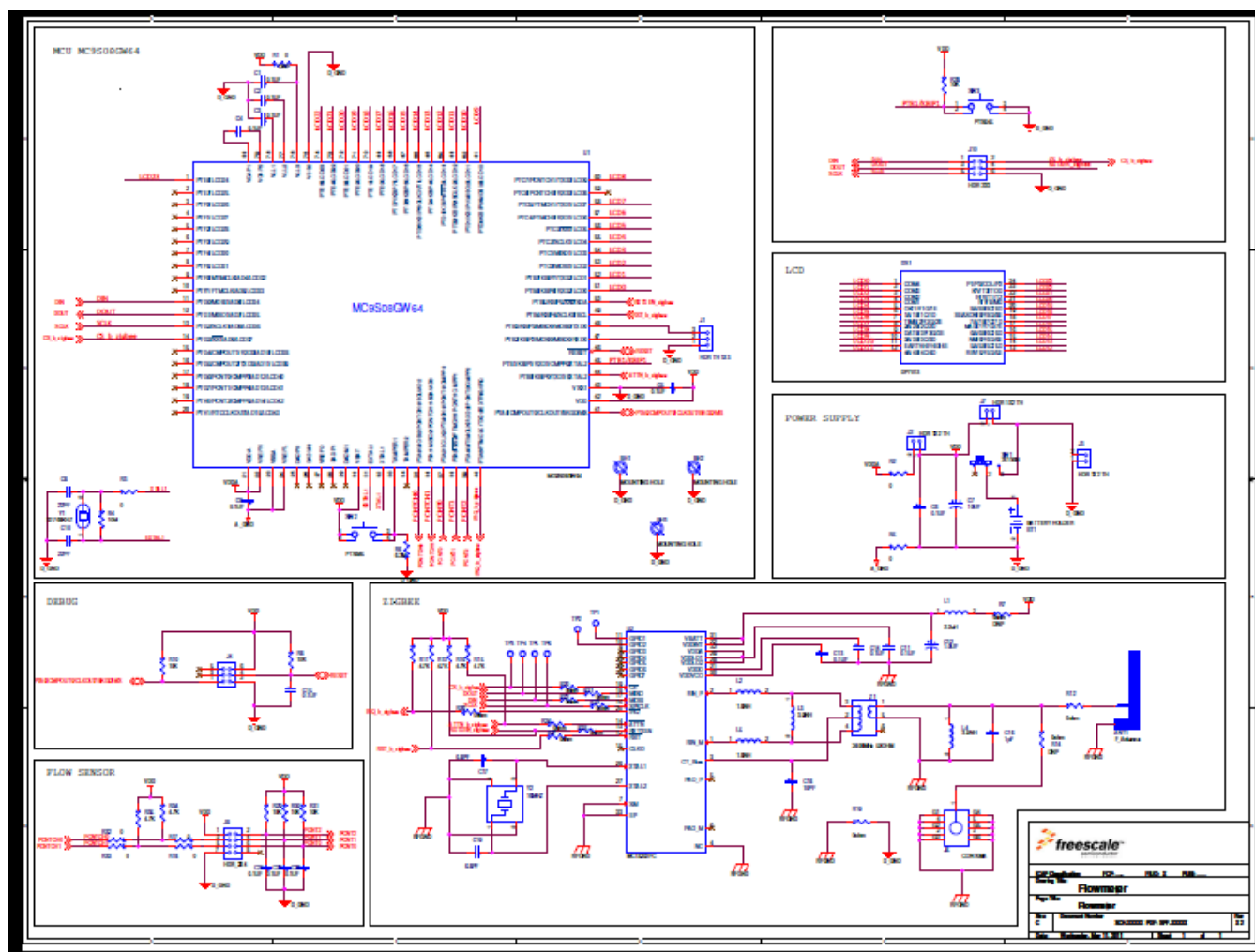


Figure A-1. Schematic

A.2 Layout

A.2.1 Silkscreen top

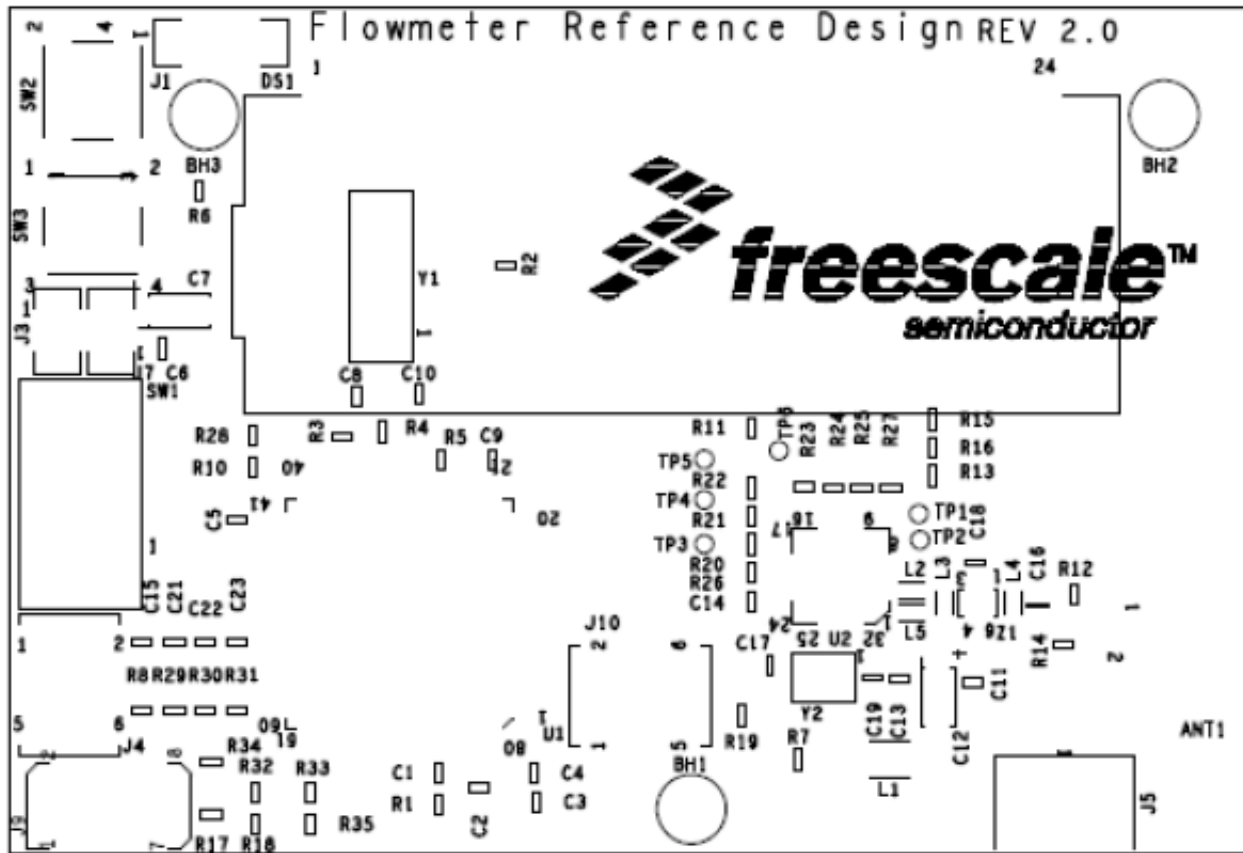


Figure A-2. Silkscreen – top

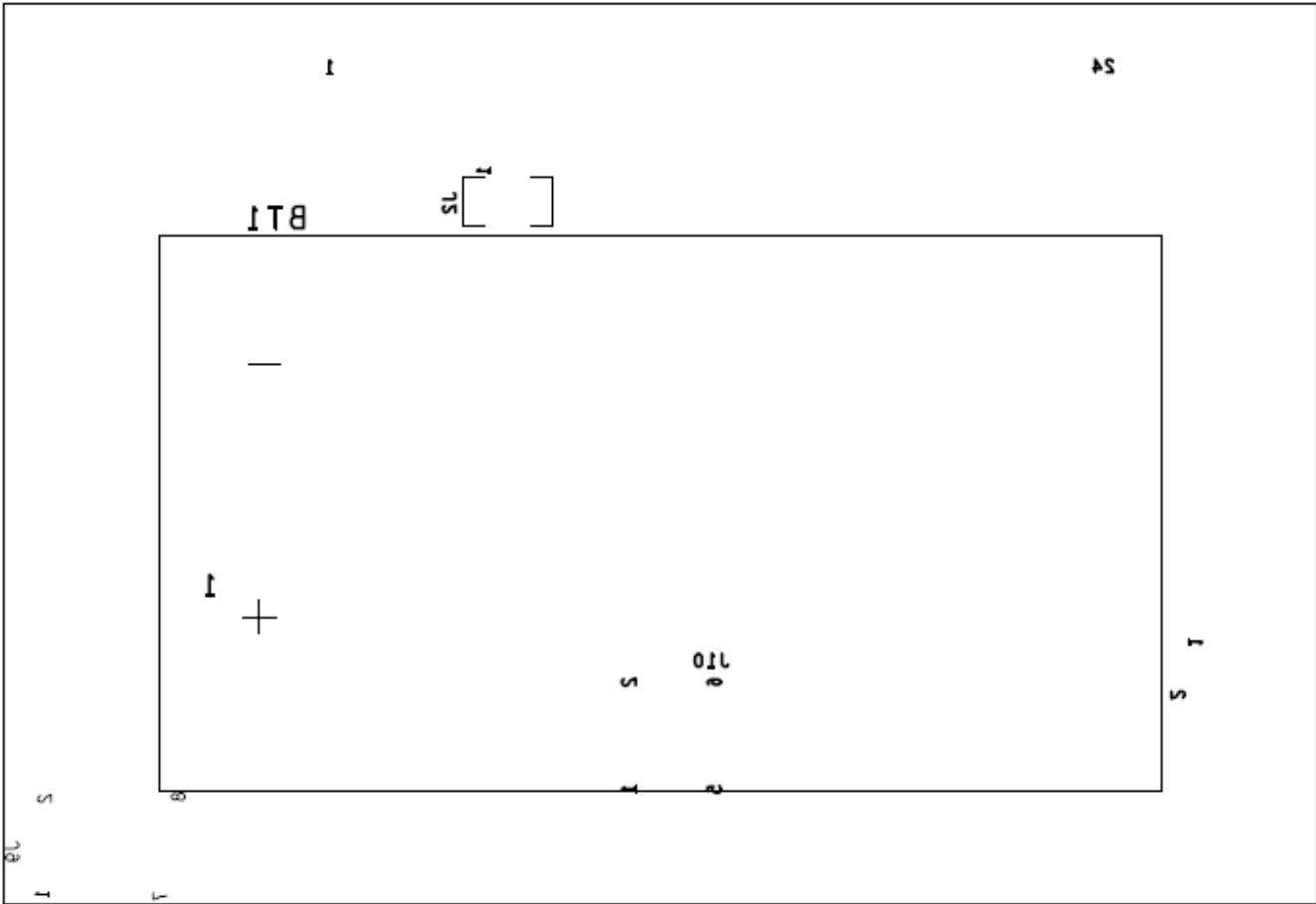


Figure A-3. Silkscreen – bottom

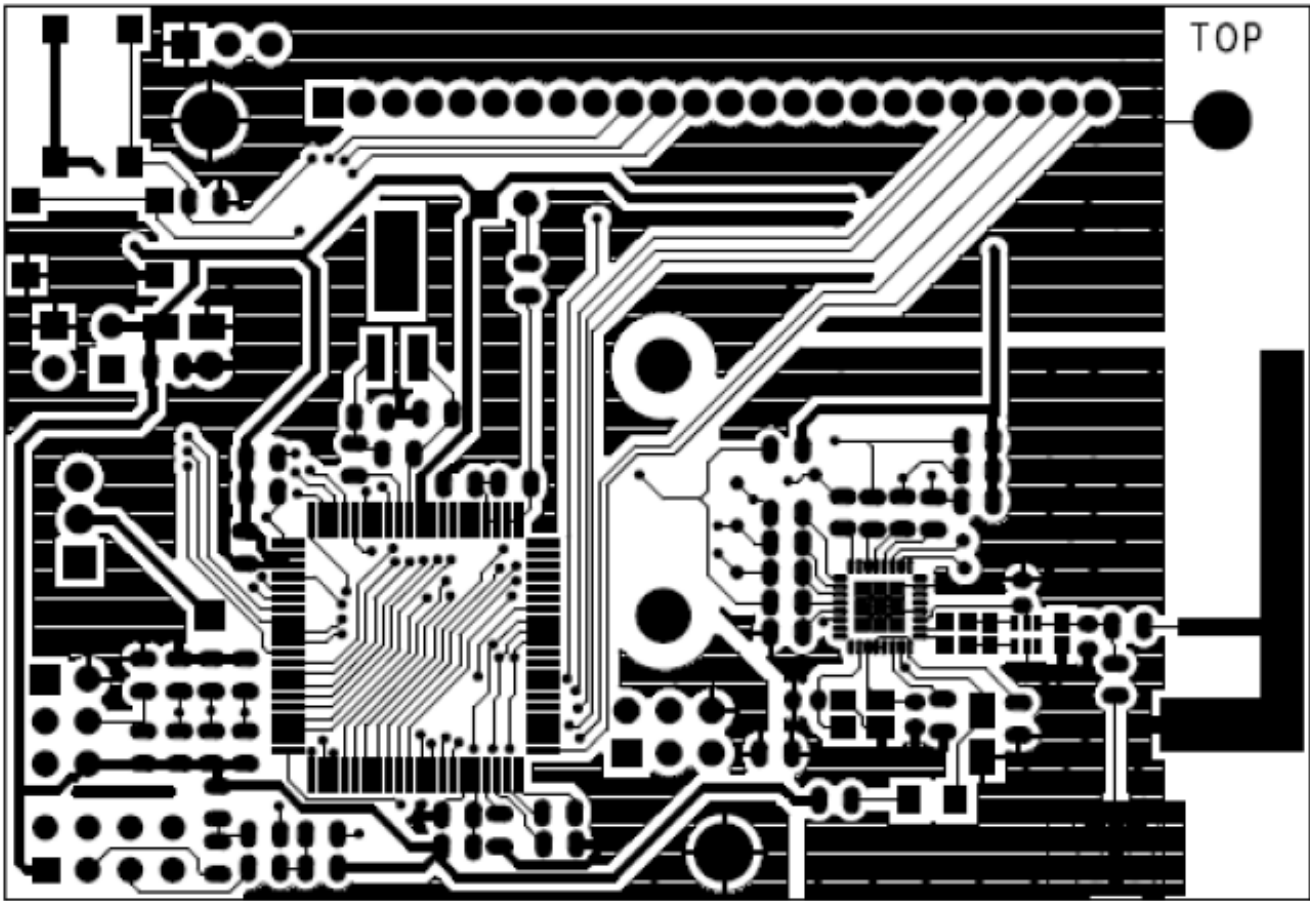


Figure A-4. Layout – top

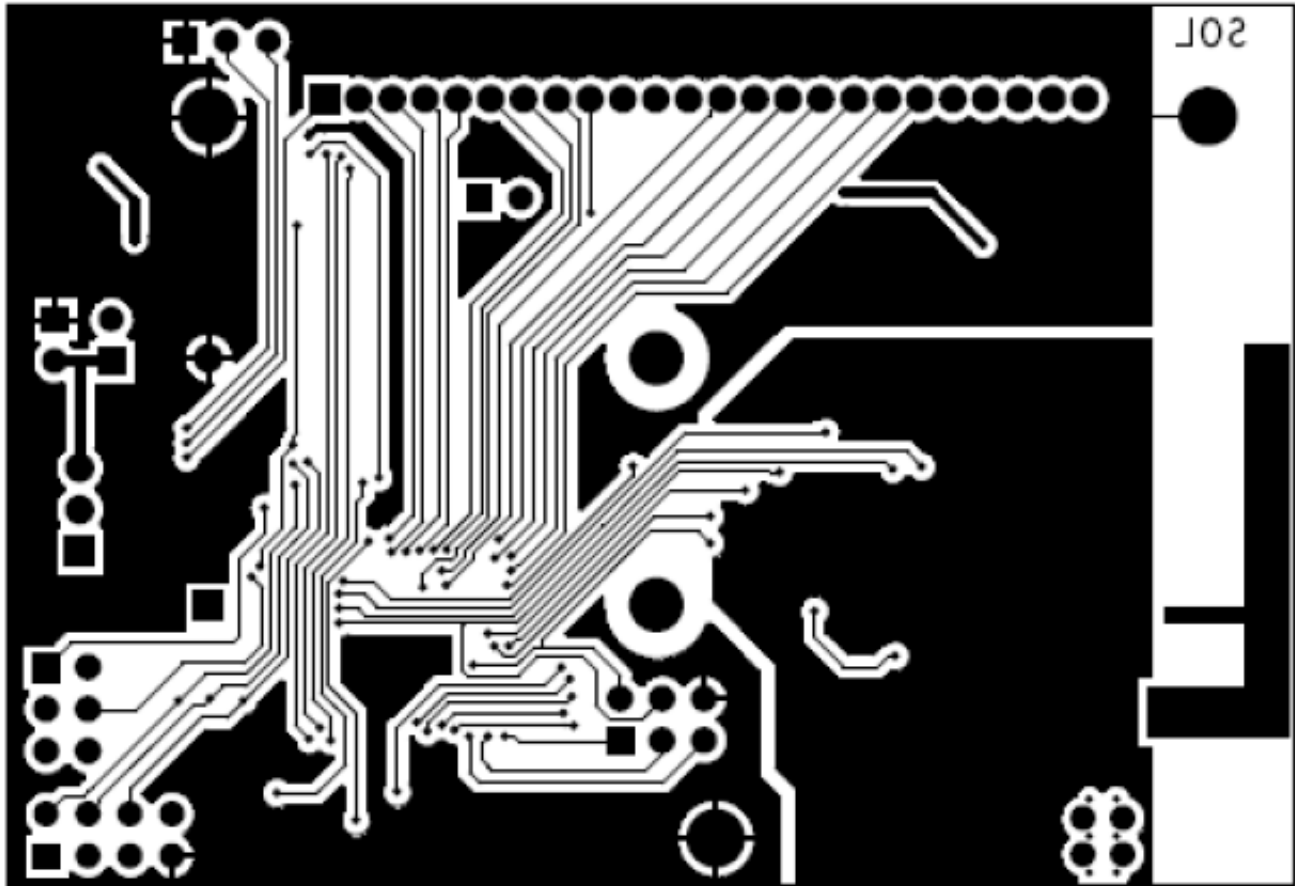


Figure A-5. Layout – bottom

Appendix B Bill of Material

Item	Quantity	Agile PN	ASSY_OP T	Referenc e	Value	Descripti on	ASSY_NO TE	Mfg name	Mfg part number
1	1	510-75678		ANT1	F_Antenna	PCB F ANTENNA, NO PART ORDER		NO PART TO ORDER	NOT A PART
2	3	280-76468		BH1,BH2, BH3	MOUNTIN G HOLE	MOUNTIN G HOLE DRILL 108 PAD 140 PLATED TH NO PART TO ORDER		NO PART TO ORDER	Mounting Hole - 108 mil Drill PTH
3	1	801-75636		BT1	BATTERY HOLDER	BATTERY HOLDER 2XAA TH		KEYSTON E ELECTRO NICS	2462
4	9	150-75599		C1,C2,C3, C4,C5,C9, C21,C22,C 23	0.1 μ F	CAP CER 0.1 μ F 25 V 10% X7R 0805		PANASON IC-ECG	ECJ-2VB1 E104K
5	5	150-78252		C6,C11,C1 3,C14,C15	0.1 μ F	CAP CER 0.1 μ F 16 V 10% X7R 0805		Panasonic	ECJ2VB1C 104K
6	1	150-75055		C7	10 μ F	CAP TANT 10 μ F 16 V 10% -- 3216-18		AVX	TAJA106K 016R
7	2	150-75202		C8,C10	22 pF	CAP CER 22 pF 50 V 5% C0G 0805		KEMET	C0805C22 0J5GAC
8	1	150-30310		C12	1.0 μ F	CAP TANT 1.0 μ F 16 V 20% -- 3216-18		KEMET	T491A105 M016AT

Table continues on the next page...

Item	Quantity	Agile PN	ASSY_OP T	Referenc e	Value	Descripti on	ASSY_NO TE	Mfg name	Mfg part number
9	1	150-77934		C16	1 pF	CAP CER 1 pF 50 V 10% C0G 0603		TDK CORPOR ATION (VA) V	C1608C0G 1H010B
10	2	150-30054		C17,C19	6.8 pF	CAP CER 6.8 pF 50 V +/- 0.25 pF C0G 0603		MURATA ELECTRO NICS (VA) V	GRM1885 C1H6R8C Z01D
11	1	150- 3024 8		C18	10 pF	CAP CERAMIC 10 pF 50 V NP0 0603		YAGEO (VA) V	CC0603JR N P09BN100
12	1	TMPWF- 1378 0		DS1	DP701 3	LCD glass 3 V 24 pins		Deepakshi displays	DP7013
13	1	210- 7572 6		J1	HDR TH 1X3	HDR 1X3 TH 100 mil SP 339H AU 118L		SAMTEC	TSW-103- 07-G-S
14	3	210- 7543 9		J2,J3,J7	HDR 1X2 TH	HDR 1X2 TH 100 mil SP 335H AU 95L		SAMTEC	TSW-102- 07-G-S
15	2	210- 7729 5		J4,J10	HDR 2X3	HDR 2X3 TH 2.54 MM SP 340H AU 118L		HARWIN INC	M20- 9980345
16	1	210- 7787 2		J5	CON SMA	CON 1 COAX SKT SMA TH 120 mil LEADS -- AU		JOHNSON COMPON E NTS INC	142-0761- 811
17	1	210- 7554 1		J9	HDR_ 2X4	HDR 2x4 TH 100 mil CTR 330 H AU 100 I		SAMTEC	TSW-104- 07-S-D
18	1	180- 7743 8		L1	2.2 µH	IND -- 2.2 µH@7.96M Hz 200 MA 5% SMT		TDK	NLV25T- 2R2J-PF
19	2	180- 7619 7		L2,L5	1.8 NH	IND -- 1.8NH @ 100 MHz 300MA 0.3NH 0603		TAIYO YUDEN	HK16081N 8 S-T

Table continues on the next page...

Item	Quantity	Agile PN	ASSY_OP T	Referenc e	Value	Descripti on	ASSY_NO TE	Mfg name	Mfg part number
20	2	180- 7741 6		L3,L4	3.9 NH	IND -- 3.9NH@10 0MHZ 300MA 0.3NH 0603		TAIYO YUDEN	HK16083N 9 S-T
21	1	470- 7544 2	DN P	R1	0	RES MF ZERO OHM 1/8W -- 0805		YAGEO AMERICA	RC0805JR - 070RL
22	7	470- 7544 2		R2,R3,R5, R17,R 18,R32,R3 3	0	RES MF ZERO OHM 1/8W -- 0805		YAGEO AMERICA	RC0805JR - 070RL
23	1	470- 7868 7		R4	10 M	RES MF 10.0M 1/8W 1% 0805		YAGEO AMERICA	RC0805FR - 0710ML
24	1	470- 8019 5		R6	6.2 M	RES MF 6.2M 1/8W 5% 0805		PANASON I C	ERJ6GEYJ 62 5 V
25	2	470- 7611 1	DN P	R7,R14	0 ohm	RES 0.0 OHM 1/8W 5% 0805 SMD		YAGEO (VA) V	RC0805JR - 070RL
26	2	470- 7590 4		R8,R10	10K	RES MF 10K 1/8W 5% 0805		Yageo	RC0805JR - 0710KL
27	6	470- 7590 8		R11,R13,R 15,R1 6,R34,R35	4.7K	RES MF 4.7K 1/8W 5% 0805		Yageo	RC0805JR - 074K7L
28	10	470-76111		R12,R19,R 20,R21,R2 2,R23,R24, R25,R26,R 27	0 ohm	RES 0.0 OHM 1/8W 5% 0805 SMD		YAGEO (VA) V	RC0805JR -070RL
29	4	470-75904		R28,R29,R 30,R31	10K	RES MF 10K 1/8W 5% 0805		YAGEO AMERICA	RC0805JR -0710KL
30	1	510-30026		SW1	25136 N	SW SPDT SLD 125 V 4A TH		APEM COMPON ENTS	25136NAH
31	2	510-75922		SW2,SW3	PTS645	SW SPST MOM NO PB 12 V 50MA SMT		ITT CANNON	PTS645SL 50SMTR LFS

Table continues on the next page...

Item	Quantity	Agile PN	ASSY_OP T	Referenc e	Value	Descripti on	ASSY_NO TE	Mfg name	Mfg part number
32	6	280-75148		TP1,TP2,TP3,TP4,TP5,TP6	TEST POINT	TEST POINT PAD 35 mil SMT, NO PART TO ORDER		NA	NA
33	1	TMP-WF-11879		U1	MC9S08GW64	IC MCU 8 bit 3 V LQFP 80		Freescale Semiconductor	MC9S08LW64
34	1	312-76396		U2	MC13202FC	IC XCVR 2.4 GHz 2/3.4 V QFN32		FREESCALE SEMICONDUCTOR	MC13202FC
35	1	230-77671		Y1	32.768 kHz	XTAL 32.768 kHz RSN -- SMT		Abrakon Corporation	AB26TRB-32.768 kHz
36	1	230-75677		Y2	16 MHz	XTAL 16MHZ FIXED -- SMT 3.2X2.5MM		NDK	NX3225SA-16.000000 MHz
37	1	560-75093		Z1	2400 MHz 50 ohm	XFMR BALUN 2400 +/-100 MHz SMT			

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