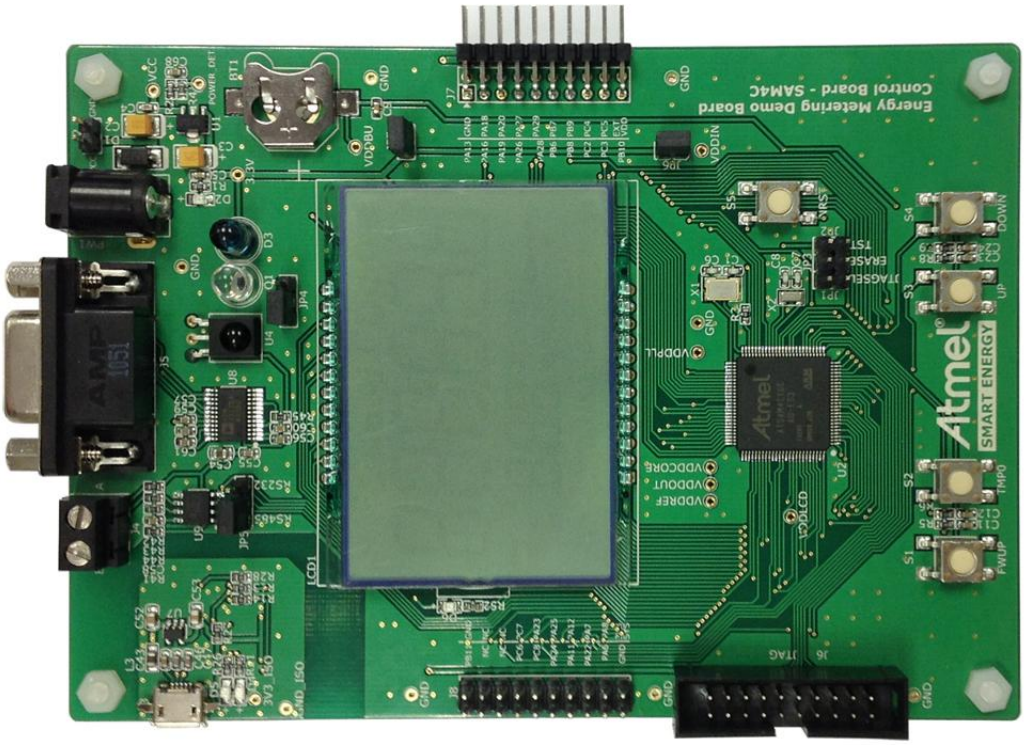
USER GUIDE

AFE Control Board-SAM4C Firmware



Preface

AFE Control Board-SAM4C is the control board in Atmel Metering Demo Kit. The kit also includes the daughter board: either ATM90E25 or ATM90E3x demo board. The AFE Control Board-SAM4C communicates with and controls the daughter boards, providing ease access to evaluate the energy metering chips.

Supported by the IAR integrated development platform, the AFE Control Board-SAM4C also provides easy access to the features of the Atmel ATSAM4C and explains how to integrate ATSAM4C in a customer design.

The AFE Control Board-SAM4C evaluation kit includes an SAM-ICE debug tool and AC-DC adapter. It also provides the extended interface for customized applications.

Table of Contents

1. Introduction

1.1 Features

- State machine mechanism. Different states are interchangeable
- Modular design. Modules are independent from each other
- Functions divided by tasks. Each task focuses on one single kind of function
- Three types of trigger: timer, interrupt and event
- FIFO used for storage
- Modular data structure

1.2 Kit Overview

This evaluation firmware is used for the Atmel Metering Demo Kit (including the AFE Control Board-SAM4C and ATM90E25 or ATM90E3x demo board), which can fulfill mutliple tasks such as control of the AFE board, energy metering, measurement of voltage, current and so on, data display on LCD, storage of energy data in EEPROM and communication with external terminals. The firmware can automatically identify the daughter board of ATM90E25 and ATM90E3x, and adjust the configuration accordingly.

The evaluation firmware is just an independent reference program. Users can run it directly or develop their own program based on it.

2. Design Environment

There are two kinds of design environment:

- IAR Embedded Workbench 6.5 for ARM. This is a commercial C/C++ compiler for ARM.
- Atmel Studio. This is the free Atmel IDE for development of C/C++ and assembler code for Atmel microcontrollers.

2.1 Getting Started

There are four steps to run the evaluation firmware:

- Download and install IAR Embedded Workbench firmware
- Connect SAM-ICE to the JTAG port of the AFE Control Board-SAM4C
- Run IAR firmware
- Download the hex file of the AFE Control Board-SAM4C

2.2 Design Documentation

The following list contains the related documents:

1. ATSAM4C Datasheet – PDF version
2. IAR Embedded Workbench for ARM
3. AFE Control Board-SAM4C User Guide – PDF version of this user guide
4. 90E25 Demo Board User Guide – PDF version
5. 90E3x Demo Board User Guide – PDF version

3. Firmware User Guide

3.1 Initialization

The initialization process starts when power up. Figure 3-1 shows the detailed flow.

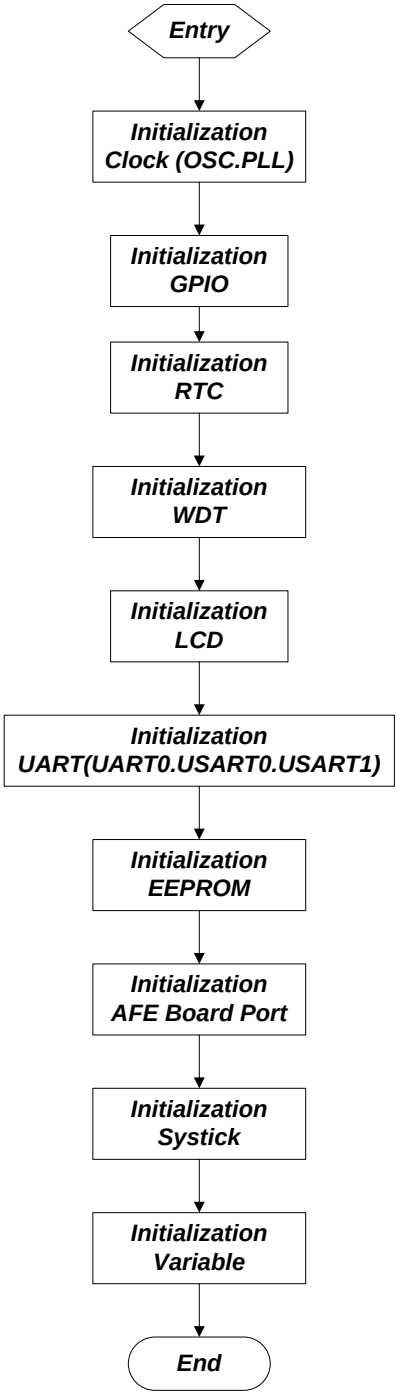


Figure 3-1 Initialization Flow Chart

3.2 Work Mode

There are altogether 4 work modes as shown in Table 3-1 and Figure 3-2.

Table 3-1 Work Mode

Work Mode	Entry	Exit	Operation
Normal Mode	power up	power down or abnormal event	perform tasks such as communication, energy metering and display.
Battery Mode	power down or LCD Mode timeout	wake up or power up or abnormal event	keep RTC running; respond to wake up signal
LCD Mode	wake up from Battery Mode	timeout or abnormal event	display data when no power
Restart Mode	abnormal event	-	reset SAM4C

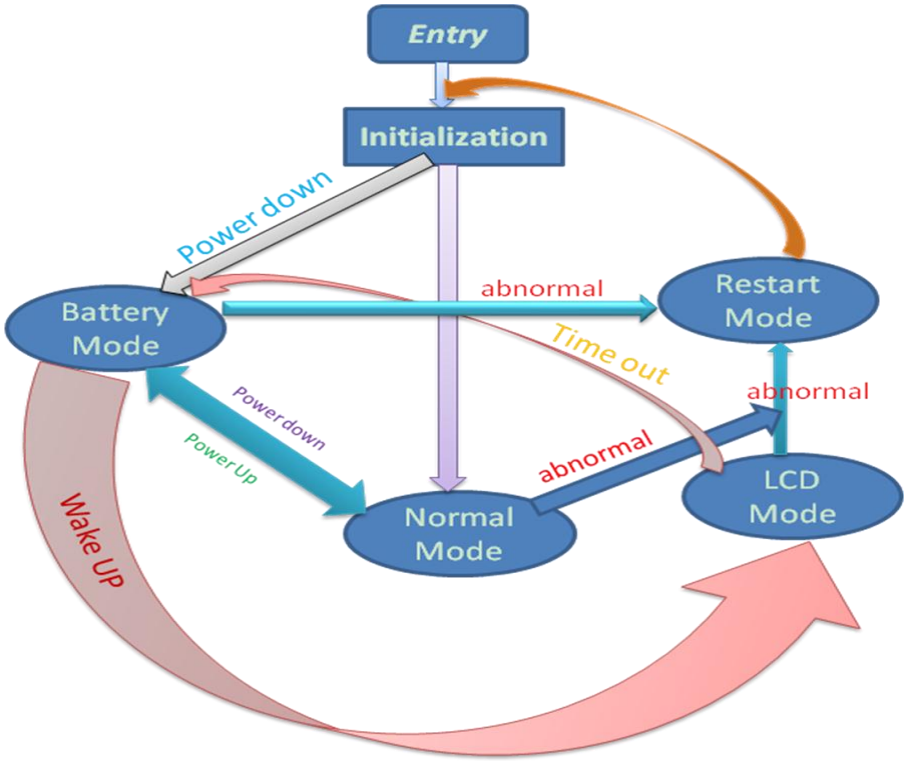


Figure 3-2 Work Mode Transition

3.2.1 Normal Mode

The AFE Control Board works in Normal Mode after normal power up. All tasks can be completed in this mode. Table 3-2 shows the complete list of tasks and Figure 3-3 shows the flow chart in Normal Mode.

Table 3-2 Task Definition

Task Name	Task ID	Description
Read RTC	1	Read Real Time Clock in SAM4C. Executed once every 500ms
1s Process	2	Measure RMS of the AFE daughter board. Executed once every 1s
Scroll Display	4	Scroll display once every 500ms
Scroll Display Number	5	Scroll the display number when the current display is time out or the display button is pressed
USB Command Process	7	Process the command received from the USB COM port
USB Transmit	8	Transmit data through the USB COM port
IR Command process	9	Process the command received from the IR COM port
IR Transmit	10	Transmit data through the IR COM port
RS485 Command process	13	Process the command received from the RS485 COM port
RS485 Transmit	14	Transmit data through the RS485 COM port
Check Major Parameter	16	Check major parameters for the system. Executed once every 1 minute
Pulse Process	17	Process when receiving energy pulse from the AFE daughter board
Energy Process	18	Process when energy is accumulated to a certain amount
Load Calibration Parameter	20	Load calibration parameter from EEPROM to the AFE daughter board when power up

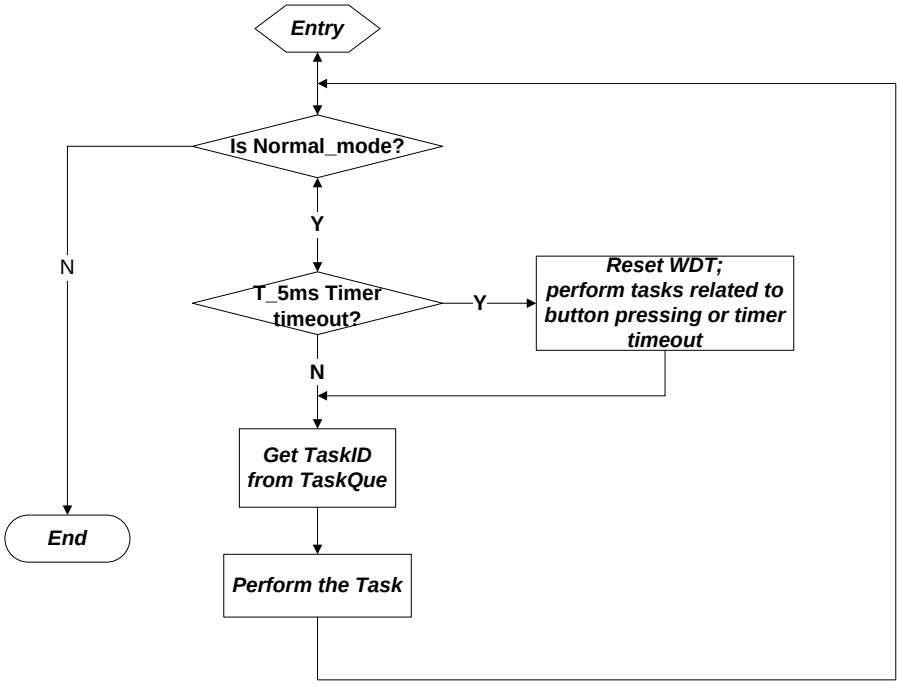


Figure 3-3 Normal Mode Flow Chart

3.2.1.1 5ms Timer

The following tasks will be performed upon the timeout of the 5ms timer:

- Reset watch dog
- Perform the task related to any button pressing
- Perform the task related to timeout of any timer. Table 3-3 shows different timers and Figure 3-4 shows the timer process flow chart.

Table 3-3 Timer

Timer Name	Type	Source	Timeout	Description
T_5ms	increase	SysTick	1	SysTick generates an interrupt every 5ms.
RS485_overtimer	increase	T_5ms	60	Configure RS485 when the timer is time out. The timer resets when overflow or when one byte is received/ transmitted.
IR_overtimer	increase	T_5ms	60	Configure IR when the timer is time out. The timer resets when overflow or when one byte is received/ transmitted.
USB_overtimer	increase	T_5ms	60	Configure USB when the timer is time out. The timer resets when overflow or when one byte is received/ transmitted.
T_500ms	increase	T_5ms	100	May be used as the source for the other timers and trigger tasks such as read RTC and scroll display. The timer resets when overflow.
T_1s	increase	T_5ms	200	Calculate RMS when the timer is time out. The timer resets when overflow.
T_1Min	increase	T_1s	60	Check important parameters such as energy and communication address when the timer is time out. The timer resets when overflow.

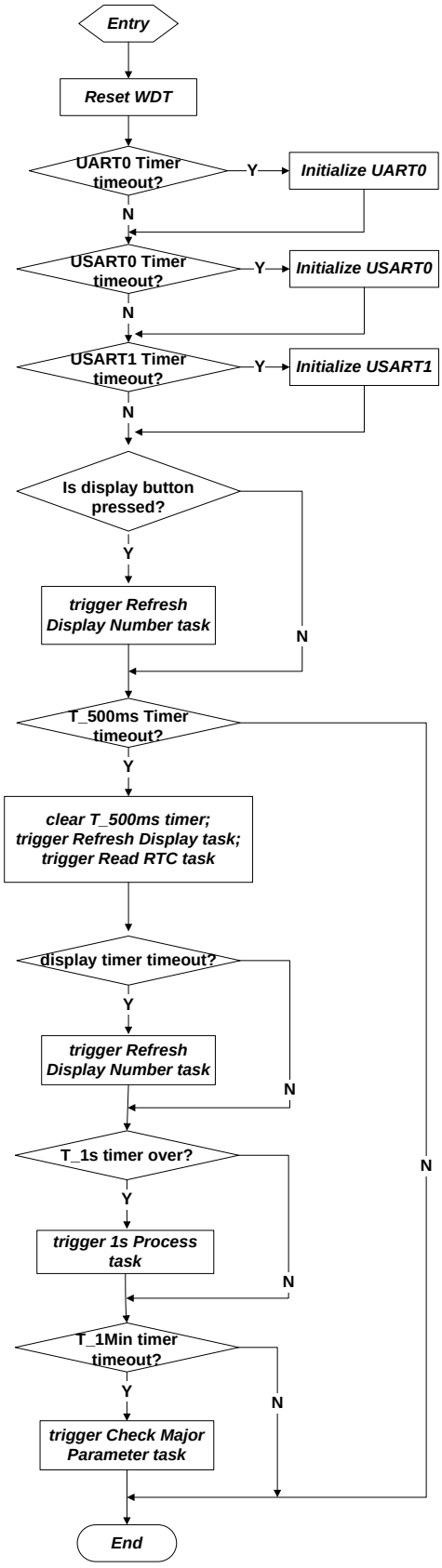


Figure 3-4 Timer Process Flow Chart

3.2.1.2 Read RTC

This task is to read data from RTC and store them in RAM. It executes every 500ms.

3.2.1.3 Scroll Display

There are two sources to trigger the Scroll Display task. One is the T_500ms timer, the other is the Scroll Display Number task. This task uses the display number as the index, and sends the corresponding data to the LCD panel. Table 3-4 shows various options of the display content.

Table 3-4 Display Options

Serial No.	Display Content	Format	Parameters Set		Remark
			Byte	Bit	
FFF	display all		-	-	Display when power on
254	firmware version	Ux.xx	-	-	Display when power on
000	AFE types	90Exxx	-	-	Fixed display
001	phase A Vrms	XXX.XX	byte0	bit0	Configurable
002	phase B Vrms	XXX.XX		bit1	Configurable
003	phase C Vrms	XXX.XX		bit2	Configurable
004	phase A Irms	XXX.XXX		bit3	Configurable
005	phase B Irms	XXX.XXX		bit4	Configurable
006	phase C Irms	XXX.XXX		bit5	Configurable
007	total active power	XX.XXX		bit6	Configurable
008	phase A active power	XX.XXX		bit7	Configurable
009	phase B active power	XX.XXX	byte1	bit0	Configurable
010	phase C active power	XX.XXX		bit1	Configurable
011	Total reactive power	XX.XXX		bit2	Configurable
012	phase A reactive power	XX.XXX		bit3	Configurable
013	phase B reactive power	XX.XXX		bit4	Configurable
014	phase C reactive power	XX.XXX		bit5	Configurable
015	(arithmetic sum) Total apparent power	XX.XXX		bit6	Configurable
016	(vector sum) Total apparent power	XX.XXX		bit7	Configurable
017	phase A apparent power	XX.XXX	byte2	bit0	Configurable
018	phase B apparent power	XX.XXX		bit1	Configurable
019	phase C apparent power	XX.XXX		bit2	Configurable
020	total power factor	X.XXX		bit3	Configurable
021	phase A power factor	X.XXX		bit4	Configurable
022	phase B power factor	X.XXX		bit5	Configurable
023	phase C power factor	X.XXX		bit6	Configurable
024	frequency	XX.XX		bit7	Configurable
025	ConfigStart		byte3	bit0	Configurable
026	CalStart			bit1	Configurable
027	HarmStart			bit2	Configurable
028	AdjStart			bit3	Configurable
029	SysStatus0			bit4	Configurable
030	SysStatus1			bit5	Configurable
031	FuncEn0			bit6	Configurable

032	FuncEn1			bit7	Configurable
033	total energy	XXXX.XX	-	-	Fixed display
038	current time	XX:XX:XX	-	-	Fixed display
039	current date	XXXXX	-	-	Fixed display

3.2.1.4 Scroll Display Number

There are four sources to trigger the Scroll Display Number task: display timeout, display key pressed, write the meter address and modify RTC.

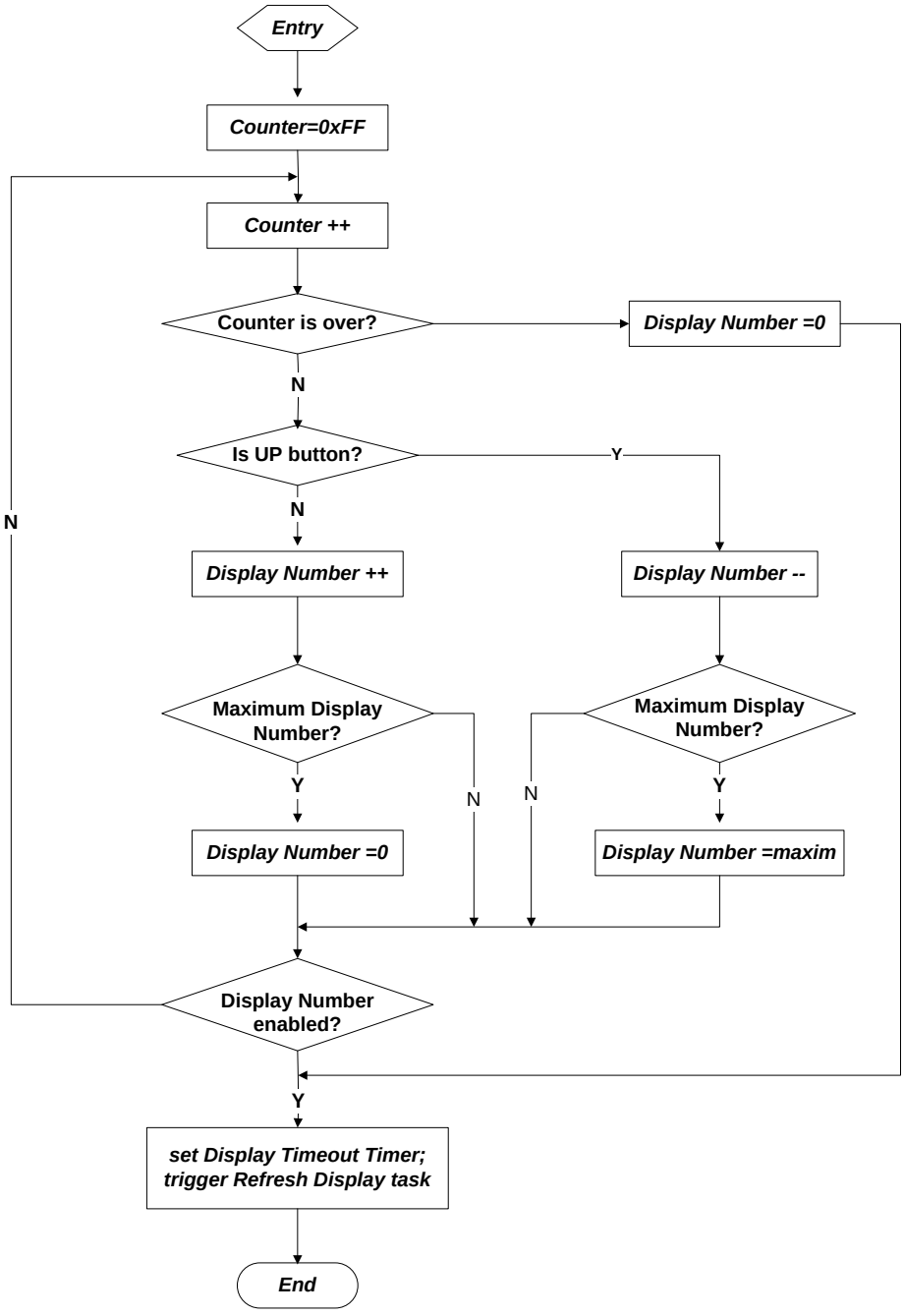


Figure 3-5 Scroll Display Number Flow Chart

3.2.1.5 1s Process

This task reads parameters such as voltage, current, power and so on from the AFE daughter board, and calculate the corresponding RMS for display and communication. This task executes once every second.

3.2.1.6 USB Command

This task is triggered by any USB command. The communication process function is called to analyze and process the USB command. The function needs the communication port ID as the input parameter. Table 3-5 lists all the communication ports.

Table 3-5 COM Port

Com Port Name	UART on SAM4C	COM ID	Baud Rate	Start Bit	Data Bit	Parity	Stop Bit
USB	UART0	0	115200	1	8	Event	1
RS485	USART0	3	4800				
IR	USART1	1	1200				

3.2.1.7 USB Transmit

This task is triggered when there is data to be transmitted following the above USB Command task. The communication transmit function is called to transmit the data stored in the buffer one by one. The function needs the communication port ID as the input parameter.

3.2.1.8 RS485 Command

This task is triggered by any RS485 command. The communication process function is called to analyze and process the RS485 command. The function needs the communication port ID as the input parameter.

3.2.1.9 RS485 Transmit

This task is triggered when there is data to be transmitted following the above RS485 Command task. The communication transmit function is called to transmit the data stored in the buffer one by one. The function needs the communication port ID as the input parameter.

3.2.1.10 IR Command

This task is triggered by any IR command. The communication process function is called to analyze and process the IR command. The function needs the communication port ID as the input parameter.

3.2.1.11 IR Transmit

This task is triggered when there is data to be transmitted following the above IR Command task. The communication transmit function is called to transmit the data stored in the buffer one by one. The function needs the communication port ID as the input parameter.

3.2.1.12 Check Major Parameter

The task is to check the major parameters. Details as follows:

- Read EEPROM to get communication address. Replace the communication address in RAM with the one from EEPROM if reading is successful.
- Read EEPROM to get the energy data. Replace the energy data in RAM with the one from EEPROM if reading is successful.

3.2.1.13 Pulse Process

This task is to accumulate energy pulses, trigger the Energy Process task and clear energy data when overflow.

3.2.1.14 Energy Process

This task is to accumulate energy.

3.2.1.15 Load Calibration Parameter

This task is to read out the calibration parameters from EEPROM, and writes them to the AFE chip on the AFE daughter board.

3.2.2 Battery Mode

Battery Mode is a low-power dissipation mode. Figure3-6 shows the flow chart.

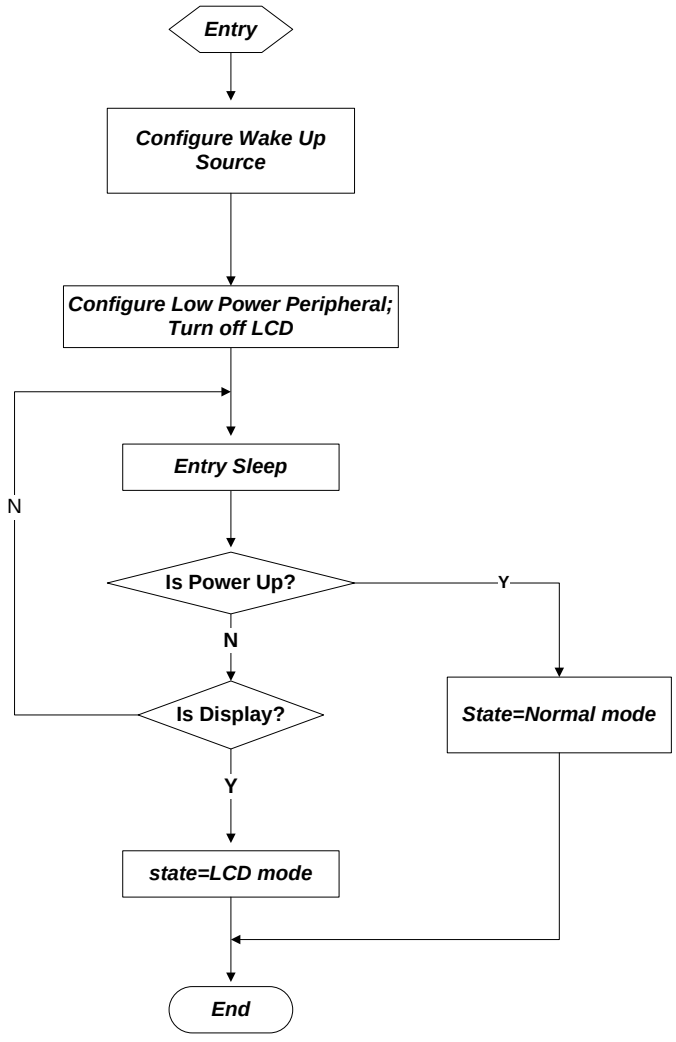


Figure 3-6 Battery Mode Flow Chart

3.2.3 LCD Mode

LCD Mode is a low-power dissipation mode. Figure3-7 shows the flow chart.

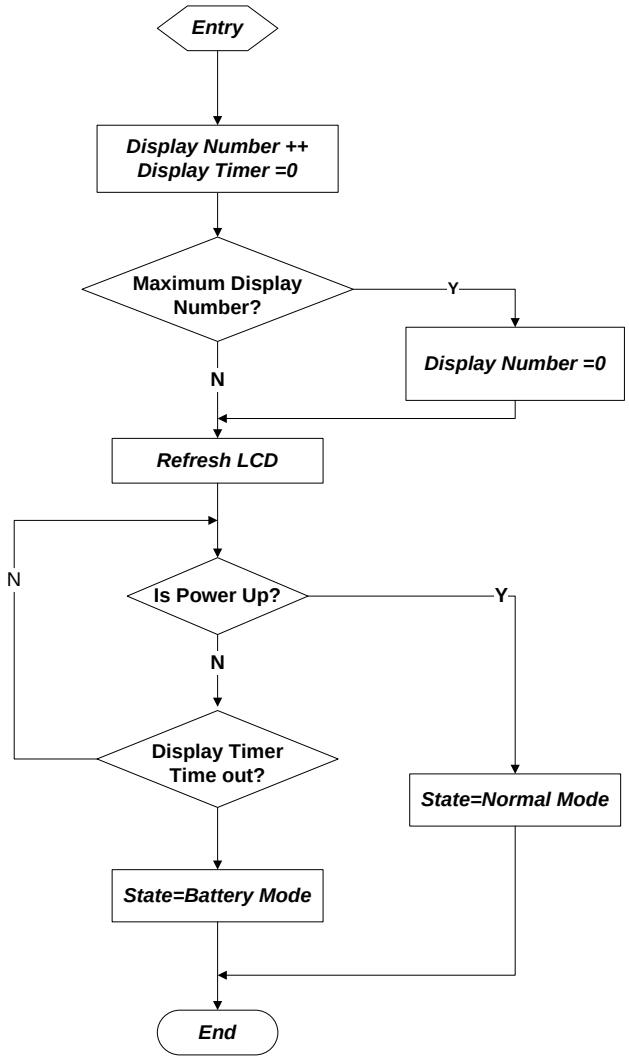


Figure 3-7 LCD Mode Flow Chart

3.2.4 Restart Mode

Restart Mode is entered when there is any abnormality. During restart, RTC can still work normally as RTC is powered by the backup battery through the VDDBU pin.

4. AFE-Related Operation Subroutine

void AFE_DMA_ENABLE (void);

void AFE_DMA_DISABLE (void);

void AFE_Normal_MODE (void);

void AFE_Patial_MODE (void);

void AFE_Detect_MODE (void);

void AFE_Idle_MODE (void);

```
void        SET_AFE_MODE ( AFE_MODE mode );
void        AFE_CS_ENABLE (void);
void        AFE_CS_DISABLE (void);
void        AFE_Configure_IRQ0 (void);
void        AFE_Configure_IRQ1 (void);
void        AFE_Configure_WarmOut (void);
void        AFE_SPI_Init (void);
void        Identify_AFE_Type (void);
uint32_t    Read_AFE_1Reg (uint16_t regaddr);
uint32_t    write_AFE_1Reg (uint16_t regaddr,uint16_t regdata);
uint32_t    CMD_Rd_AFE_Reg (uint8_t *ptr,uint16_t regadr);
uint32_t    CMD_Wr_AFE_Reg ( uint8_t *ptr,uint16_t regadr );
void        Sag_check ( void );
void        Enable_Harmonic_Calculate (void);
uint32_t    Rd_Measure_Parameter (uint16_t regh_addr,uint16_t regl_addr);
uint32_t    Calculate_V_I_Mul_Scal (uint32_t rmsval,uint16_t scale);
uint32_t    Calculate_V_I_RMS ( uint32_t *rmsptr,uint32_t rmsval);
void        Calculate_Power ( uint32_t *rmsptr,uint32_t rmsval );
void        Calculate_PowerFactor ( uint32_t *rmsptr,uint32_t rmsval );
uint32_t    Calculate_Frequency ( uint32_t *rmsptr,uint32_t rmsval );
uint32_t    Calculate_THDNx ( uint32_t *rmsptr,uint32_t rmsval );
void        Calculate_angle ( uint32_t *rmsptr,uint32_t rmsval );
uint32_t    Calculate_V_I_Peak ( uint32_t *rmsptr,uint32_t rmsval,uint32_t regid );
uint32_t    Calculate_I_V_HarmonicRatio ( uint16_t reg_addr );
float       Calculate_I_V_Fundamental ( uint16_t reg_addr,uint16_t scale );

uint32_t    Measure_RMS ( uint32_t *ptr,const RMS_TYPE rms_id );
void        Load_AFE_Cal_Para_From_Eprom (void);
```

5. Revision History

Doc. Rev.	Date	Comments
1.0	09/09/2013	Initial release.

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