Kinetis M Family Single-Phase Energy Meter Design Reference Manual

Contents

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

Chapter 4
Software Design

Chapter 5
Revision history

Chapter 1
Introduction

1.1 Overview

This document describes the design of a single-phase energy meter reference design, based on Freescale KM family microcontroller specifically targeted for single-phase metering applications. This design is targeted for basic and smart meters. This design is a reference for designing energy meter or electricity meter, which measures and displays active energy (kWh), reactive energy (kVArh), apparent energy (kVAh), voltage, current, frequency, power factor, active power (kW), reactive power (kVAr), apparent power (kVA), and maximum demand in kW. The LCD panel displays current date and time.

1.2 Application features

The features of KM family reference design are as follows:

- Mode:
    - Single-phase (1Φ-2W)
- Measurement and LCD display of:
    - RMS
        - Voltage
        - Phase current
        - Neutral current
    - Total
        - Active power
        - Reactive power
        - Apparent power
    - Frequency
    - Tamper count
    - Power factor
    - Energy

- • Active
- • Reactive
- • Apparent
  - • Date
  - • Time
  - • Maximum demand
- • Operating frequency range 45–65 Hz
- • Tamper information
- • Optical port interface (IEC62056–21)
- • Serial port for calibration and diagnostics
- • Navigation using key
- • Selectable display list in auto scroll and push button modes
- • Expansion port for AMR via SCI

The following items are provided to the user to develop energy meter:
- • Reference energy meter.
- • Software – design document, and source code.
- • Hardware documentation – detailed design document (excel format), BOM, Schematics, wiring diagram, and EMI/EMC test reports of reference energy meter.

1.3 KM devices advantages

The advantages of using KM devices are as follows:

- • Core frequency can go up to 50 MHz, thus capable of enough horsepower for computation intensive applications.
- • 24-Bit Sigma-Delta Analog Front End (AFE) with four independent channels; two with independent PGA.
- • Built-in stable voltage reference.
- • Selectable voltage reference - Internal or External.
- • External gain switching is not required.
- • Signal conditioning is not required.
- • Phase error compensation using delay registers in AFE.
- • PLL for stable clock generation for AFE and other peripherals.
- • Watchdog runs on independent RC oscillator which is separate from core clock.
- • Capable of running from a single clock source (external 32 kHz crystal).
- • Ultra low-power independent RTC with calendar features and three tamper pins.
- • RTC runs in independent power domain (always on battery); thus no switch and hence no possibility of any glitch.
- • AMR SCI or SPI can communicate with 5 V AMR interfaces.

- Peripheral crossbar that can help in connecting a peripheral to any peripheral including inputs and outputs; helps in layout and other functionalities.
- 4-Channel DMA for data transfers without core intervention.
- Integrated 16-bit SAR Analog-to-Digital Converter.
- Single cycle 32x32 Multiply.
- Built-in LCD controller.

The following figure shows the reference design of a single phase meter:

Figure 1-1. KM device based on 1-Ph reference design

Chapter 2
Metering Theory and Configurations

2.1   Energy meter

Current is sensed using current transformer or shunt resistor or hall sensors. Voltage is sensed using potential divider circuit or voltage transformer. Sensed voltage and current signals are multiplied and integrated over period of time to obtain energy and it is stored in a register.

The following figure shows the concept of block diagram of Energy Meter:
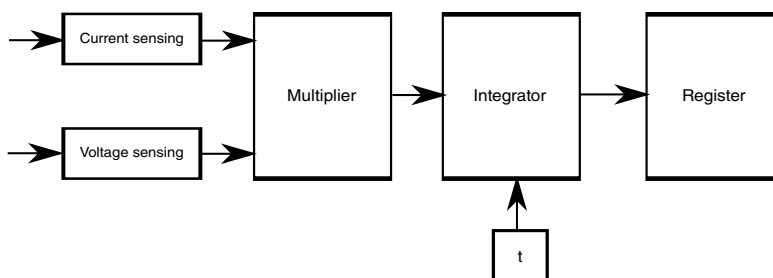
Figure 2-1. Block diagram of basic energy meter

- An Electricity Meter or Energy Meter is a device that measures the amount of electrical energy supplied to a residence, business, or machine.
- The unit for measurement of active electrical energy is kilowatt hour (kWh), which is equal to the amount of energy used by load of one kilowatt over a period of one hour.
- Demand is normally measured in watts or VA, but averaged over a period, most often a quarter or half hour.
- Reactive power is measured in "Volt-amperes reactive", (VArh) in kilovar-hours. A lagging or inductive load have negative reactive power, such as an induction motor. A leading or capacitive load have positive reactive power.
- Volt-amperes measures all power passed through a distribution network, including reactive and actual. This is equal to the product of root-mean-square volts and amperes.
- Distortion of the electric current by loads is measured in several ways:

- Power factor—It is the ratio of resistive (or real power) to volt-amperes (apparent power). A capacitive load has a leading power factor, and an inductive load has a lagging power factor. A purely resistive load exhibits a power factor of 1.
- Current harmonics—This is a measure of distortion of the current waveform. Odd harmonics are not permissible to exceed specific limits because it may interfere with the operation of other equipment.

2.2   Common terms used in metering

Burden: The load, usually expressed in volt-amperes at a specified power factor, placed on instrument transformer secondary by the associated meter coils, leads, and other connected devices.

Capacitive reactance: Impedance due to capacitance. This is expressed in ohms. The capacitive reactance varies indirectly with frequency.

Circuit, three-wire: It is a metallic circuit formed by three conductors insulated from each other.

Circuit, two-wire: It is a metallic circuit formed by two adjacent conductors insulated from each other. When serving domestic loads one of these wires is usually grounded.

Constant, watt-hour: The number of watt-hours represented by one increment (pulse period) of serial data. Example: Kh or Kt = 1.25 watt-hours/pulse.

Current transformer: Current transformer (CT) is used for measurement of electric currents.

Current transformer phase angle: The angle between the current leaving the identified secondary terminal and the current entering the identified primary terminal. This angle is considered positive when the secondary current leads the primary current. Or The angle between the primary current vector and the secondary current vector reversed; it is conveniently considered as positive when the reversed secondary current vector leads the primary current vector.

Cycle: One complete set of positive and negative values of an alternating current or voltage. These values repeat themselves at regular intervals.

Demand: The average value of power or related quantity over a specified interval of time. Demand is expressed in kilowatts, kilovolt amperes, kiloVARs, or other suitable units. Its interval could be like 1, 5, 10, 15, 30, or 60 minutes.

Demand, maximum: The highest demand measured over a selected period of time such as 30 minutes. It is also termed as Peak Demand.

Effective value (root-mean-square value): The effective value of a periodic quantity is the square root of the average of the squares of the instantaneous value of the quantity taken throughout one period. This value is also called the root-mean-square value and is the value normally reported by alternating current instruments.

Electrical degree: The 360th part of one complete alternating current cycle.

Electricity meter: A device that measures and records the summation of an electrical quantity over a period of time.

Frequency: Frequency is the number of occurrences of a repeating event per unit time. Period is the duration of one cycle in a repeating event, so the period is reciprocal of frequency. The unit of frequency is hertz (Hz). One hertz is equal to one cycle per second.

Lagging current: An alternating current which, in each half-cycle, reaches its maximum value a fraction of a cycle later than the maximum value of the voltage which produces it.

Leading current: An alternating current which, in each half-cycle, reaches its maximum values a fraction of a cycle sooner than the maximum value of the voltage which produces it.

Meter constant: The number of times the "Calib LED" blinks to record 1 kWh or 1 unit of energy. For example, if the meter constant is 3200, it means that 3200 impulses of the calib LED will result in the unit register incrementing by 1.

Optical port: A communication interface on metering products, which allows the transfer of information while providing electrical isolation and metering security. The communication medium typically used is infrared light transmitted and received through the meter cover.

Phantom load: A device which supplies various load current for meter testing, used in portable form for field testing. The power source is usually the service voltage which is transformed to a low value. The load currents are obtained by suitable resistors switched in series with the isolated low secondary voltage and output terminals. The same principle is used in most meter test boards.

Phase angle: The phase angle or phase difference between a sinusoidal voltage and a sinusoidal current is defined as the number of electrical degrees between the beginning of the cycle of voltage and the beginning of the cycle of current.

Active power: The time average of the instantaneous power over one period of the wave. For sinusoidal quantities in a two-wire circuit, it is the product of voltage, current, and cosine of the phase angle between them. For non-sinusoidal quantities, it is the sum of all the harmonic components, each determined as above. In a poly-phase circuit it is the sum of the active powers of the individual phases.

Apparent power: The product of the root-mean-square current and root-mean-square voltage for any waveform. For sinusoidal quantities, apparent power is the square root of the sum of the squares of active and reactive powers.

Reactive power: For sinusoidal quantities in a two-wire circuit, reactive power is the product of voltage, current, and sine of the phase angle between them with the current taken as reference.

With non-sinusoidal quantities, it is the sum of all the harmonic components, each determined as above. In a poly-phase circuit, it is the sum of the reactive powers of the individual phases.

Power factor: The ratio of the active power to the apparent power.

Reference meter: A meter used to measure the unit of electric energy. It is usually designed and operated to obtain the highest accuracy and stability in a controlled laboratory environment.

Watt: The practical unit of active power which is defined as the rate at which energy is delivered to a circuit. It is the power expended when a current of one ampere flows through a resistance of one ohm.

Watt-hour: The practical unit of electric energy which is expended in 1 hour when the average power during the hour is 1 watt.

2.3 Metering calculations

The formulas used for calculating various electrical parameters in Freescale reference energy meter are explained in subsequent subsections. These formulae are for reference only and the results obtained from these formulae may be averaged over the period of time to obtain stabilized readings.

$$V_{AN} = \sqrt{\frac{V_{A1}{}^2 + V_{A2}{}^2 + \cdots \cdots \cdots + V_{An}{}^2}{n}}$$

Equation 1. Line to neutral voltages

$$I_A = \sqrt{\frac{I_{A1}^2 + I_{A2}^2 + \cdots + I_{An}^2}{n}}$$

$$I_N = \sqrt{\frac{I_{N1}^2 + I_{N2}^2 + \cdots + I_{Nn}^2}{n}}$$

Equation 2. Phase and average current

Where,
- n = number of samples per cycles
- VAN = Line to neutral RMS voltages for A phase. VAn is the instantaneous nth sample (1 to 60) of A Phase Voltage.

$$W_A = \frac{(V_{A1} * I_{A1}) + (V_{A2} * I_{A2}) + \cdots \cdots \cdots + (V_{An} * I_{An})}{n}$$

Equation 3. Active and net active power

Where,
- n = number of samples per cycles
- IA = Line Currents for A Phase.
- IN = Neutral current. IAn is the instantaneous sample (1 to 60) of A Phase Current

$$VAr_A = \frac{(V_{A1} * I_{A(n/4+1)}) + \cdots \cdots \cdots + (V_{An} * I_{A(n/4+n)})}{n}$$

Equation 4. Reactive and net reactive power

$$VA_A = \sqrt{(W_A)^2 + (VAr_A)^2}$$

Equation 5. Apparent and net apparent power

$$PA_A = \frac{W_A}{VA_A}$$

Equation 6. Power factor

$$FREQ_A = \frac{1}{t_A}$$

Equation 7. Frequency

$$Wh = W_A * Accumulationtimehours$$
$$VA_{rh} = Accumulationtimehours$$
$$VAh = VA_A * Accumulationtimehours$$

Equation 8. Energy calculation

NOTE

All the calculations discussed in this section are in terms of ADC counts. The calculated results will be further computed using calibration constants.

RMS apparent power is computed from product of V_{rms} and I_{rms}. Angle compensation of total power is calculated as follows:

Power Factor = Total Active Power / RMS Apparent Power

Angle = acos (Power Factor)

An error in angle measurement is derived by measuring powers as shown in the below table:

Current	Actual Power	Measured Power at 60	Error in Angle	Measured Power at 300	Error in Angle
40	4800	4750	-0.343986459	4865	0.448974936
25	3000	2962	-0.418132799	3039.5	0.436514072
10	1200	1187.5	-0.343986459	1212	0.331352363
5	600	595	-0.275283697	605.3	0.292637051
1	120	119.2	-0.220287608	120.77	0.212489601
0.25	30	29.8	-0.220287608	30.15	0.165536962

It is difficult to identifying whether the voltage is leading or lagging. This is identified by checking the sign of current sample immediately after voltage's zero crossover. The sign of current at that instance tells lag/lead. Then, the derived current angle derived above is rotated by "Error in Angle" amount to bring it to normal.

2.3.1 Wiring system

The following figure shows the one-phase two-wire wiring system:
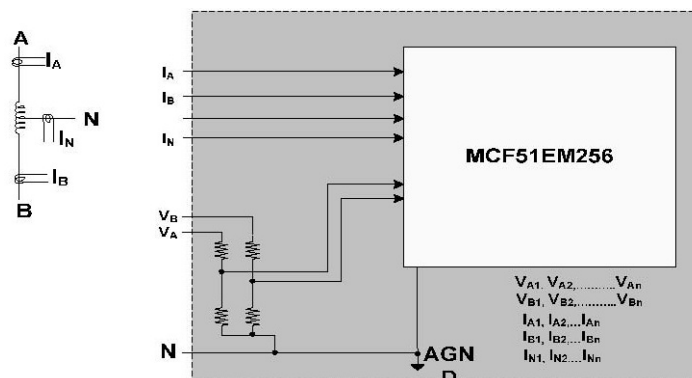

Figure 2-2. One-phase two-wire wiring system wiring system

The following figure shows the Lag and Lead concept of an energy meter
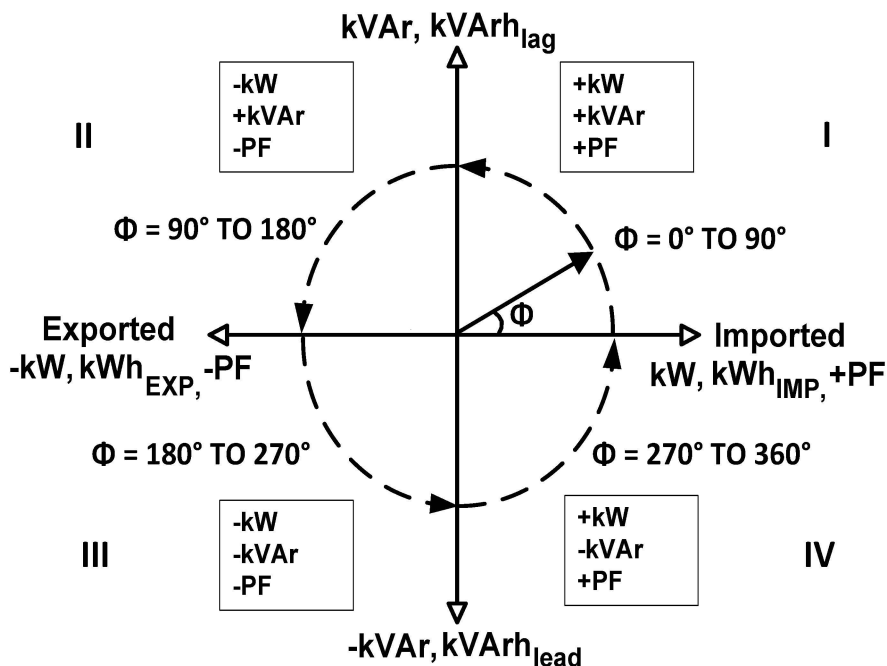
Figure 2-3. Phasor diagram of an energy meter

Where,

- Φ = (phase angle between voltage and current) = $\Phi V - \Phi I$
- ΦV = phase angle of voltage signal
- ΦI = phase angle of current signal

From the Trigonometric functions, Cosine (cos) components are positive in first and fourth quadrant and negative in second and third quadrant. Similarly, Sine (sin) components are positive in first and second quadrant and negative in third and fourth quadrant. Power (kW) and Power factor (PF) are cosine components and Reactive Power (kVAr) is sine component.

Current lags by an angle Φ with respect to Voltage is called lagging power factor and the sign of the angle within voltage and current will be positive. Typical example for this load is Inductive load, that is, Induction motor.

Current leads by an angle Φ with respect to Voltage is called leading power factor and and the sign of the angle within voltage and current will be negative. Typical example for this load is capacitive load, that is, Synchronous motor.

A quantity which includes magnitude, direction, and time relationship is known as Phasor. The Phasors are used to represent sinusoidal voltages and currents by plotting on rectangular coordinates.

Chapter 3
Hardware Design

3.1 Block diagram

The following block diagram gives the overview of single-phase reference energy meter based on KM family devices.
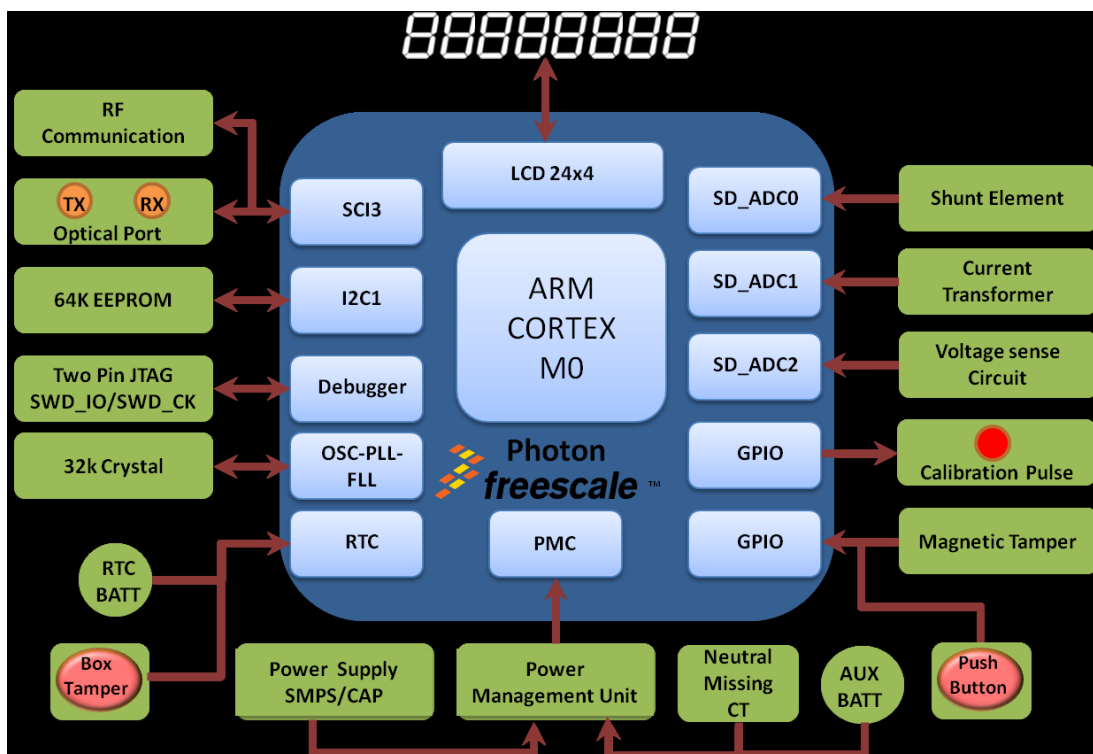
Figure 3-1. Hardware block diagram

3.2 Power supply

The reference design runs on one of the following three power sources:

1. Main power supply

2. Auxiliary battery
3. Neutral missing CT

3.2.1   Main power supply

This is a capacitive power supply rating 4 VA. This power supply can provide up to 11.5 ma current at 240 V.
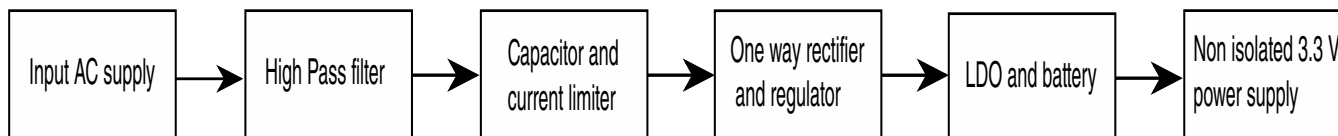
Figure 3-2. Block diagram of main power supply

All the blocks and corresponding schematic of Main Power Supply block diagram are explained as follows:

Input AC is fed through two pin terminal and varacter U5 protects against surge. The resistor R30 limits the current in the power supply section which is followed by a high-pass filter formed by the C25 capacitor.
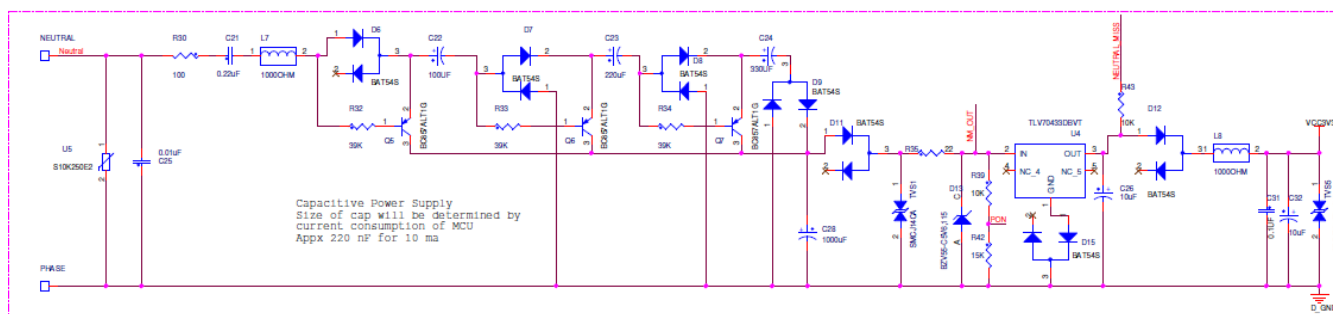
Figure 3-3. Circuit diagram of capacitive power supply

The AC capacitor C21 offers impedance to the current and decides the maximum value of average DC current (Iin) that can be fed to the MCU.

$$Iin = (Vpeak x 2\pi F x C)/\pi$$

Equation 9. Maximum value of average DC current

Where,
- Iin is the average value of DC current

- F is the frequency of input supply voltage
- $2\pi FC$ is the impedance offered (in the schematic C is C21)

The further diodes and transistor network act as one way rectifier and zener diode (D13) acts as voltage regulator. C26 capacitor is the bulk storage capacitor and is charged up to 5.6 V. So the voltage rating should be more than 10 V. This capacitor reduces ripples from the output supply. As one tries to withdraw more and more current, the ripples will increase. The high value of C21 capacitor would reduce the ripples from the supply up to a certain limit; this will increase the rating of power supply. The LDO U4 has an enable input and provides stable 3.3V output.

3.2.2 Auxiliary battery

Auxiliary battery provides power to meter in case of mains power missing. This activates the meter whenever Push Button (PB) is pressed and keeps meter powered till the all LCD parameters are displayed once and PB is not pressed further.
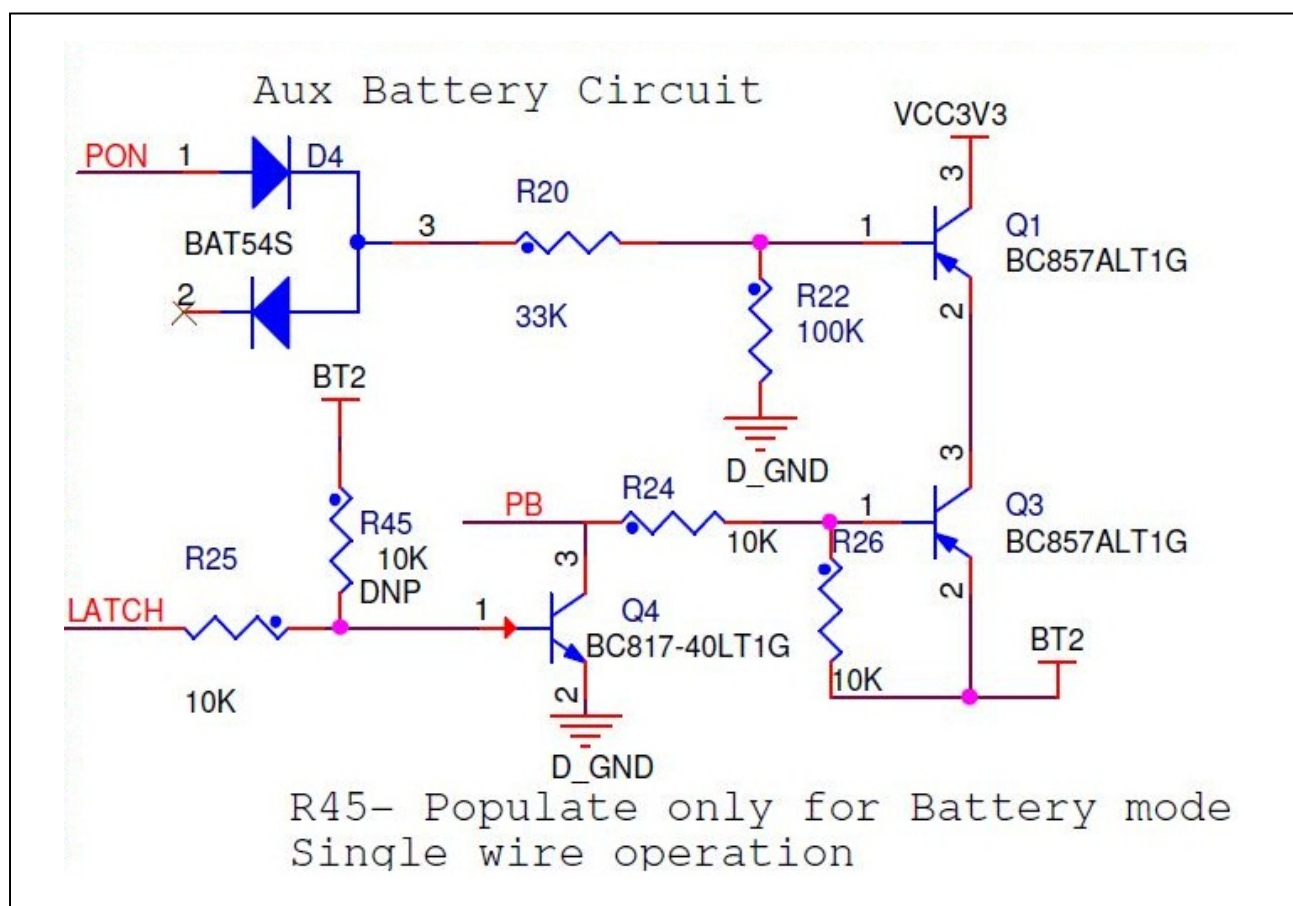
Figure 3-4. Circuit diagram of battery supply

PON signal is generated from the power supply section, so this auxiliary battery will power up meter only in case main power is absent. Latch signal driven from MCU keeps meter ON till its battery operated operation is not completed after the PB is pressed.

3.2.3 Neutral missing CT

Neutral missing CT provides the power in case of single-wire metering for tamper detection. If any of the two wires (Phase or Neutral) is removed from the meter terminal and current is passing through the single connecting wire then meter will get power up using this CT.
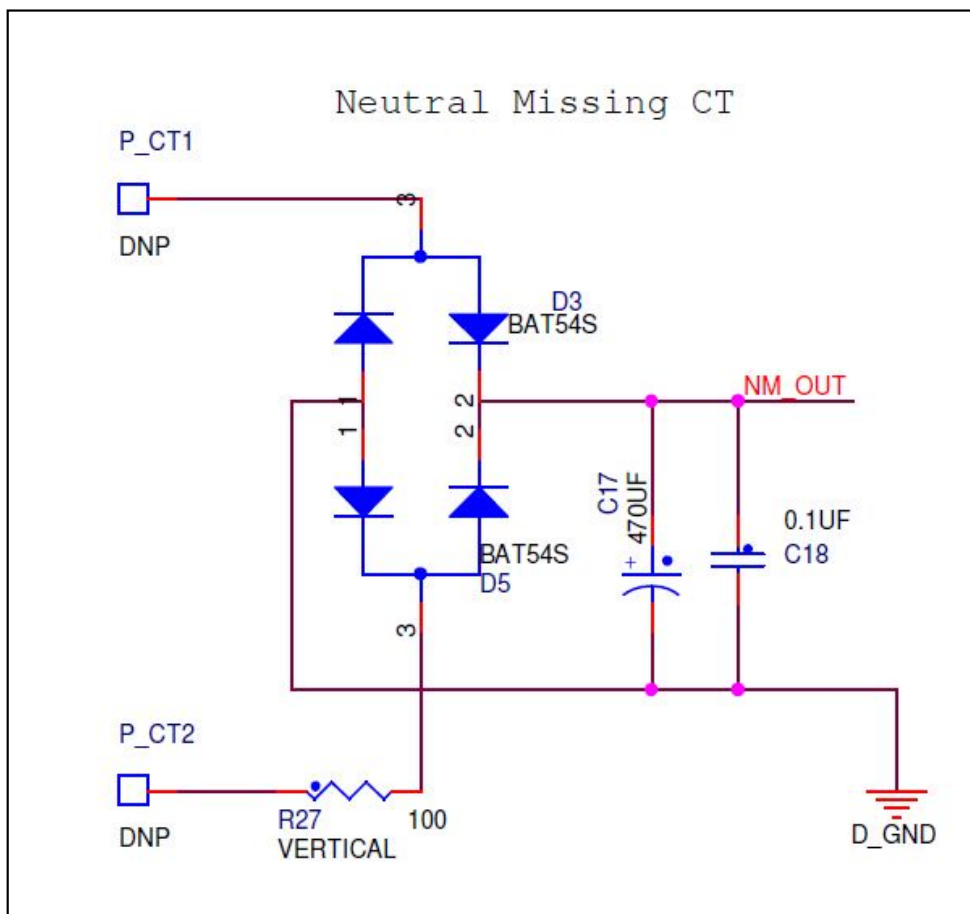
Figure 3-5. Circuit diagram of neutral missing power CT

3.3 Display interface

3.3.1   Liquid Crystal Display (LCD) interface

The following figure represents the typical example of LCD displays used in single-phase metering:
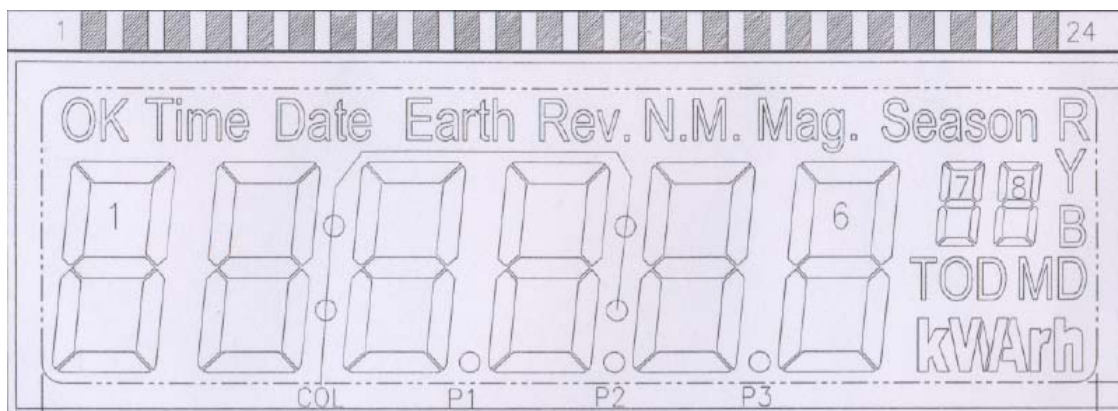
Figure 3-6. LCD display

- **Display type:** STN/Yellow-Green
- **Viewing direction:** 6 o'clock
- **Polarizer type:** Transflective, positive.

The LCD can display import, export, lead, lag, kW, kVAr, kWh, kVArh, number of tampers, maximum demand, date, time, frequency (Hz) and many more.

LCD has 80 segments and ¼ duty cycle (4 backplanes).

LCD interfaces to the 'built-in LCD driver' of the controller and driver is operating in ¼ duty cycle and 1/3 bias (voltage levels) mode.

3.3.2   LCD backlight

The LCD built without an internal back light source which necessitates the use of external sources of light to make the screen and information visible.

The following figure shows the circuit diagram of LCD backlight:
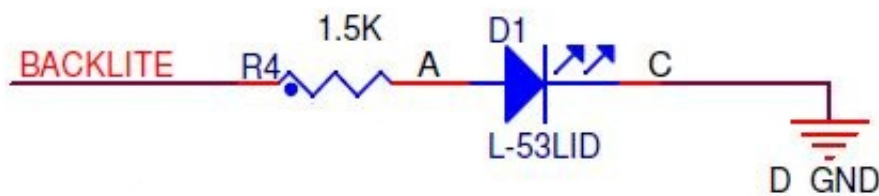
Figure 3-7. Circuit diagram of LCD backlight

Backlight illuminates the LCD from back of the display panel which increases readability in low light conditions.

3.4 LED interface

This is the calibration LED. Active energy accuracy of the meter is verified by pulse method. kWh LED pulses are used to measure the accuracy of active energy. As the active energy starts accumulating kWh LED will blink at the rate of 3200 impulses/kWh.

The following circuit shows how Calib LED is driven from MCU:
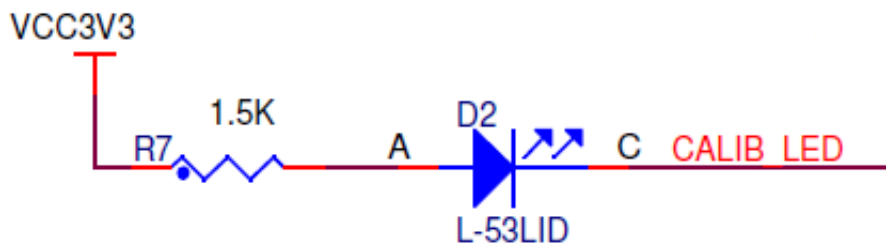
Figure 3-8. Circuit diagram calib LED

3.5 Keyboard (User) interface

There is one push button on the meter, which is used to scroll the display through display list. It powers ON the meter if the main power is OFF.

3.6 Analog signal conditioning

A signal conditioning block is used to bring voltage and load currents to the required voltage levels.
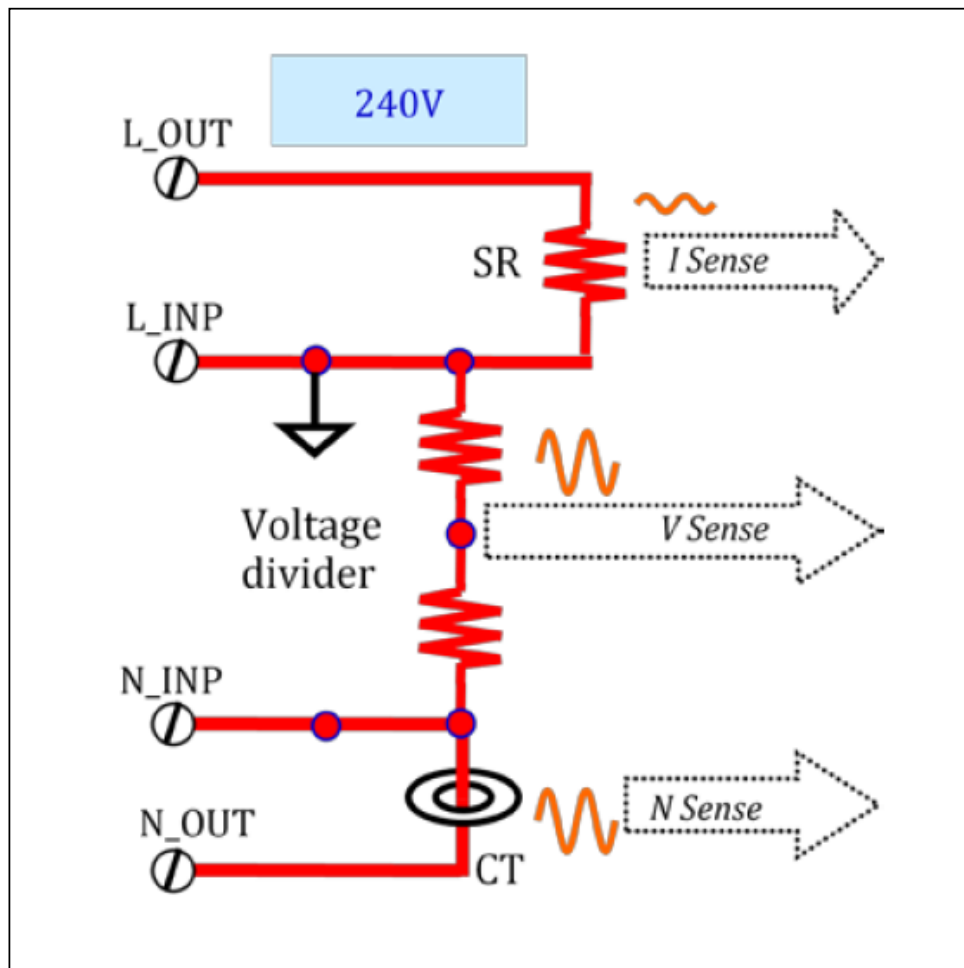
Figure 3-9. Circuit diagram for signal conditioning

3.6.1   Current signal conditioning circuit

A shunt resistor is present on the phase element and a Current Transformer (CT) on the neutral element. Shunt value is 500 µΩ, which just about saturates at approximately 44 A if a gain of 8 is used on the PGA. A burden resistor of 10 Ω on the CT secondary saturates at 44 A. Signal conditioning like level shifting or external gain is not required for the signals.

3.6.2   Voltage signal conditioning circuit

A resistor divider network is used to step down the voltage to measurable level. No other signal conditioning is required.

3.7 Cover open tamper detection

SW2 switch contact position will be open when the enclosure top cover is closed. This would be considered as no tamper condition and BT1 will not be loaded by R31. When enclosure top cover is opened, SW2 contacts position will be closed. This is Tamper condition and BT1 will be loaded by R31.

The battery voltage will drop across the resistor R31 and the voltage will appear at the tamper pin. The tamper will be detected by RTC inside meter.

The cover open tamper can be detected even under power OFF condition of the meter. There is provision of power on the meter when SW2 switch is closed. This will connect the BT2 power back-up battery to system supply. The following figure displays the circuit diagram of cover open tamper:
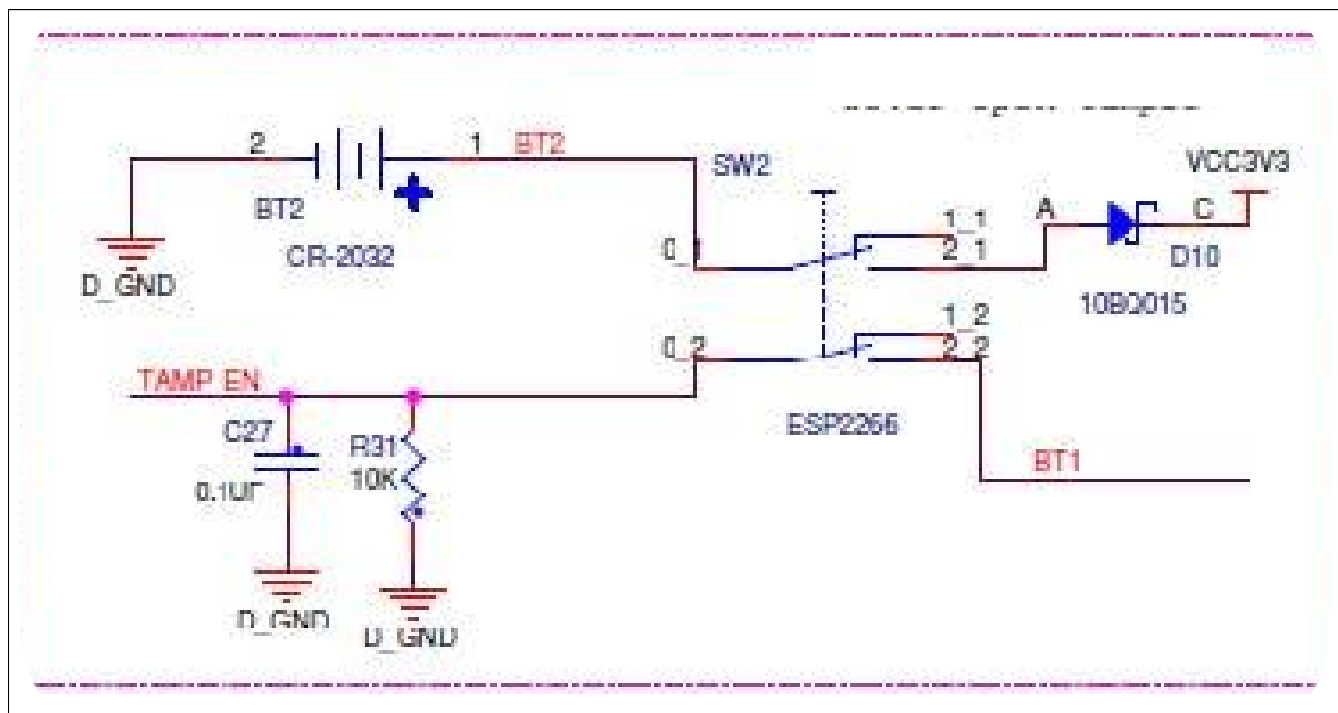
Figure 3-10. Circuit diagram of cover open tamper

3.8 Optical communication port

The Meter has one optical communication port as per IEC62056-21. The following figure displays the hardware circuit associated with optical port communication:
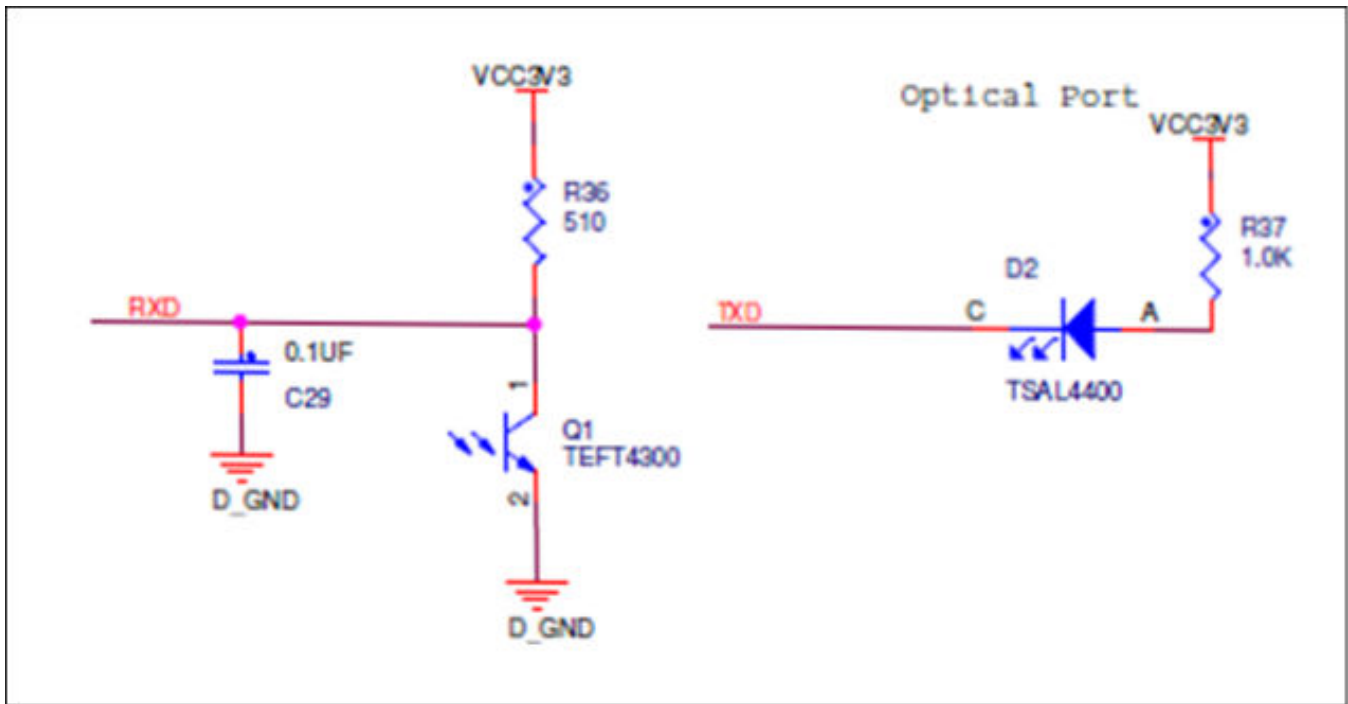
Figure 3-11. Circuit diagram of optical port

Optical communication—data exchange for metering reading, tariff, and load control. It is complied with IEC62056-21 standard. The standard is International Energy Metering data exchange Specification.

The following figure displays the position of receiver and transmitter of optical port on the meter:
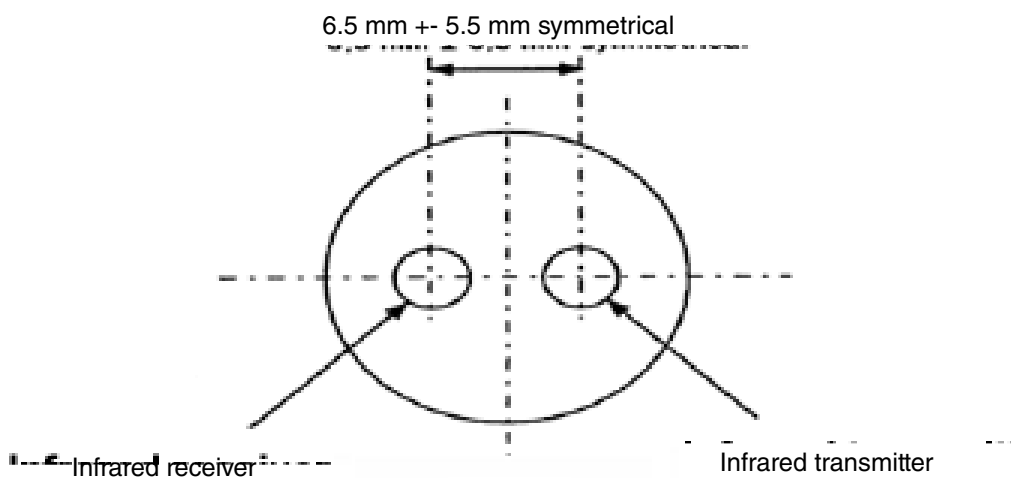
Figure 3-12. Position of receiver and transmitter of optical port on meter

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

In Figure 3-12 the optical head (optical to RS232 converter) is placed over the optical port interface of the meter and RS232 is connected to PC for communication. The pitch provided on the tariff device is 6.5 mm. The infrared receiver in the tariff device is aligned directly opposite the infrared transmitter in the reading head and infrared receiver in the reading head is directly opposite the infrared transmitter in the tariff device.

3.9 Serial Wire Debug (SWD) module

J-link is a 20-pin header, so an adapter cable is used to connect the 20-pin. J-link connector with 6-pin headers on board. Its communication interface is used for programming the controller. Reduced 6-pin nonisolated header is available on the meter. So, user must use the isolated power source to power meter, when jlink is connected on meter.

The following figure shows a IAR J-link debugger which is used to program and debug the MCU:

Figure 3-13. IAR J-link debugger
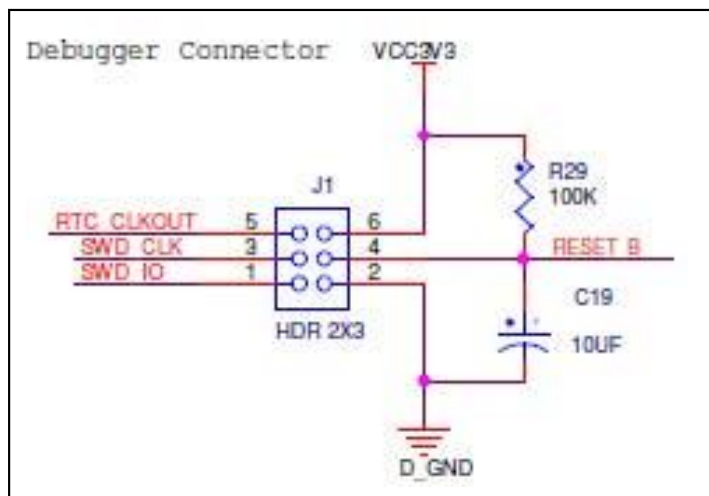
Figure 3-14. Board debugger connector
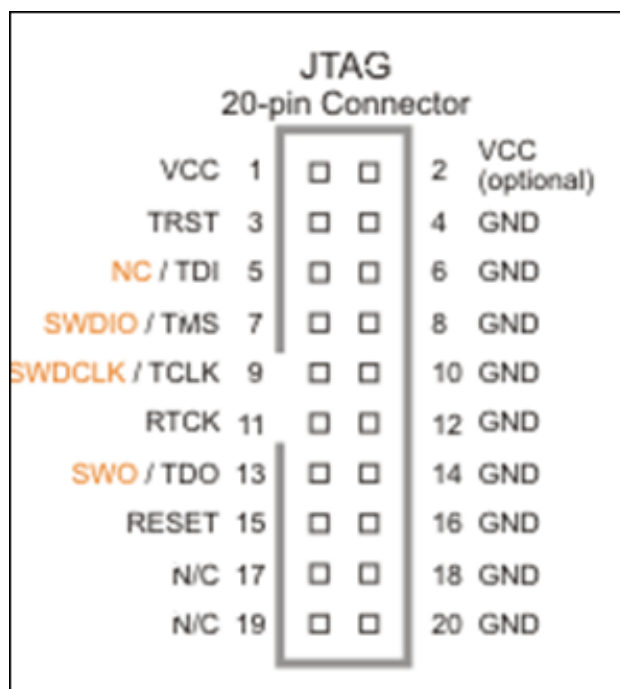
Figure 3-15. J-link debugger connector

3.10   Microcontroller requirements

Following are the requirements for MCU:

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

3.10.1   Crystal requirements

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

3.10.2   LCD requirements

LCD driver of the controller requires three ceramic capacitors whose typical value is 0.1 µF for LCD bias voltages and 0.1 µF for LCD charge pump.

3.11   Assembled printed circuit board

Figure 3-16 shows the top view of the assembled board:
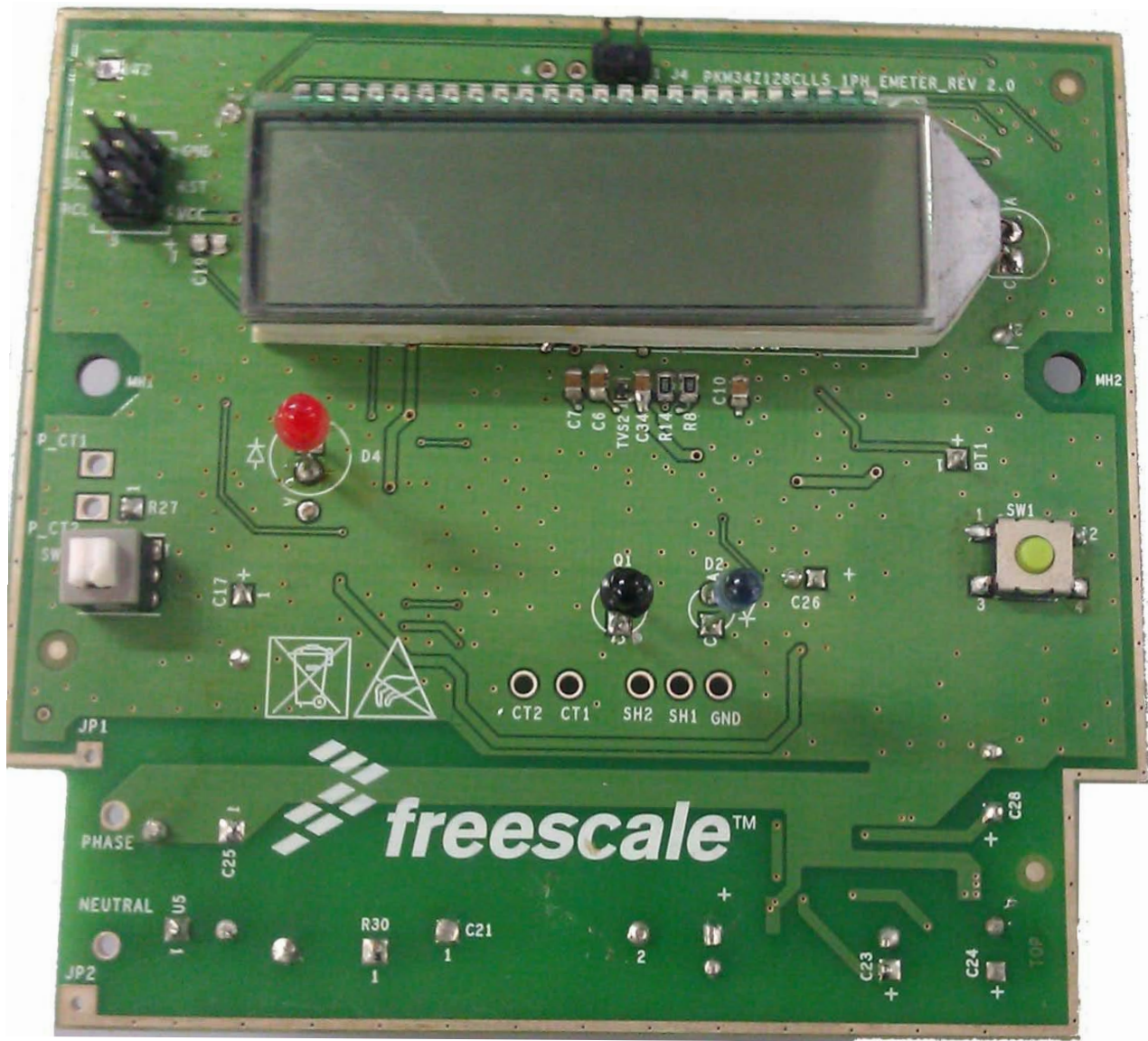
Figure 3-16. Board top view

Figure 3-17 shows the bottom view of the assembled board:
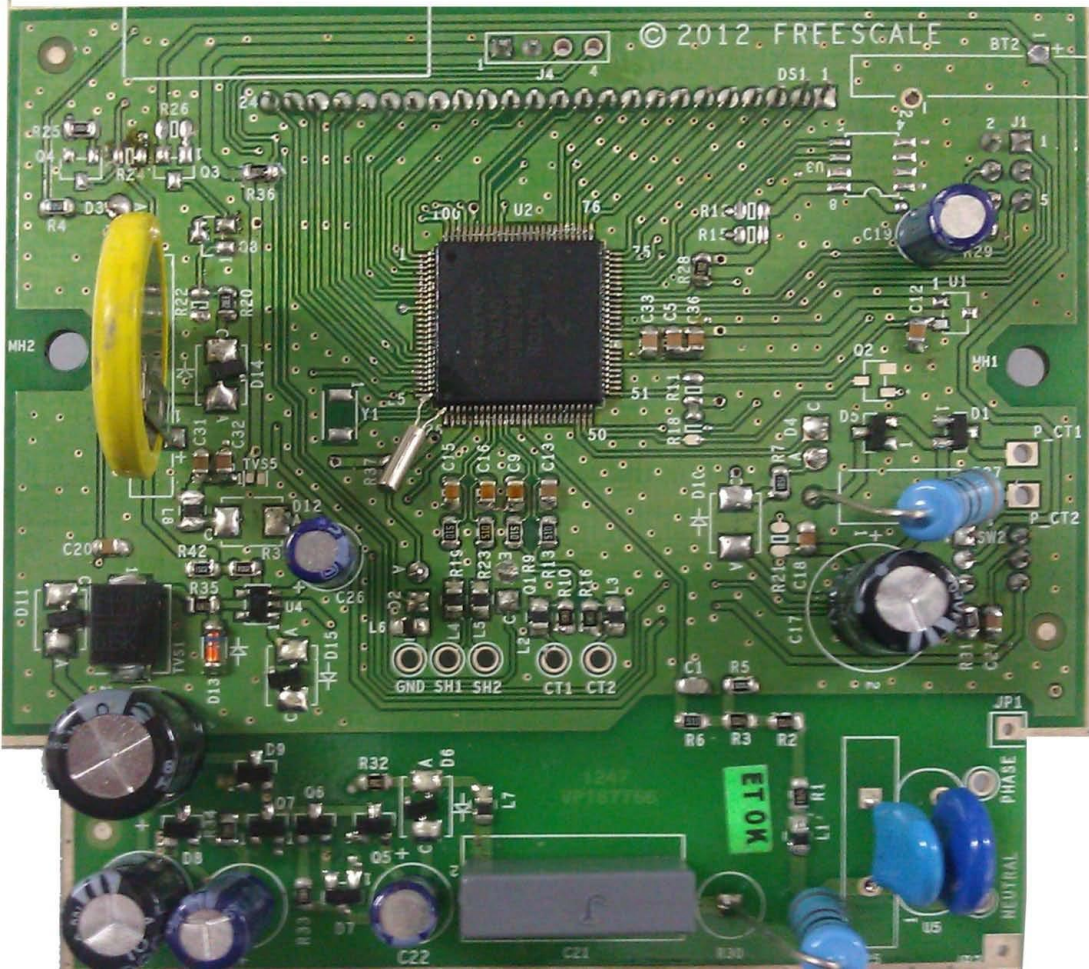
Figure 3-17. Board bottom view

Chapter 4
Software Design

4.1 Introduction

This section describes the software design of Single-Phase Energy Meter application. Software design mainly consists of measurement, database, user interface, and communication modules. The objective of this chapter is to understand the software design. The software architecture is custom kernel running on KM device controller. The controller uses the external RTC clock source and PLL to generate the system clock of 12.28 MHz.

The software has following main modules:

- Measurement Module
- Database Management Module
- User Interface Module
- Communication Module

4.2 Hardware resource allocation

The following table lists the MCU resources used in metering application.

Table 4-1. Hardware resource allocation

Peripherals	Usage
TMR1	General purpose timeout timer
TMR2	Zero crossing timing to compute frequency
AFE0	Phase Current
AFE1	Neutral Current
AFE2	Voltage
I2C1	EEPROM
SCI1	Optical communication

Table continues on the next page...

Table 4-1.   Hardware resource allocation (continued)

Peripherals	Usage
XBAR	Connect CMP1 to TMR2
CMP1	Zero cross detection to detect voltage and compute frequency
LCD	Display
VREF	Voltage reference for AFE
RTC	Real time management and cover open tamper
NVIC	Interrupt controller for various interrupts
PLL	Bus and AFE clock source

4.3 Interrupt priority

The following table shows interrupts priorities of various modules that are set in the software. The lowest number denotes the highest priority.

Table 4-2.   Interrupt priorities

Interrupts	Priority level
TMR1	2
TMR2	2
AFE0	3
AFE1	3
AFE2	3
I2C1	0
SCI1	2
RTC	3
DMA	2
Push button	3

4.4 Measurement

Metering application software operates MCUs in different configuration depending on the input conditions. The following sections describe the requirement of the different modes, what are the different modes, and how they have been implemented.

4.4.1   Modes

The modes are required because the meter should power up at 90 V upwards and should be fully functional at 120 V upwards. This lays a lot of restrictions on the power supply. The capability of the power supply is as under.

Table 4-3.   Metrology engine has various modes

Mode	Voltage
Run	V >= 115
Brownout	V < 115
Single Wire	V = 0, I ≠ 0
Battery	V = 0, I = 0

In run mode, the meter consumes about 9.6 mA of current. Hence a new mode – Brownout was created in which the meter runs off 2 MHz IRC. All the parameters are measured but the accuracy is not as good as it is in Run mode, thus allowing meter to function in limited capacity. This process is seamless to the user.

In single wire mode, the meter runs off power up CT (or battery) and hence the capacity of the supply is much limited. The meter is made to run off 2 MHz IRC so that the consumption is brought down to minimum.

In battery mode, the meter is powered up to allow the reading and display. In this mode, the meter is powered up for a very short duration and no measurements are made. This mode allows only three display cycle per day.

Voltage (V)	Capacity (mA)
240	17.8
180	15
150	13
120	10.5
90	9

4.4.2   Meter startup sequence

While booting, depending upon the supply condition and the mode of wake-up (from RESET), the meter takes some time to settle down into the mode. The software first checks if the output from regulator is low. If it is, then an external key press in absence of mains has woken up the meter and it should allow the user to read via communications and/or scroll through the display list.

If the regulator output is high, then initialize analog comparator to check for zero crossing (presence of mains voltage). If voltage is present, comparator interrupt would be visible in a very short duration – of the order of ~20 ms. Otherwise it times out to switch to battery mode. If zero crossing is detected, the brownout mode is selected. Measurement is done in brownout mode and if voltage is above 120 V, then mode is switched to Run mode.
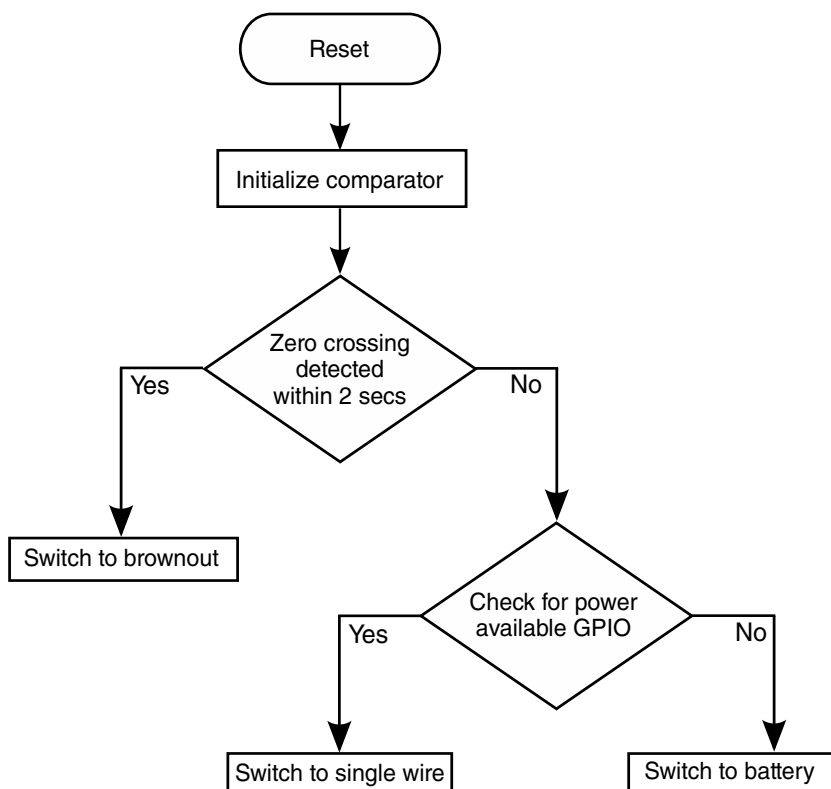
Figure 4-1. Metering on boot

When the meter is running, changes in supply conditions may require it to switch to another mode. Mode switches are done as per the following flow diagram.
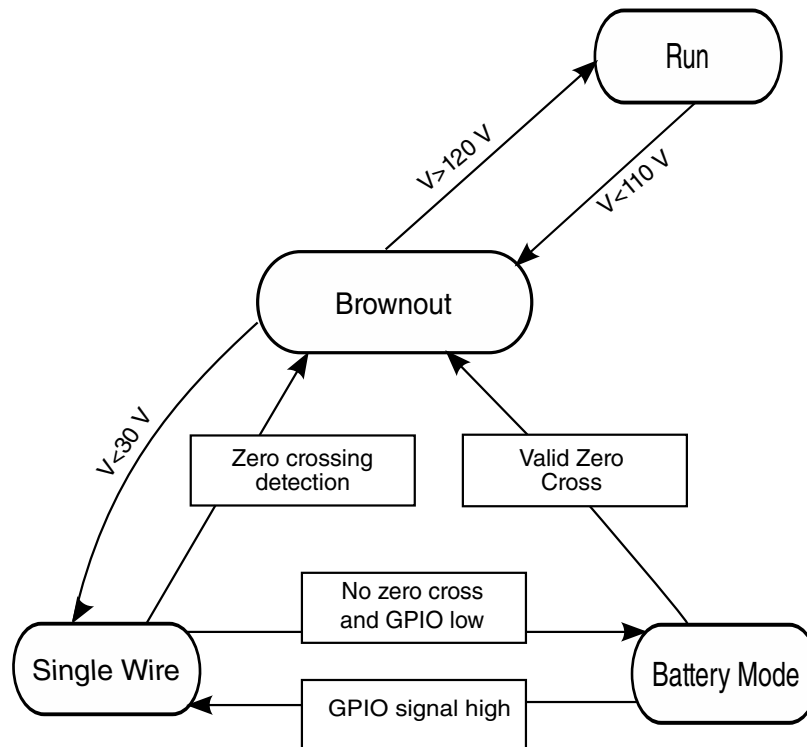
Figure 4-2. Switching between modes

4.4.3 Metering modes

1. **RUN**

   Clocking scheme: Controller is in PEE mode (PLL Engaged External). AFE runs off PLL at 768 kHz. Running AFE at less than 1 MHz is required for low-power operation and saves about 1 mA per channel while compromising very little on signal measurement accuracy.
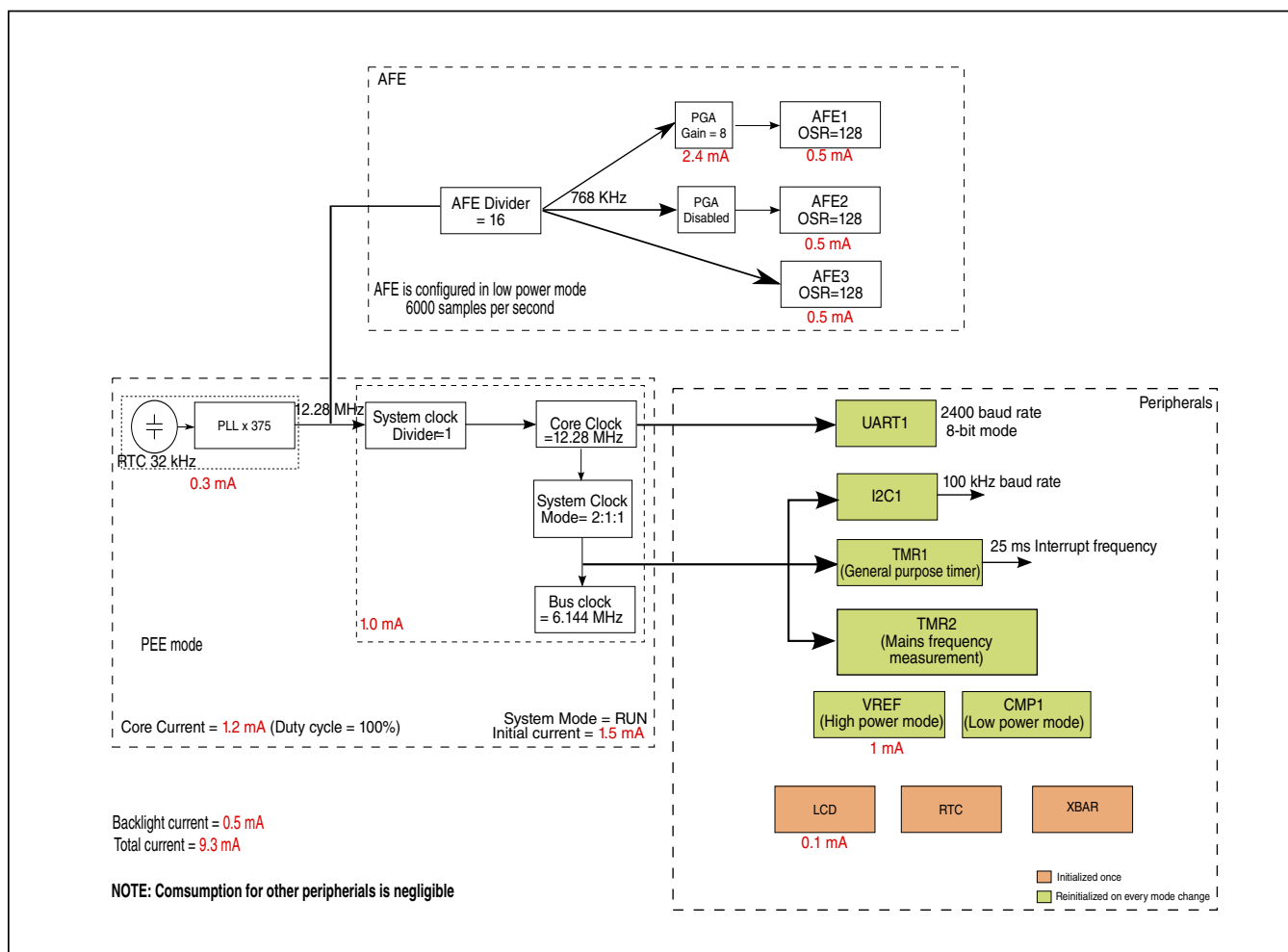
Figure 4-3. Run mode

Type	Used	Available
AFE	AFE0, AFE1, AFE2	AFE3
TMR	TMR1, TMR2	TMR0, TMR3
LPTMR	–	LPTMR
UART	UART3	UART0, UART1, UART2
I²C	I²C1	I²C0
CMP	CMP1	CMP0
RTC	RTC, TAMPER0	TAMPER1, TAMPER2
LCD	4x20	4x20
PLL	PLL	–

2. **Brownout**

   Clocking scheme: Controller is in BLPI mode (FLL Bypassed Low Power Internal).
   AFE runs off IRC.
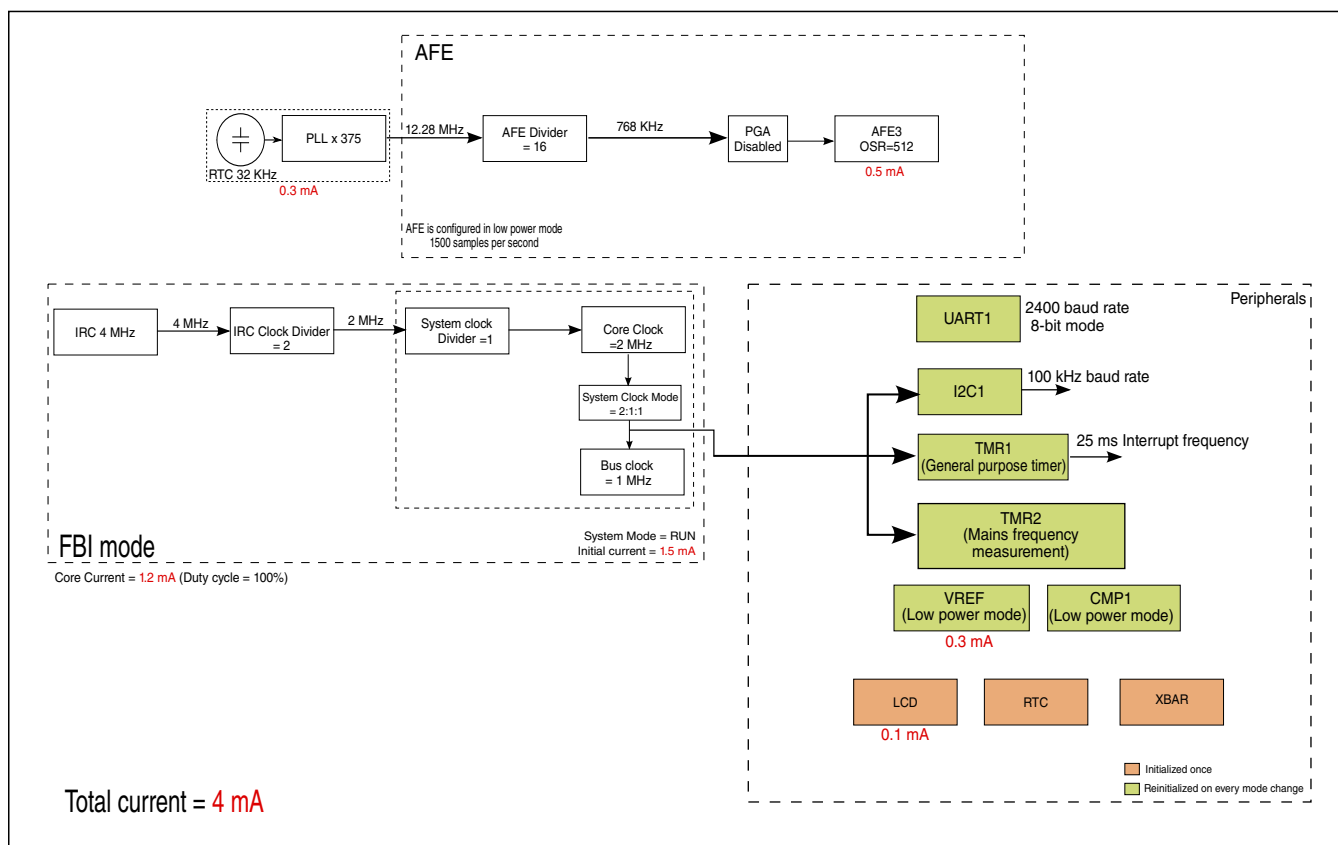
Figure 4-4. Brownout mode

Type	Used	Available
AFE	AFE0, AFE1, AFE2	AFE3
TMR	TMR1, TMR2	TMR0, TMR3
LPTMR	–	LPTMR
UART	UART3	UART0, UART1, UART2
I²C	I²C1	I²C0
CMP	CMP1	CMP0
RTC	RTC, TAMPER0	TAMPER1, TAMPER2
LCD	4x20	4x20
PLL	–	PLL

3. **Single Wire**

Clocking scheme: Controller is in BLPI mode (FLL Bypassed Low Power Internal). AFE runs off IRC.
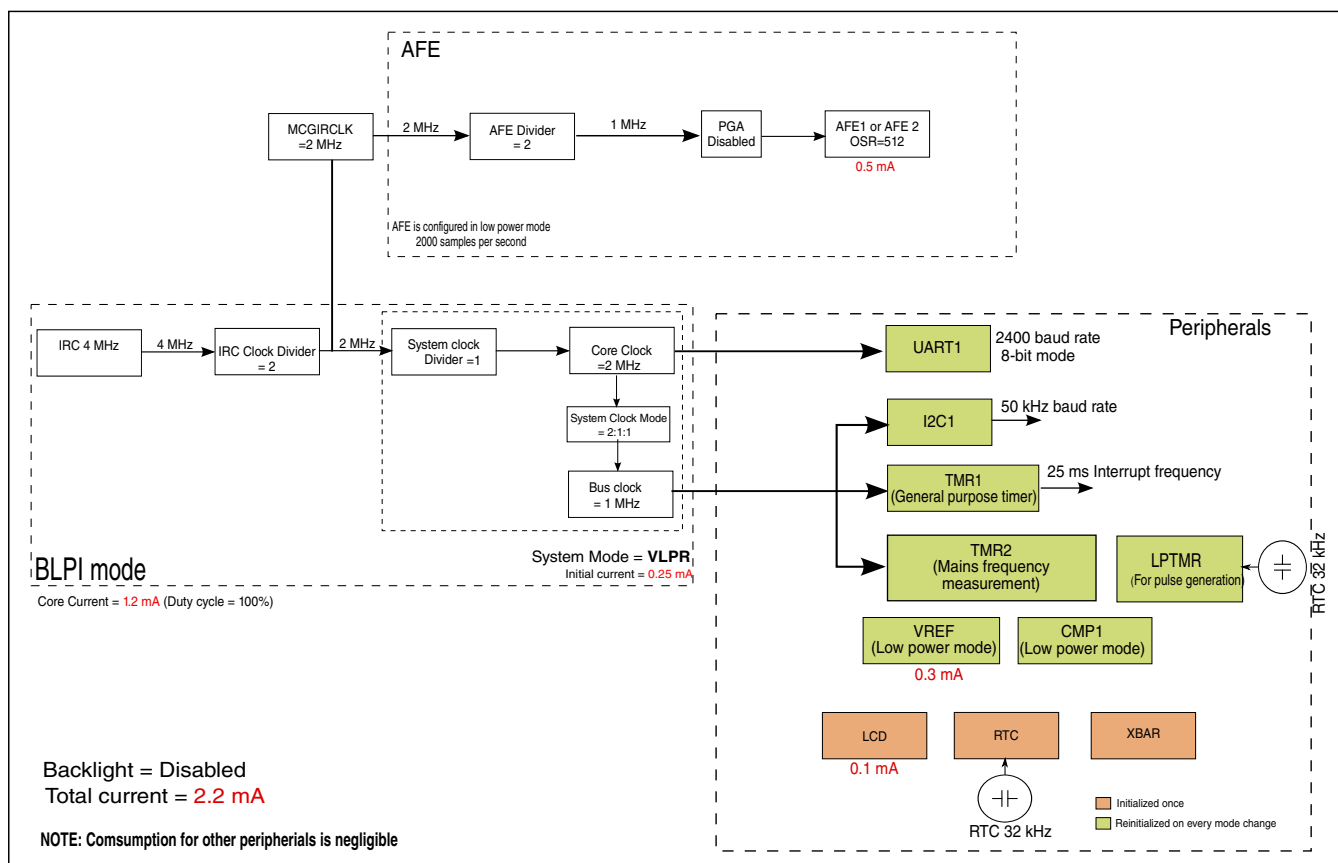
Figure 4-5. Single wire mode

Type	Used	Available
AFE	AFE0, AFE1	AFE2, AFE3
TMR	TMR1, TMR2	TMR0, TMR3
LPTMR	LPTMR	–
UART	UART3	UART0, UART1, UART2
I²C	I²C1	I²C0
CMP	CMP1	CMP0
RTC	RTC, TAMPER0	TAMPER1, TAMPER2
LCD	4x20	4x20
PLL	–	PLL

4. Battery

Clocking scheme: Controller is in BLPI mode (FLL Bypassed Low Power Internal). Metrology is disabled.
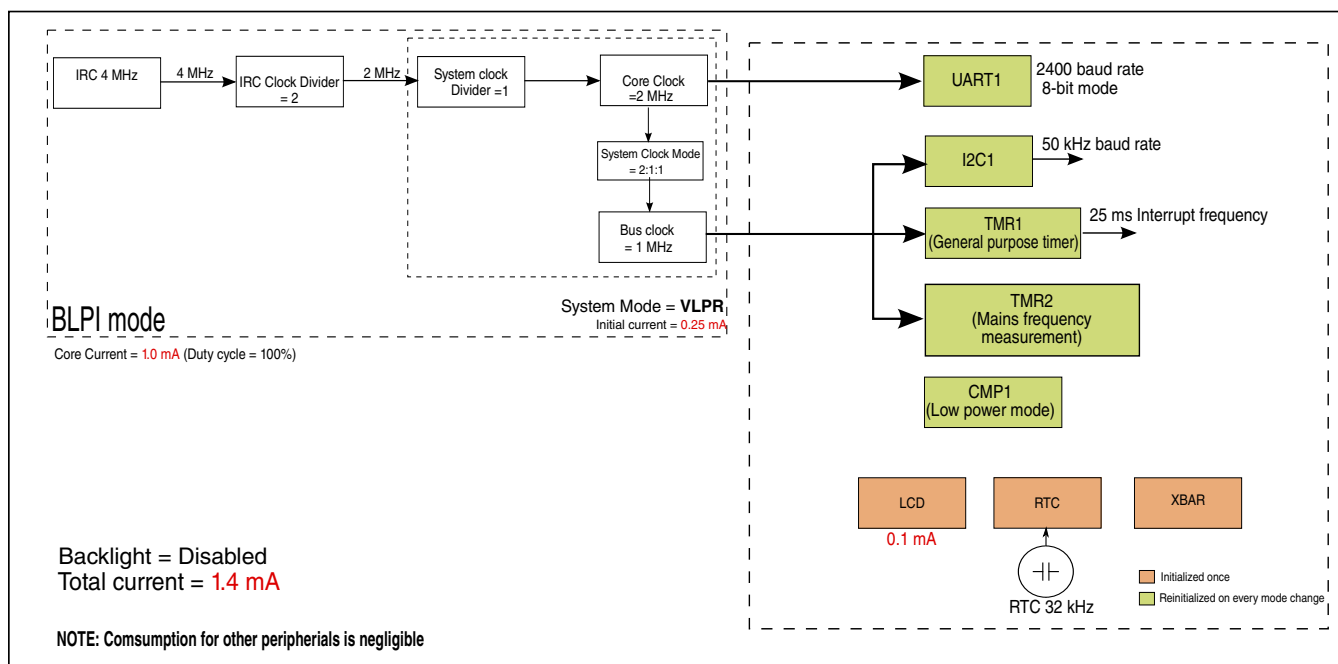
Figure 4-6. Battery mode

Type	Used	Available
AFE	–	AFE0, AFE1, AFE2, AFE3
TMR	TMR1, TMR2	TMR0, TMR3
LPTMR	–	LPTMR
UART	UART3	UART0, UART1, UART2
I^{2}C	I^{2}C1	I^{2}C0
CMP	CMP1	CMP0
RTC	RTC, TAMPER0	TAMPER1, TAMPER2
LCD	4x20	4x20
PLL	–	PLL

4.4.4 Measurement parameters

Table 4-5. Parameters

Parameter	Run	Brownout	SingleWire	Comments
V$_{rms}$	Yes	Yes	—	Assumed in Single Wire
Ip$_{hrms}$	Yes	Yes	Yes	—
In$_{rms}$	Yes	Yes	Yes	—
Active power	Yes	Yes	Yes	—
Reactive power	Yes	Yes	—	Calibration only and compile time option

Table continues on the next page...

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

Table 4-5. Parameters (continued)

Parameter	Run	Brownout	SingleWire	Comments
Apparent power	Yes	Yes	—	—
Power factor	Yes	Yes	—	Assumed in Single Wire
Active energy	Yes	Yes	Yes	—
Reactive energy	Yes	Yes	—	Calibration only and compile time option
Apparent energy	Yes	Yes	Yes	—

4.4.5 Initialization

The metering engine requires the following peripherals:
- PLL
- AFE
- Vref
- TMR2
- XBAR
- CMP1

Depending on the mode metering engine is working on, these peripherals are selectively initialized. CMP1 is always initialized to either detect presence of voltage (for battery and single wire modes) or for frequency (brownout and run modes).

Mode	Peripheral initialized
Brownout	AFE2, AFE1, AFE0, Vref
Run	AFE2, AFE1, AFE0, Vref
Battery	—
Single Wire	AFE0/1, Vref

NOTE

In Single wire mode, the current channels are enabled one at a time to check current on the two channels and use the one that's higher of the two.

In Battery mode (which is essentially used for display in mains off mode), CMP1 is enabled to see if mains supply is restored.

Transition from any mode to another mode is done via brownout.

RMS is the typical mode of computation.

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

4.4.6   Sampling

Samples of the enabled AFE channels are accumulated in data structures for fixed duration, that is, 1 second. At that instance, the sampler triggers metering. Metering is triggered either by sampling count (if PLL is active) or when a second has elapsed (when source is RTC). Offsets are removed from samples before banks are updated. Sums which are updated during sampling are:

- Voltage rms
- Phase current rms
- Neutral current rms
- Active Phase power
- Active Neutral power
- Reactive Phase power
- Reactive Neutral power

4.4.7   Metering process

Every one second the metering processing engine is triggered. This engine computes the gathered raw samples into metering parameters. The steps involved are (slightly vary for different modes):

1. Scale the gathered sums in 64 bits into floating point.
2. Calibration constants are applied. RMS parameters are computed in this step itself as they don't need any further calculations.
3. Active, Reactive and Apparent powers are computed for phase and neutral elements. Total powers are also computed.
4. Power factor is derived.
5. Phase correction is applied (see method below).
6. Powers computed are converted into energies. Energy is recorded only in import mode (always forwarded).
7. Energy registers are updated.
8. Energy accumulated in this metering period is updated for driving calibration LED.
9. Auto-Calibration is invoked, if enabled.
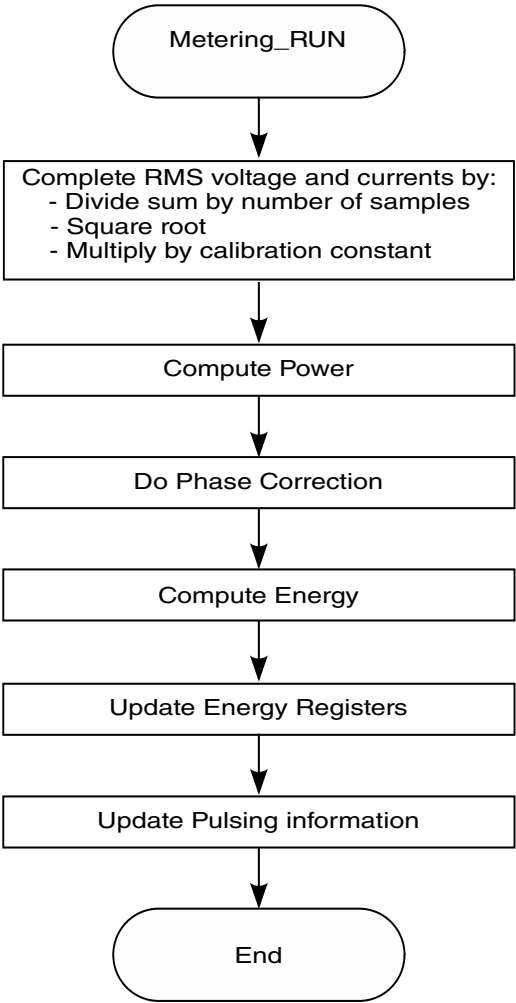
Figure 4-7. Metering process

Apply Phase
Correction

Get sin of power factor
from sign of I at zero
cross over of V

Power factor $\varnothing = \cos^{-1}\left(\dfrac{\text{Active Power}}{\text{Apparent Power}}\right)$

If leading PF,
Apply Phase Correction
$\varnothing = \varnothing \times -1$

Phase Correction
$\varnothing_c = \varnothing + \varnothing'$ (From calib)

New active power = App power x $\cos \varnothing_c$
Reactive Power = App Power x $\sin \varnothing_c$

End
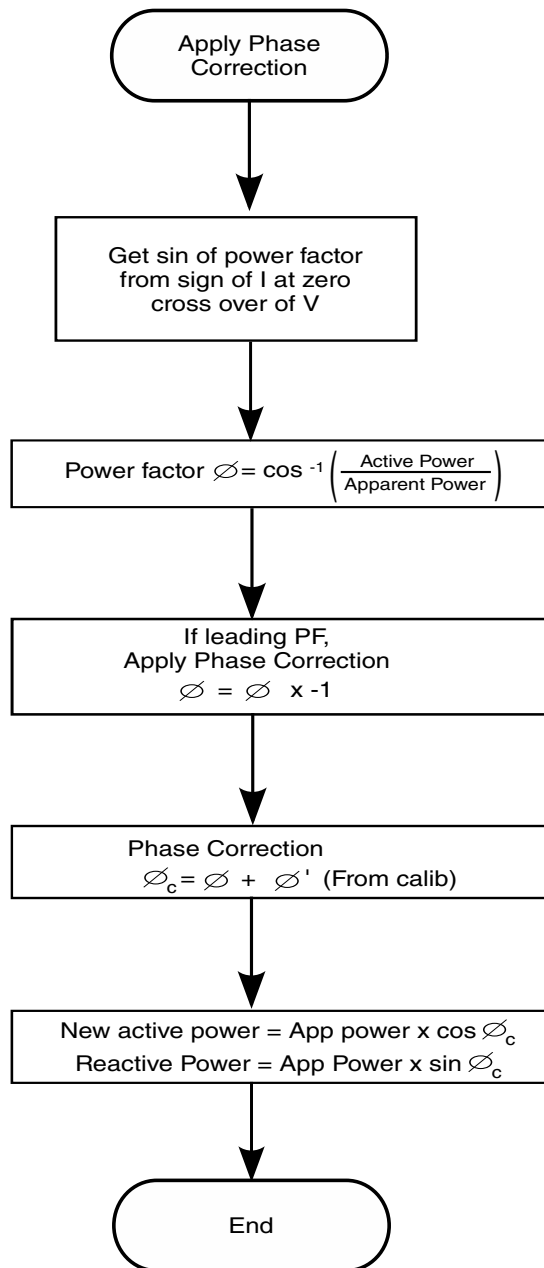
Figure 4-8. Phase error correction
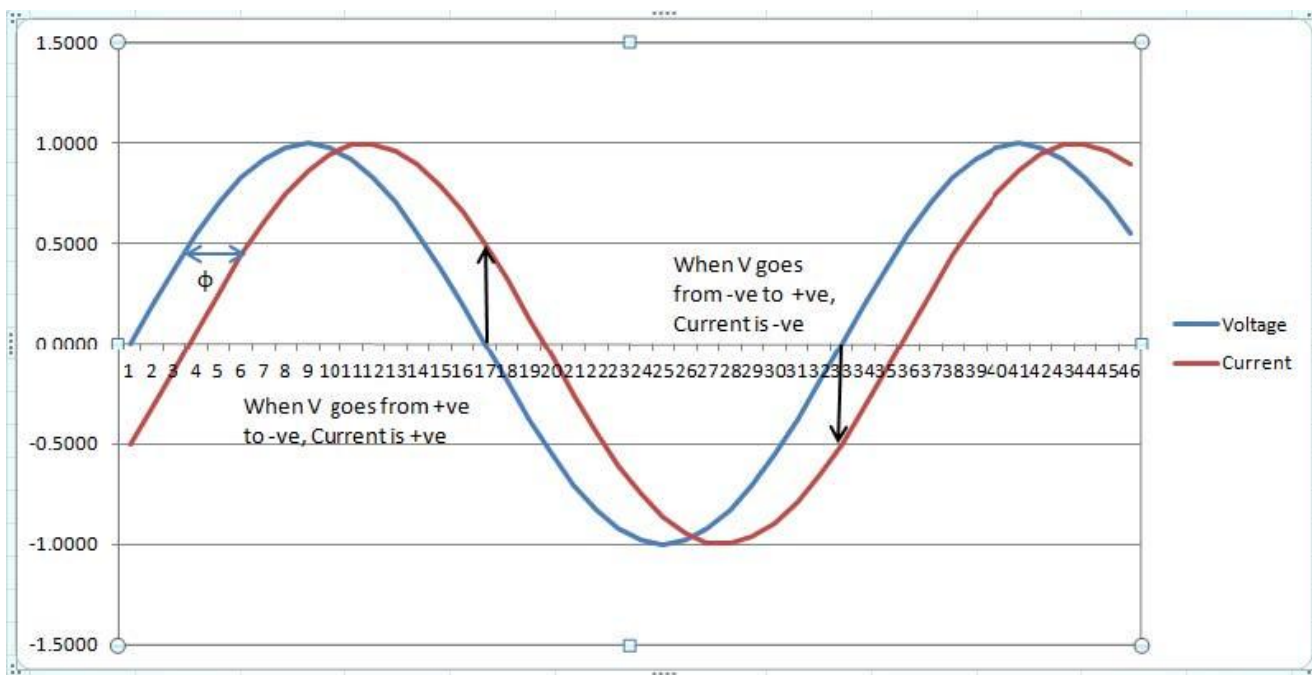
Figure 4-9. Lagging
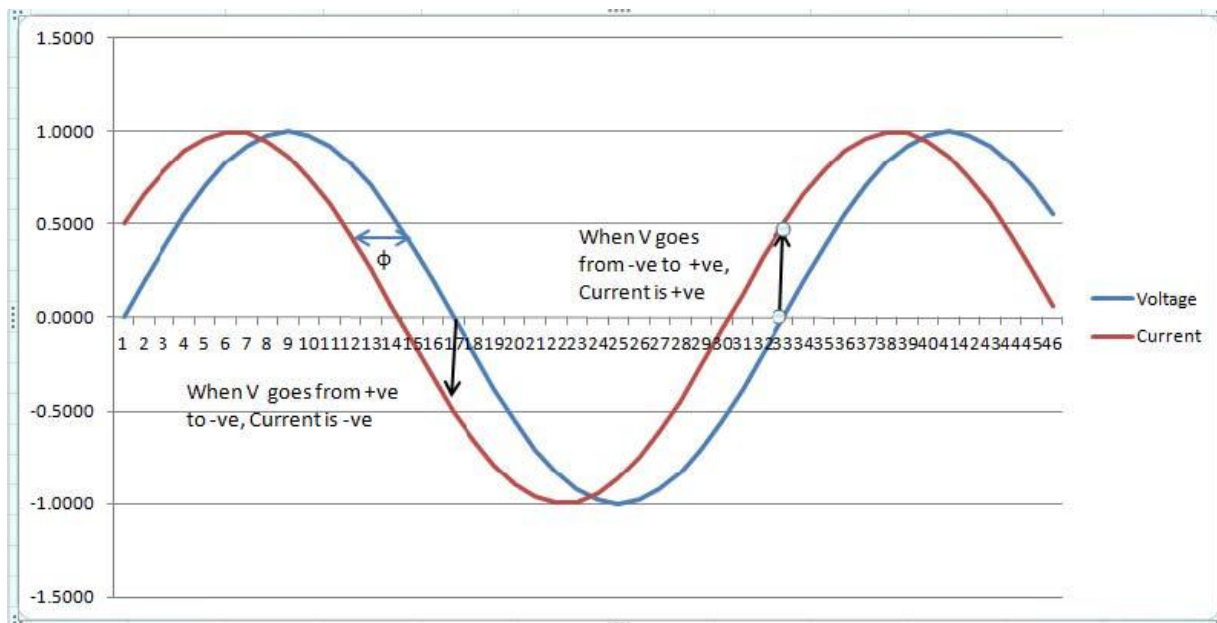
Figure 4-10. Leading

4.5   User interface

4.5.1   Introduction

The User Interface Module comprises of LCD, keypad, and LEDs and their respective drivers. Custom LCD specific for metering application to displaying various Electrical parameters. Meter has Push button key for manually control the display of parameters. Meter has LED for energies pulse generation. Backlight control of LCD through I/O pin controller .
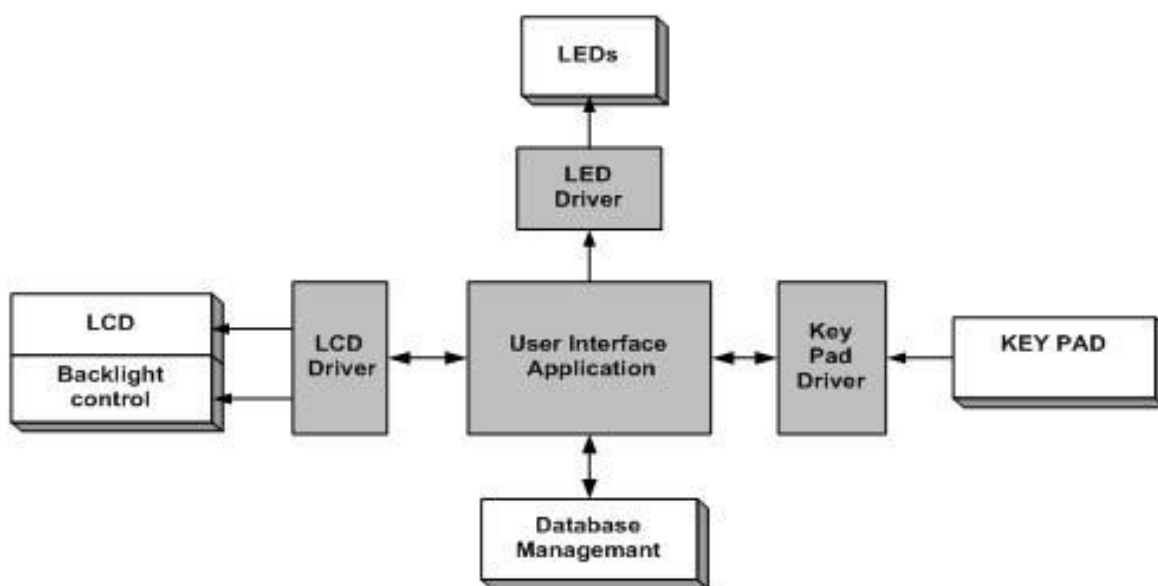
Figure 4-11. LCD block diagram

4.5.2   LCD panel

This reference design has a configurable list of parameter to be displayed on the LCD. User will select the list of parameter and the sequence of parameter to be displayed on LCD by controlling the Mask set defines. There are two mode for the display Auto Scroll Mode and Manual Scroll Mode. Currently following parameters has been implemented.

- LCD Self Test
- Phase current
- Neutral current
- Voltage
- Frequency
- Active power

- Apparent Power
- Active Energy (Complete Value)
- Maximum Demand (kW)
- Maximum demand Time
- Maximum demand Date
- Power Factor
- Real Time
- Real Date
- Tamper status of meter cover open
- Latest Cover Open Tamper event date
- Latest Cover Open Tamper event time
- Active Energy (Integer value only)
- Status of Magnetic Tamper
- Latest Magnetic Tamper event date
- Latest Magnetic Tamper event time
- Cumulative active energy for each calendar month for previous six month with display of Month
- Maximum demand (kW MD) in a calendar month for previous six months with date and time

NOTE

Any parameter in the above list can be configured to display in the two modes, that is, Auto Scroll Mode and Manual Scroll Mode.

4.6 Communication

Meter facilitates optical port for serial communication, using IEC62056-21 Mode C protocol, with external world for data exchange. On personal computer, hyper terminal or any standard windows utility, like InTerm Version 1.1 from RF innovations, is used for communication purpose. Transmission and reception takes place by interrupt method.
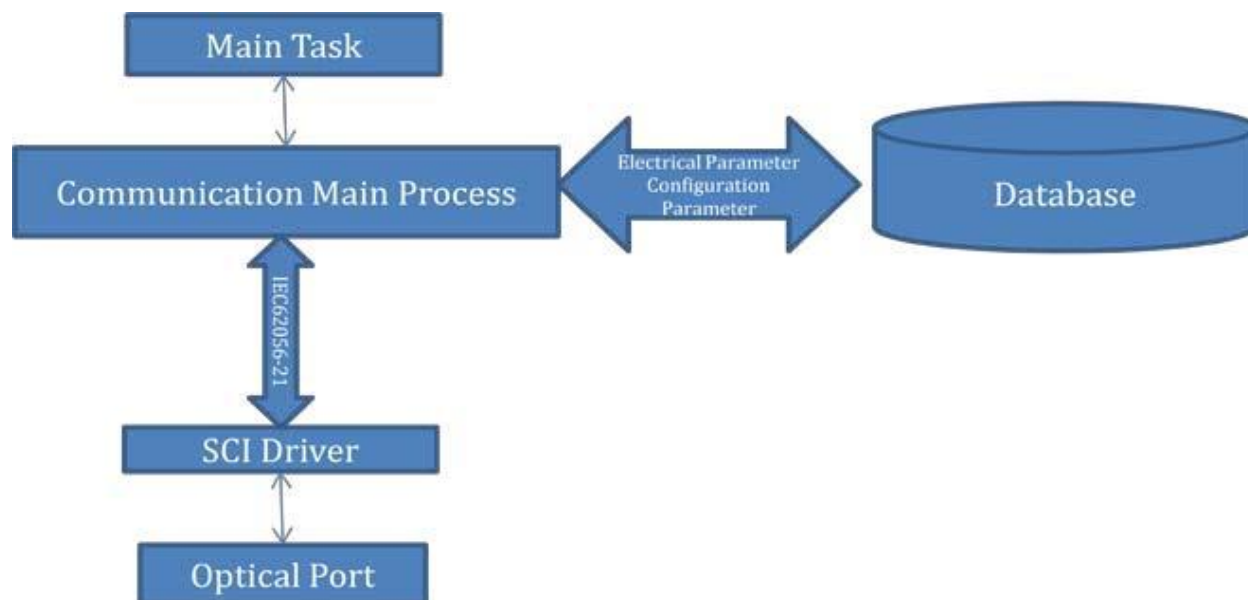
Figure 4-12. Optical communication block diagram

4.6.1 Implementation

- IEC 62056-21 Mode C protocol is used for data exchange.
- An optical head is used for over the optical port interface on the meter and RS232 port connected to PC for communication.
- Transmission and reception is on interrupt based. Reception is disabled until the received packet is processed.
- Data verification implemented in programming mode to ensure correct entry of data.
- Character Transmission
    - Asynchronous serial bit (Start-Stop) transmission
    - Half duplex communication
    - Baud rate – 2400, Standard Baud rate – 300, 600, 1200, 2400, 4800, 9600,19200
    - Character format: 1 start bit, 7 data bits, 1 parity bit, 1 stop bit
    - Character security: Even Parity
- COM port settings
    - Baud Rate : 2400 bps
    - Data Bits : 8
    - Parity : None
    - Stop Bit(s) : 1
    - Flow control : None
- Optical port interface supports following modes
    - Data Collection Mode: Data collection consists of header information (MFG identity, unit serial number and name, version, revision etc.), electrical parameters etc

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

- Programming Mode: This mode is used to configure the following meter parameters and settings.
  - Read date, time and configuration parameters.
  - Program date and time.
  - Program serial name and number.
  - Program nominal voltage, current and frequency.
  - Program MD integration period.
  - Program auto scroll period.
  - Program LP interval time.
  - Program persistence time.
  - Program optical baud rate.
  - Program pulse constant.
  - Clear MD parameters, tamper headers and load profile headers.
- Calibration Mode: Calibration of the meter is done in this mode which includes manual and auto calibration. Please refer section 4.7 or user guide for details of calibration.

NOTE

Select odd parity in the com settings to configure for even parity and vice versa. This is a known bug in the In-Term Utility.

4.7 Calibration

Calibration of the meter is done in order to compensate for variations introduced by hardware. Calibration of the meter can be done in auto calibration method only. In Auto Calibration user feeds a known voltage and current and the software calculates the coefficients and stores them in NV memory if calibration is successful.

4.7.1 Auto calibration process

Auto Calibration Module calibrates the meter for various parameters to compensate errors due to tolerance of external components. Calibration of the meter is a single point process. The load points are as follows:

- 240 V
- 10 A
- UPF

NOTE

The load point can be changed as the calibration engine can take any load point.

Once the load point is set, calibration is started. Accumulation happens normally for 10 cycles referred as n following in steps. The following flowchart explains the calibration process:

```
                    ┌──────────────┐
                    │    Start     │
                    └──────┬───────┘
                           │
            ┌──────────────▼──────────────────┐
            │  Wait for 5 cycles for stabilization │
            └──────────────┬──────────────────┘
                           │
            ┌──────────────▼──────────────────┐
            │       Accumulate Phase Angle     │
            └──────────────┬──────────────────┘
                           │
            ┌──────────────▼──────────────────┐
            │         Apply Phase error        │
            └──────────────┬──────────────────┘
                           │
            ┌──────────────▼──────────────────┐
            │       Accumulate Magnitude       │
            └──────────────┬──────────────────┘
                           │
            ┌──────────────▼──────────────────┐
            │         Apply Ratio error        │
            └──────────────┬──────────────────┘
                           │
                    ┌──────▼───────┐
                    │     End      │
                    └──────────────┘
```
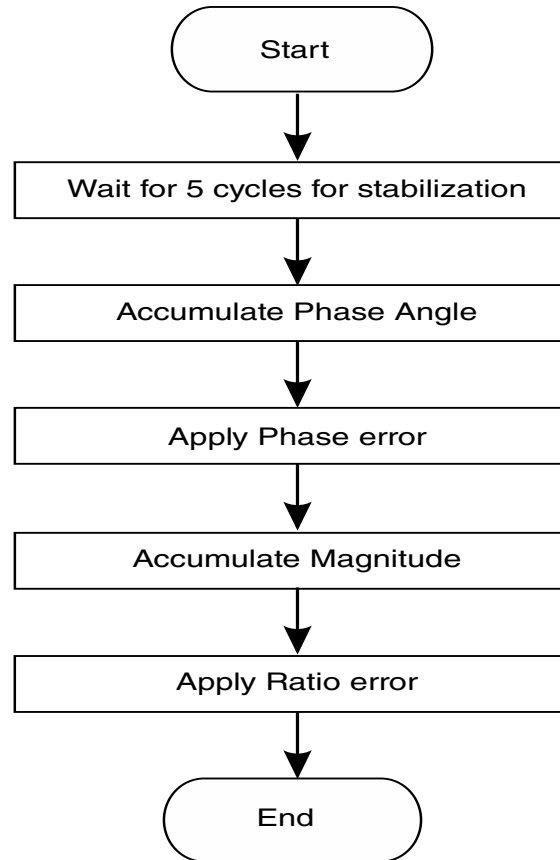
Figure 4-13. Flow diagram of calibration

Ratio error is elaborated in the following flow diagram:

Accumulate RMS value for 5 cycles (V, I_{ph}, I_N)

Measured value = Average Accumulated RMS value

New calib co-efficient = $\left(\dfrac{\text{Applied value}}{\text{Measured value}} \right)$ x Old calib co-efficient
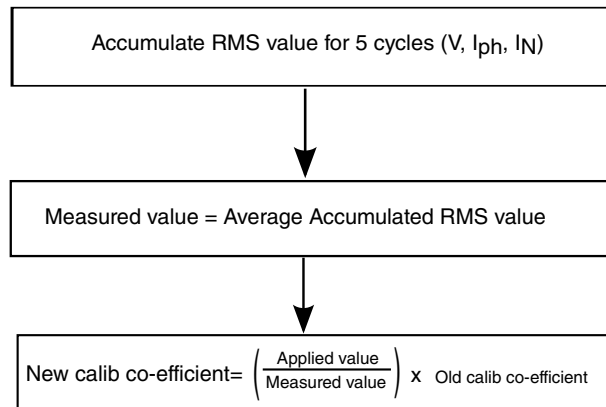
Figure 4-14. Flow diagram of ratio error

Phase error is elaborated in the following flow diagram:

Ph Angle = $\tan^{-1}$(Reactive Power/Active Power)

Accumulate Phase Angle for 5 metering cycles

Average Phase Angle = $\sum / 5$

Phase Error = Phase Angle - Applied Angle
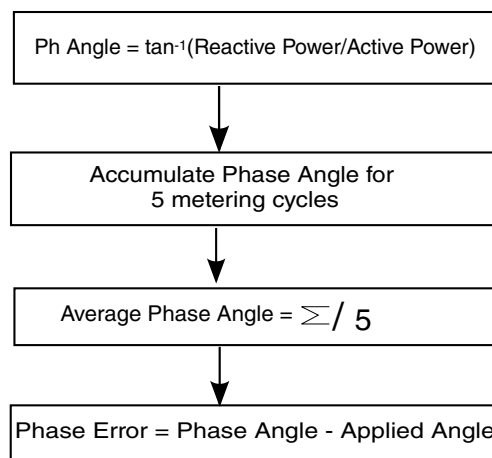
Figure 4-15. Flow diagram of phase error

4.8 Tamper detection

Following Tampers are detectable by the meter:

1. Box Open
2. Magnetic
3. Phase Reversal
4. Partial Earth
5. Neutral Missing

4.8.1 Box Open tamper

Box open tamper switch is mounted on the meter. Each time box cover is open, a tamper is registered in the RTC. This tamper is active even if the main power is OFF. Time stamp of this tamper is also recorded in the RTC. Metering software takes care of the tamper occurrence and release time.

4.8.2 Magnetic tamper

Magnetic tamper is a high magnetic field presence condition near the meter. This tamper condition results in inappropriate functioning of current transformer. A magnetic switch is used in the hardware to detect magnetic tamper condition. Output signal of this switch toggles whenever magnetic field is applied and this signal is tied with one I/O of microcontroller in GPIO mode, this toggle is detected as a tamper. Magnetic tamper is not tested on the reference design.

4.8.3 Phase reversal tamper

Phase reversal tamper is a condition in which meter starts registering energy consumption in negative direction when phase and neutral are reversed. This causes energy units to decrement. So this condition is detected as a tamper in software and energy is always treats as positive. Occurrence and Release time stamp of this tamper is stored in EEPROM.

4.8.4 Partial Earth tamper

Partial earth tamper is a condition in which phase and neutral current are not equal. A partial amount of current is returned back to local earth. Amount of current returning back in neutral line is not equal to the phase line, rather it is lesser. This tamper condition is detected in software. Occurrence and release date and time of this tamper is stored in EEPROM.

4.8.5 Neutral Missing tamper

Neutral missing tamper is a condition in which user disconnects the neutral from the meter. This will causes meter to power OFF and user can draw current from the phase line, which will not be registered in the meter. This condition is taken care by powering the meter by an auxiliary power source know as Neutral Missing power CT. So whenever

neutral missing condition occurs, neutral missing power CT will power on the meter and the current following through phase line will be detected and this condition will also be registered in EEPROM.

4.9 Database

4.9.1 Introduction

Reference Energy Meter design has external serial NV memory interfaced to KM devices over I^{2}C port. NV memory storage structures are as follows:
- Active, Reactive, and Apparent Energies
- Maximum Demand (MD)
- Calibration Coefficients
- Configuration Parameters
- Previous Month MD and Cumulative Energy.
- Tamper Headers and Tamper Data
- Load Profile Header and Load Profile Data.

The details of each structure can be found in the following excel file.

4.9.2 Assumptions, constraints, and limitations

Meter will be configured with default values if nonvolatile memory gets corrupted.
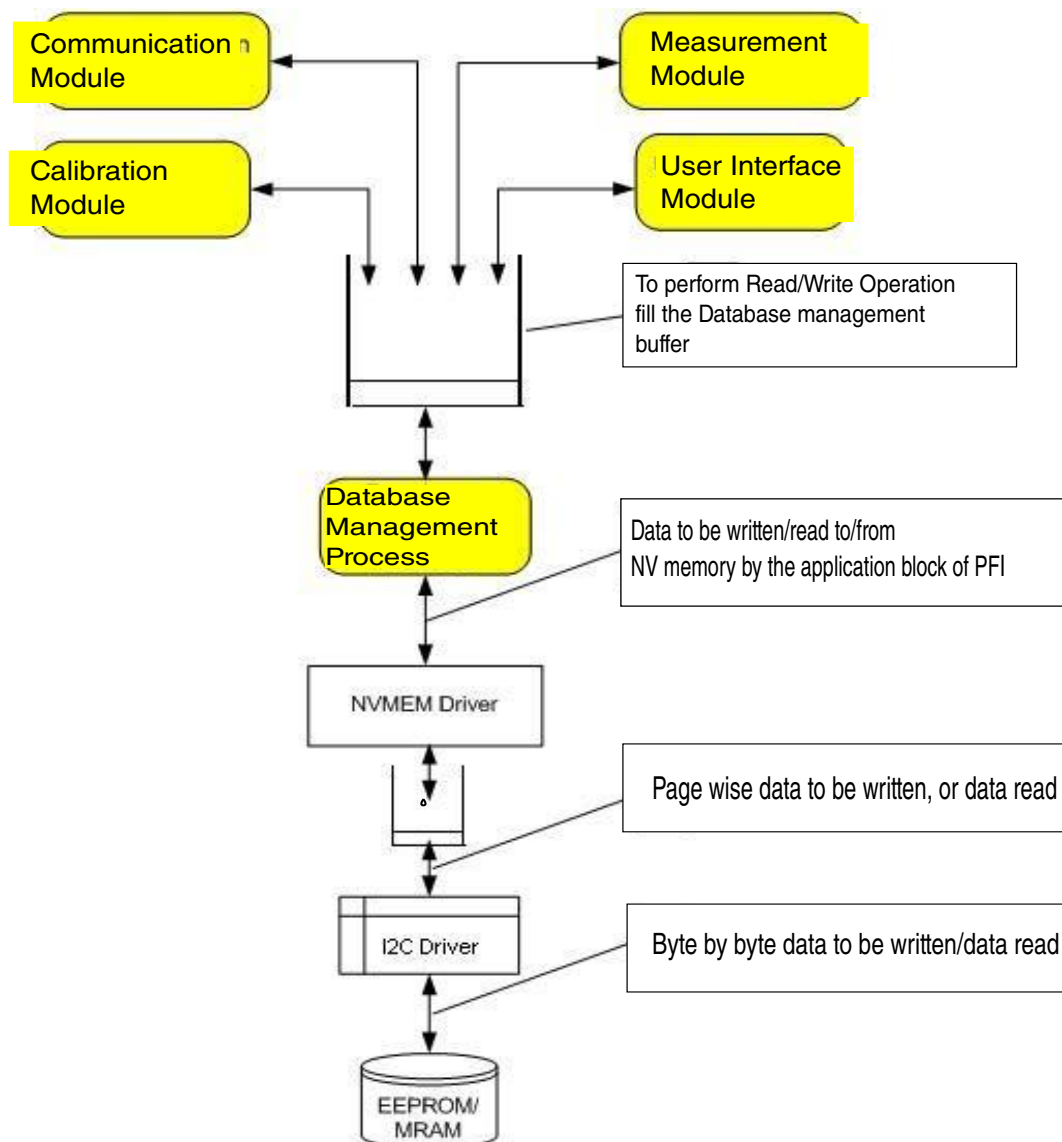
Figure 4-16. Database module block diagram

4.9.2.1   DB Application Block

- DB Application block will handle the Read/Write operations to NV memory, depending upon other module request.
- Write/Read operations are done one structure at a time.
- Any module can initiate read/write operation after get the database lock.
- DB Applications block handle Init operation, write, read, post wait, bank update and retry states for any read/write operation initiated by other modules.

NV Driver

- NV driver will receive a read/write request from the DB Application block.
- Based on type of NV memory, write operation will be executed.
- EEPROM paging concept (maximum of 128 bytes write at a time) will be executed.
- NV driver will call I^{2}C drivers for read/write operation.

I^{2}C Driver

- I^{2}C driver will write and read the data to and from NV memory

4.9.3 Implementation

- The module which needs to access NV memory should first obtain LOCK. Only one module can access NV memory at a time. In case the lock is unavailable the requesting module can either wait until lock is released or can terminate the request by itself.
- Transmission and reception over I^{2}C are interrupt based.
- I^{2}C baud rate configured for EEPROM is 100 kHz.
- NV Read/Write Success – Database application block returns DB_SUCCESS and releases the lock
- NV Read/Write Failure – The application retries the read/write operation for 3 times in case of failure. If read/write is unsuccessful for retry number of counts then database application block returns DB_FAILURE and releases the lock.
- Active Energy and status of various Tampers will be saved in RTC nonvolatile memory at a fixed interval of 1 min
- At the time of power up latest energy from RTC Ram is copied into EEPROM on active bank of energy structure.
- At power ON application validates the signature of current bank. If either of the bank signatures is valid, application reads Energies, Maximum Demand Parameters, load profile, Configuration Parameters , Calibration Parameters, Previous Month MD and Energy headers and tamper headers from NV memory. If both the bank signatures are invalid then defaults are written to NV memory.
- CRC check for each structure for data integrity.

4.9.4 Memory map

EEPROM Size = 64 Kbytes

Table 4-7. NV memory details

Structure	Bytes
Bank Status and Signature for each bank	10

Table continues on the next page...

Table 4-7.   NV memory details (continued)

Number of bytes required by Energy Registers	64
Number of bytes required by Maximum demand	32
Number of bytes required by Calibration coefficients	64
Number of bytes required by Configuration parameters	96
Number of Bytes Required MD and Energy Cumulative Header	10
Number of Bytes Required MD and Energy Cumulative Data Part	192
Number of Bytes Required Reverse Tamper Header	12
Number of Bytes Required Reverse Tamper Data	1100
Number of Bytes Required Earth Tamper Header	12
Number of Bytes Required Earth Tamper Data	1100
Number of Bytes Required Magnetic Tamper Header	12
Number of Bytes Required magnetic Tamper Data	1100
Number of Bytes Required Cover Tamper Header	12
Number of Bytes Required Cover Tamper Data	1100
Number of Bytes Required Neutral Missing Tamper Header	12
Number of Bytes Required Neutral Missing Tamper Data	1100
Number of bytes required by Load profile	25938
Total number in Bytes	37512
Total number in Kbytes	36.633

4.9.5 State Machines / Control Charts

Following figure describes the state diagram of Database Communication on EEPROM.
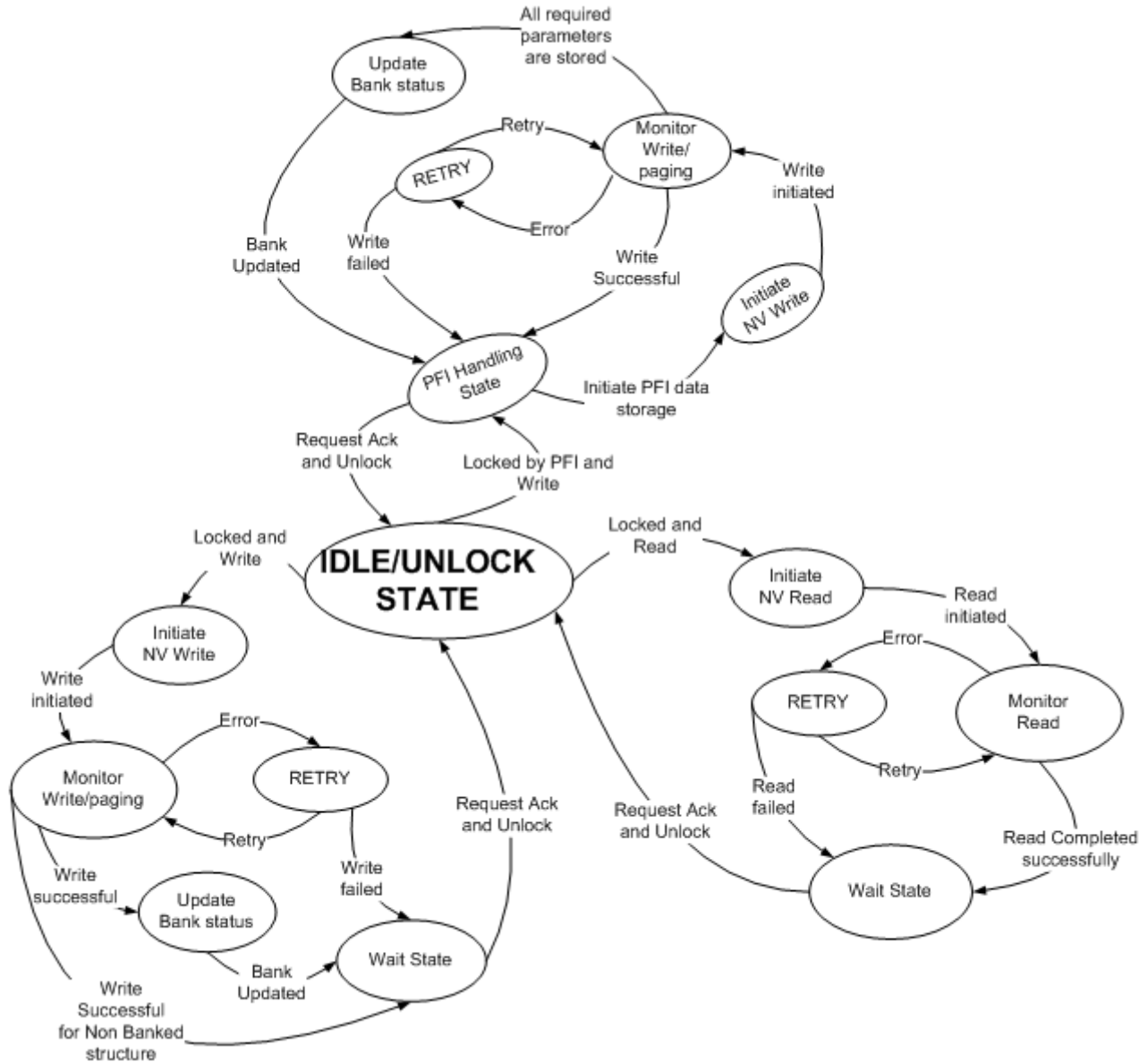
Figure 4-17. State diagram of database communication on EEPROM

Events	Descriptions
Locked and Write	Event indicates any one of Metering, Init Database, Communication or User interface has locked the database module for writing data to nonvolatile memory
Locked and Read	Event indicates any one of Metering, Init Database, Communication or User interface has locked the database module for reading data to nonvolatile memory
Write Initiated	Event indicates to initiate writing corresponding data structure to nonvolatile memory.
Read Initiated	Event indicates to initiate reading of corresponding data structure from nonvolatile memory.
Error	Event indicates error happened during write/read operation and need to retry
Retry	Event indicates the retry of the write/read operation has been started
Write Failed	Event indicates write operation has been failed even after maximum number of retries.
Read Failed	Event indicates read operation has been failed even after maximum number of retries.

Table continues on the next page...

Events	Descriptions
Write Successful	Write operation of banked structure is successfully over and bank status has to be updated
Read Successful	Read operation is successfully over release of database module has to be done
Write Successful for non-banked structure	Write operation of non banked structure is successfully over and release of database module has to be done
Bank Updated	Bank status structure is updated for corresponding banked structure and written into nonvolatile memory.
Request ACK and UnLock	Indicates respective module that write/read operation done and request to release database module

4.9.6 Maximum demand

Maximum Demand Register
- Meter will record the Maximum Demand (kW MD) with time stamp in non-volatile memory.
- Maximum demand will be calculated from accumulated imported/exported Active energy for MD interval.
- Maximum Demand and Cumulative Energy for previous six months will be stored in EEPROM
- Configurable MD integration time – 30 and 60 minutes

Maximum Demand Calculation – Fixed Window Method
- At the end of each fixed integration period, average power for that period is calculated. If this value is greater than the already existing MD value then this is stored as new MD.
- MD value is cleared in NV memory whenever there is change in date, time or MD integration period.

MD Reset
- MD reset by serial communication (optical port). All the MD parameters will be cleared in NV memory.
- MD can be read through serial communication (optical port) with the help of AMR protocol utility.

MD parameters stored in NV memory

Following parameters are stored in non-volatile memory:
- Maximum Demand (kW)
- MD Date and Time

4.9.7 Load profile

- Meter shall maintain Load profile data in non-volatile memory as per load profile interval time in circular buffer.
- Load profile parameters for each record
  - Exported kWh for interval period
- Load Profile will only be saved for the last 45 days on FIFO basis.
- Load profile records cleared through serial communication (optical port) with the help of In Term utility.
- Load profile records can be read through serial communication (optical port) with the help of AMR protocol utility.
- Load profile of the day on which the Meter was powered off will not be recorded. For example Let's assume Load Profile Interval-60 min Meter was powered on for duration in which load profile event storage is triggered on 22nd Nov 2012 and 24th Nov 2012 but it was powered off for whole day on 23rd Nov 2012. Then load profile will not be stored for 23rd November 2012.

NOTE
Note: EEPROM Size = 64 Kbytes

Load profile in EEPROM will be stored like shown in the following table:

Table 4-9. Load profile of EEPROM

Day 1(Date)	Day 2 (Date)	Day ...	Day ...	Day 45(Date)
LP 00:00 to 01:00	LP 00:00 to 01:00	—	—	LP 00:00 to 01:00
LP 01:00 to 02:00	LP 01:00 to 02:00	—	—	LP 01:00 to 02:00
LP 02:00 to 03:00	LP 02:00 to 03:00	—	—	LP 02:00 to 03:00
LP 03:00 to 04:00	LP 03:00 to 04:00	—	—	LP 03:00 to 04:00
LP 04:00 to 05:00	LP 04:00 to 05:00	—	—	LP 04:00 to 05:00
LP 05:00 to 06:00	LP 05:00 to 06:00	—	—	LP 05:00 to 06:00
LP 06:00 to 07:00	LP 06:00 to 07:00	—	—	LP 06:00 to 07:00
LP 07:00 to 08:00	LP 07:00 to 08:00	—	—	LP 07:00 to 08:00
LP 08:00 to 09:00	LP 08:00 to 09:00	—	—	LP 08:00 to 09:00
LP 09:00 to 10:00	LP 09:00 to 10:00	—	—	LP 09:00 to 10:00
LP 10:00 to 11:00	LP 10:00 to 11:00	—	—	LP 10:00 to 11:00
LP 11:00 to 12:00	LP 11:00 to 12:00	—	—	LP 11:00 to 12:00
LP 12:00 to 13:00	LP 12:00 to 13:00	—	—	LP 12:00 to 13:00
LP 13:00 to 14:00	LP 13:00 to 14:00	—	—	LP 13:00 to 14:00
LP 14:00 to 15:00	LP 14:00 to 15:00	—	—	LP 14:00 to 15:00
LP 15:00 to 16:00	LP 15:00 to 16:00	—	—	LP 15:00 to 16:00
LP 16:00 to 17:00	LP 16:00 to 17:00	—	—	LP 16:00 to 17:00
LP 17:00 to 18:00	LP 17:00 to 18:00	—	—	LP 17:00 to 18:00
LP 18:00 to 19:00	LP 18:00 to 19:00	—	—	LP 18:00 to 19:00

Table continues on the next page...

Table 4-9. Load profile of EEPROM (continued)

Day 1(Date)	Day 2 (Date)	Day ...	Day …	Day 45(Date)
LP 19:00 to 20:00	LP 19:00 to 20:00	—	—	LP 19:00 to 20:00
LP 20:00 to 21:00	LP 20:00 to 21:00	—	—	LP 20:00 to 21:00
LP 21:00 to 22:00	LP 21:00 to 22:00	—	—	LP 21:00 to 22:00
LP 22:00 to 23:00	LP 22:00 to 23:00	—	—	LP 22:00 to 23:00
LP 23:00 to 00:00	LP 23:00 to 00:00	—	—	LP 23:00 to 00:00

Number of Load profile entries for 45 days depending on the load profile interval is given in the following table:

Load Profile Interval	Number of Entries in a day	Total Entries for 45 days
15 min	96	4320
30 min	48	2160
60 min	24	1080

Chapter 5
Revision history

5.1   Revision history

Revision number	Date	Substantial changes
0	06/2015	Initial release

Appendix A
Schematic
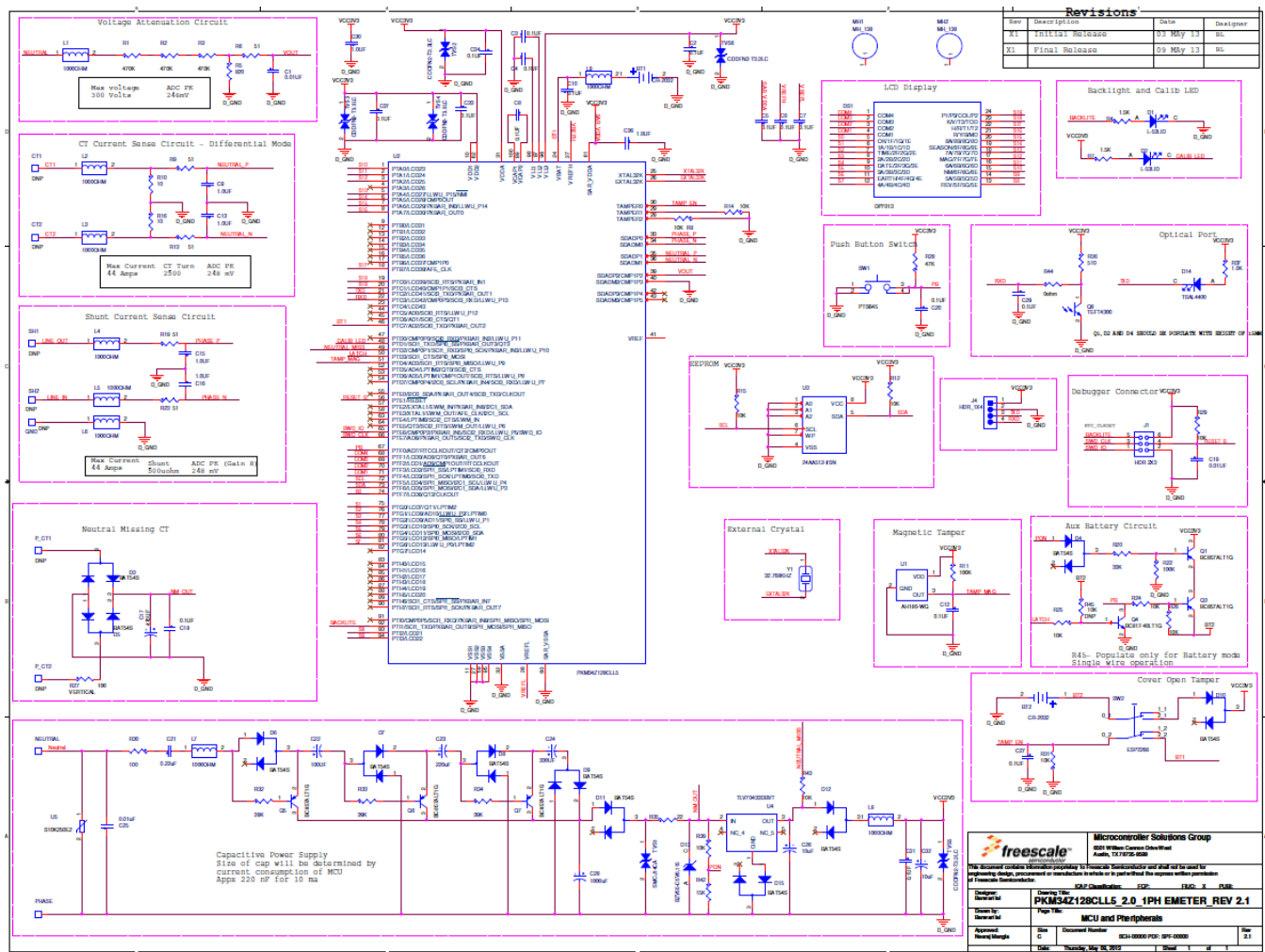
Figure A-1. Schematic

Appendix B
Bill of materials

Table B-1. Bill of matirial

Item	Quantity	AgilePN	ASSY_OPT	Reference	Value	Description	ASSY_NOTE	Mfg Name	Mfg Part Number	PCB Footprint
1	2	801-76144	—	BT1,BT2	CR-2032	BATTERY LITHIUM COIN CELL 3V TH	—	PANASONIC	CR-2032/VCN	bat_2032_th
2	7	210-79145	DNP	SH1,P_CT1,CT1,SH2,P_CT2,CT2,GND	TP	TEST POINT PIN 0.062X0.086 TH, NO PART TO ORDER	—	N/A	N/A	tp_062_086mil_th
3	2	150-76752	—	C1,C19	0.01 µF	CAP CER 0.01 µF 250V 10% X7R 0805	—	KEMET	C0805C103KARACTU	CC0805_OV
4	17	150-75599	—	C2,C3,C4,C5,C6,C7,C8,C10,C12,C18,C20,C27,C29,C31,C33,C34,C37	0.1 µF	CAP CER 0.1 µF 25V 10% X7R 0805	—	PANASONIC-ECG	ECJ-2VB1E104K	CC0805_OV
5	6	150-75594	—	C9,C13,C15,C16,C30,C36	1.0 µF	CAP CER 1.0 µF 10V 10% X7R 0805	—	SMEC	MCCB105K2NRTF	CC0805_OV
6	1	150-30192	—	C17	470 µF	CAP ALEL 470 µF 35V 20% -- RADIAL	—	Nichicon	UPW1V471MPD	c413_rad_pol
7	1	150-78638	—	C21	0.22 µF	CAP METPLY 0.22 µF 250VAC 10% -- RADIAL	—	PANASONIC	ECQU2A224KLA	cr709_335

Table continues on the next page...

Table B-1. Bill of matirial (continued)

Item	Quantity	AgilePN	ASSY_OPT	Reference	Value	Description	ASSY_NOTE	Mfg Name	Mfg Part Number	PCB Footprint
8	1	150-77050	—	C22	100 µF	CAP ALEL 100 µF 10V 20% -- TH RADIAL	—	PANASONIC	ECA1AM101I	cap_rad_6p3mm_7mm
9	1	150-78780	—	C23	220 µF	CAP ALEL 220 µF 16V 20% -- RADIAL	—	LELON ELECTRONICS CORP	REA221M1CTAF0611	CAP_RAD_6P3_11MM
10	1	150-30094	—	C24	330 µF	CAP ALEL 330 µF 25V 20% -- RADIAL	—	PANASONIC	ECA1EM331	C335_RAD
11	1	150-78705	—	C25	0.01 µF	CAP CER 0.01 µF 2000V 20% Z5U RADIAL	—	VISHAY INTERTECHNOLOGY	S103M69Z5UP63K7R	cr690_160
12	2	150-75661	—	C26,C32	10 µF	CAP ALEL 10 µF 16V 20% -- RADIAL	—	NICHICON	UVR1C100MDD	c079_rad_pol
13	1	150-76873	—	C28	1000 µF	CAP ALEL 1000 µF 10V 20% -- TH RADIAL	—	PANASONIC	ECA1AM102	c197_rad_pol
14	1	370-76530	<ASSY_OPT>	DS1	DP7013	LCD TN DISPLAY 3V 24 PIN TH	—	DEEPAKSHI DISPLAY DEVICES PVT. LTD	DP7013	lcd_24_2p_th
15	1	370-76510	DNP	D1	L-53LID	LED RED SGL 2MA TH	—	KINGBRIGHT	L-53LID	led_2_6
16	1	370-76510	—	D2	L-53LID	LED RED SGL 2MA TH	—	KINGBRIGHT	L-53LID	led_2_6
17	11	480-75079	—	D3,D4,D5,D6,D7,D8,D9,D10,D11,D12,D15	BAT54S	DIODE DUAL SCH 200MA 30V SOT23	—	FAIRCHILD	BAT54S	SOT-23
18	1	480-78316	—	D13	BZV55-C5V6,115	DIODE ZNR 5.6V 500MW SOD80C	—	NXP Semiconductors	BZV55-C5V6,115	sod80c

Table continues on the next page...

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

Freescale Semiconductor, Inc.

Table B-1. Bill of matirial (continued)

Item	Quantity	AgilePN	ASSY_OPT	Reference	Value	Description	ASSY_NOTE	Mfg Name	Mfg Part Number	PCB Footprint
19	1	370-76502	—	D14	TSAL4400	LED IR SGL 100MA TH	—	VISHAY INTERTECHNOLOGY	TSAL4400	led2_100_3_th
20	1	210-77295	—	J1	HDR 2X3	HDR 2X3 TH 2.54MM SP 340H AU 118L	—	HARWIN INC	M20-9980345	hdr203_m20
21	1	210-75688	FEMALE PART	J4	HDR_1X4	HDR 1X4 TH 100MIL SP 336H AU 100L	—	SAMTEC	TSW-104-07-G-S	JUMP1X4-6040
22	9	TMP-WF-18038	—	L1,L2,L3,L4,L5,L6,L7,L8,L9	1000OHM	IND FER BEAD 1000OHM @100MHZ 1.5A 25% 0805	—	TDK	MPZ2012S102A	IND_0805
23	2	280-76769	—	MH1,MH2	MH_138	MOUNTING HOLE NON-PLATED 3.5MM DRILL 3.5MM TH NO PART TO ORDER	—	NO PART TO ORDER	NO PART TO ORDER	c138-138n
24	2	210-79145	—	PHASE,NEUTRAL	TP	TEST POINT PIN 0.062X0.086 TH, NO PART TO ORDER	—	N/A	N/A	tp_062_086mil_th
25	5	480-75150	—	Q1,Q3,Q5,Q6,Q7	BC857ALT1G	TRAN PNP GEN 45V 100MA SOT-23	—	ON SEMICONDUCTOR	BC857ALT1G	SOT-23
26	1	480-75158	—	Q4	BC817-40LT1G	TRAN NPN GEN 45V 0.5A SOT-23	—	ON SEMICONDUCTOR	BC817-40LT1G	SOT23
27	1	480-78124	—	Q8	TEFT4300	TRAN NPN PHOTO 50MA 70V TH	—	VISHAY INTERTECHNOLOGY	TEFT4300	tran2_100_th

Table continues on the next page...

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

Table B-1. Bill of matirial (continued)

Item	Quantity	AgilePN	ASSY_OPT	Reference	Value	Description	ASSY_NOTE	Mfg Name	Mfg Part Number	PCB Footprint
28	3	470-80010	—	R1,R2,R3	470 K	RES MF 470K 1/8W 1% 0805	—	ROhm	MCR10EZPF4703	RC0805_OV
29	2	470-75955	—	R4,R7	1.5 K	RES MF 1.5K 1/8W 1% 0805	—	BOURNS	CR0805-FX-1501ELF	RC0805_OV
30	1	470-30042	—	R5	820	RES MF 820 OHM 1/8W 5% 0805	—	BOURNS	CR0805-JW-821ELF	RC0805_OV
31	5	470-78920	—	R6,R9,R13,R19,R23	51	RES MF 51 OHM 1/8W 1% 0805	—	YAGEO AMERICA	RC0805FR-0751RL	RC0805_OV
32	11	470-75904	—	R8,R12,R14,R15,R24,R25,R26,R29,R31,R39,R43	10 K	RES MF 10K 1/8W 5% 0805	—	Yageo	RC0805JR-0710KL	RC0805_OV
33	2	470-75903	—	R10,R16	10	RES MF 10.0 OHM 1/8W 1% 0805	—	BOURNS	CR0805-FX-10R0ELF	RC0805_OV
34	1	470-75462	—	R11	100 K	RES MF 100K 1/8W 1% 0805	—	VENKEL COMPANY	CR0805-8W-1003FSNT	RC0805_OV
35	1	470-75500	—	R20	33 K	RES MF 33K 1/8W 5% 0805	—	BOURNS	CR0805-JW-333ELF	RC0805_OV
36	1	470-75577	—	R22	100 K	RES MF 100K 1/8W 5% 0805	—	BOURNS	CR0805-JW-104ELF	RC0805_OV
37	1	470-80198	VERTICAL	R27	100	RES MF 100 OHM 2W 5% AXL	—	YAGEO AMERICA	FMP200JR-52-100R	r355_axl
38	1	470-75569	—	R28	47 K	RES MF 47.0K 1/8W 1% 0805	—	BOURNS	CR0805-FX-4702ELF	RC0805_OV
39	1	470-80463	—	R30	100	RES MF 100 OHM 2W 5% AXL	—	YAGEO AMERICA	FMP200JR-52-100R	res_pr03_axial_th_vert

Table continues on the next page...

Table B-1. Bill of matirial (continued)

Item	Quantity	AgilePN	ASSY_OPT	Reference	Value	Description	ASSY_NOTE	Mfg Name	Mfg Part Number	PCB Footprint
40	3	470-80220	—	R32,R33,R34	39 K	RES MF 39K 1/8W 1% 0805	—	VISHAY INTERTECHNOLOGY	CRCW0805 39K0FKEA	RC0805_OV
41	1	470-75937	—	R35	22	RES MF 22 OHM 1/8W 5% 0805	—	BOURNS	CR0805-JW-220ELF	RC0805_OV
42	1	470-30372	—	R36	510	RES MF 510 OHM 1/10W 1% 0805	—	SMEC	RC73A2A5100FTF	RC0805_OV
43	1	470-75989	—	R37	1.0 K	RES MF 1.0K 1/8W 5% 0805	—	ROHM	MCR10EZPJ102	RC0805_OV
44	1	470-75585	—	R42	15 K	RES MF 15K 1/8W 5% 0805	—	BOURNS	CR0805JW153ELF	RC0805_OV
45	1	470-76111	—	R44	0 Ω	RES 0.0 OHM 1/8W 5% 0805 SMD	—	YAGEO (VA) V	RC0805JR-070RL	RC0805_OV
46	1	470-75904	DNP	R45	10 K	RES MF 10K 1/8W 5% 0805	—	Yageo	RC0805JR-0710KL	RC0805_OV
47	1	510-75922	—	SW1	PTS645	SW SPST MOM NO PB 12V 50MA SMT	—	ITT CANNON	PTS645SL50SMTRLFS	sw4_pb_6x6_sm
48	1	510-77868	—	SW2	ESP2266	SW DPDT PB 30V 0.1A TH NON ROHS COMPLIANT	—	ELCON (INDIA)	ESP2266	sw6_pb_th_esp2266
49	1	TMP-WF-18040	—	TVS1	SMCJ14CA	DIODE TVS 14V 1500W BIDIR 5% SMC	—	LITTELFUSE	SMCJ14CA	do-214ab
50	5	TMP-WF-18039	—	TVS2,TVS3,TVS4,TVS5,TVS6	CDDFN2-T3.3LC	DIODE TVS BIDIR 3.3V 5A SMD	—	Bourns	CDDFN2-T3.3LC	dfn2_0p85_1x0p6
51	1	315-79304	—	U1	AH180-WG	IC SW SENSOR OMNIPOL	—	DIODES INC	AH180-WG-7	sc59

Table continues on the next page...

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

Table B-1.   Bill of matirial (continued)

Item	Quantity	AgilePN	ASSY_OPT	Reference	Value	Description	ASSY_NOTE	Mfg Name	Mfg Part Number	PCB Footprint
						AR HALL-EFFECT 2.5-5.5V SC59				
52	1	TMP-WF-16914	—	U2	PKM34Z128CLL5	IC MCU FLASH 128K 16K 50MHZ 1.71-3.6V LQFP100	—	FREESCALE SEMICONDUCTOR	PKM34Z128CLL5	LQFP100_0P5_14X14
53	1	TMP-WF-17901	—	U3	24AA512-I/SN	IC MEM EEPROM 512K 400KHZ 1.7-5.5V SOIC8	—	Microchip Technology	24AA512-I/SN	so8_1p27_4x5
54	1	315-79519	—	U4	TLV70433DBVT	IC VREG LDO 3.3V 150MA 2.5-24V SOT23-5	—	TEXAS INSTRUMENTS	TLV70433DBVT	SOT-23-5
55	1	470-79747	—	U5	S10K250E2	VARISTOR 250VRMS 10% 0.4W RADIAL	—	EPCOS	B72210S2251K101	varistor_12x5p2mm
56	1	230-76376	—	Y1	32.768 KHZ	XTAL 32.768KHZ -- SMT	—	EPSON ELECTRONICS	FC-145 32.7680KA-A3	xtal_4_1x1_5mm_2p

Kinetis M Family Single-Phase Energy Meter Design Reference Manual, Rev. 0, 06/2014

Appendix C
Connection diagram

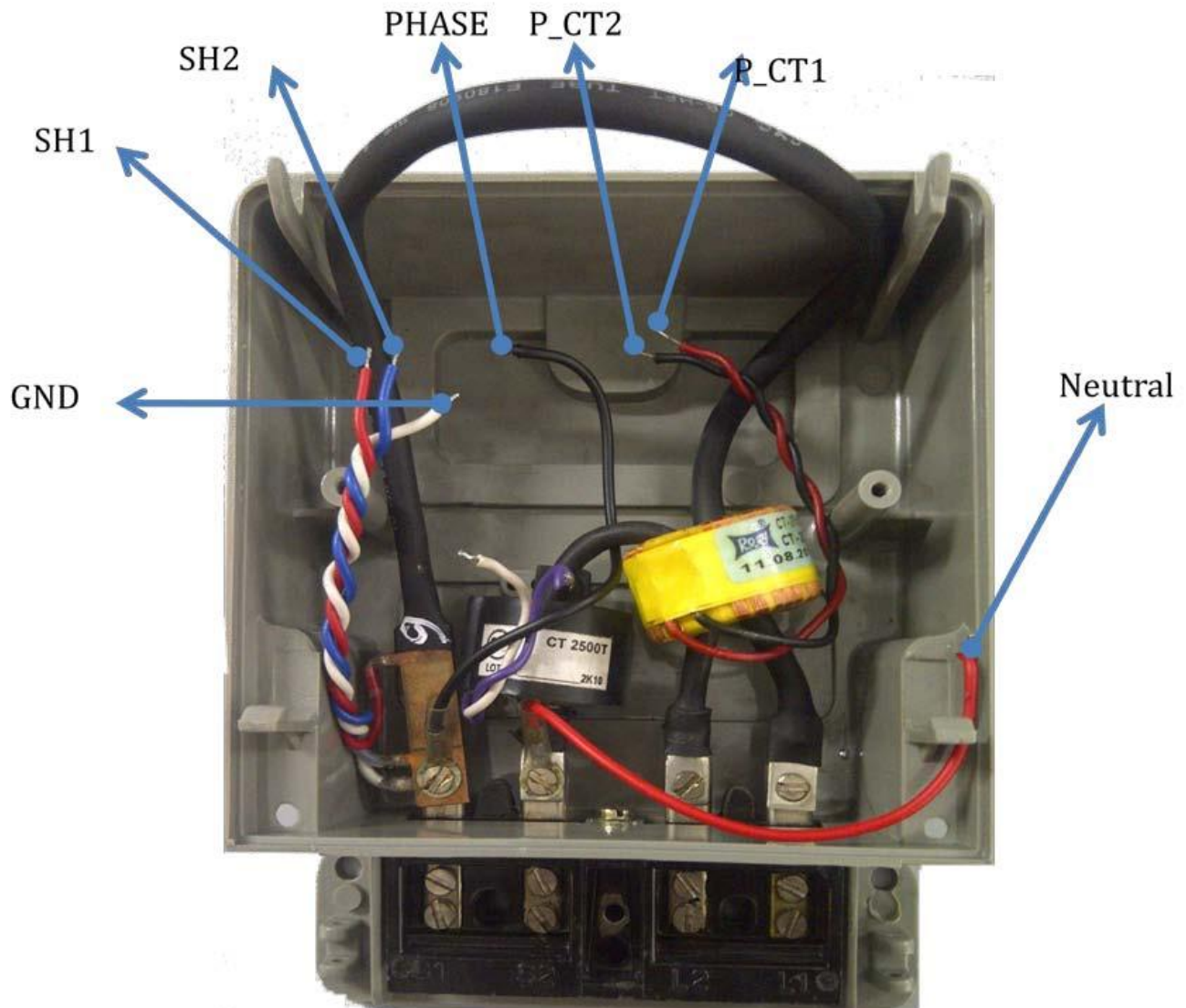Please refer following picture of the enclosure
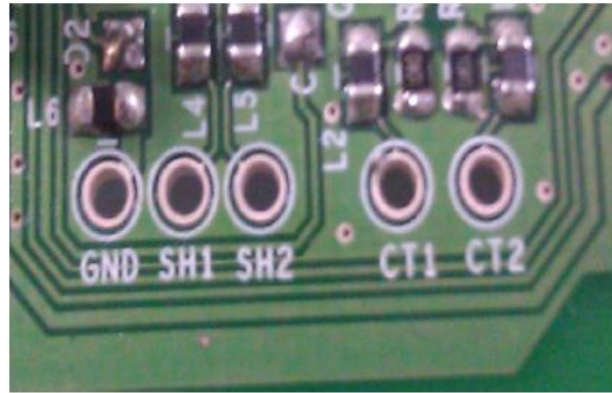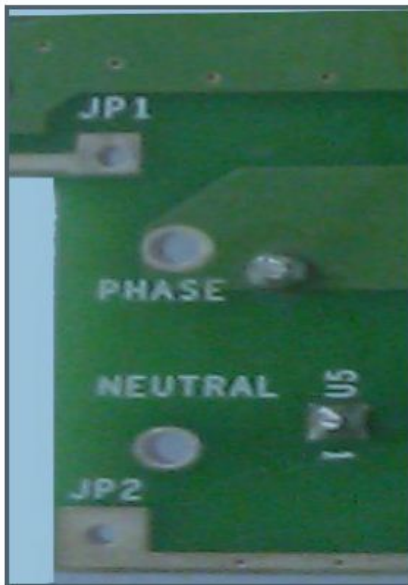

Figure C-1. Connection diagram

Figure C-2. Connection diagram

How to Reach Us:

Home Page:
freescale.com

Web Support:
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.

Freescale, the Freescale logo, Energy Efficient Solutions logo, and Kinetis 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. ARM and Cortex are registered trademarks of ARM Limited (or its subsidiaries) in the EU and/or elsewhere. All rights reserved.

© 2014 Freescale Semiconductor, Inc.