RL78/L13

Mini Power Monitor

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Introduction

This document describes a Renesas microcontroller RL78/L13 application for a mini power monitor.

Target Device

RL78/L13

When applying the sample program covered in this document to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program.

Contents

1. Description

1.1 Abstract

The mini power monitor, described in this document, is a power meter allowing the user to accurately measure power consumption of electric appliances. The mini power monitor uses an RL78/L13 microcontroller, dedicated energy metering chip, high-precision current and voltage sampling circuit and an LCD to monitor a variety of electrical parameters of electric appliances. The device can measure the total electric energy consumption, active power, voltage, current, total elapsed time, frequency and CO_2 emission values of attached appliances and display these parameters by the LCD. The device can be used for home appliances like LED lamps, air conditioners, refrigerators, microwave ovens, etc. It can also be used as a measuring instrument in teaching.

1.2 Specifications and Main Technical Parameters

Technical Parameters

- Constant: 3200 imp/kWh
- Power dissipation: < 1W

Specifications

- Function: Monitor the active power, voltage, current and frequency.
  Record the total electricity and time consumption.
  Calculate CO_2 emissions.
  Detect power factor.
  Set the alarm threshold load.
  Display data on a LCD.
- Operating temperature: -10 °C ~ 60 °C
- Storage temperature: -20 °C ~ 70 °C

  Operating humidity: 5% RH ~ 99% RH

2. RL78/L13 Microcontroller

2.1 RL78/L13 Block Diagram

Figure 2.1 shows the block diagram of RL78/L13 (80-pin products).

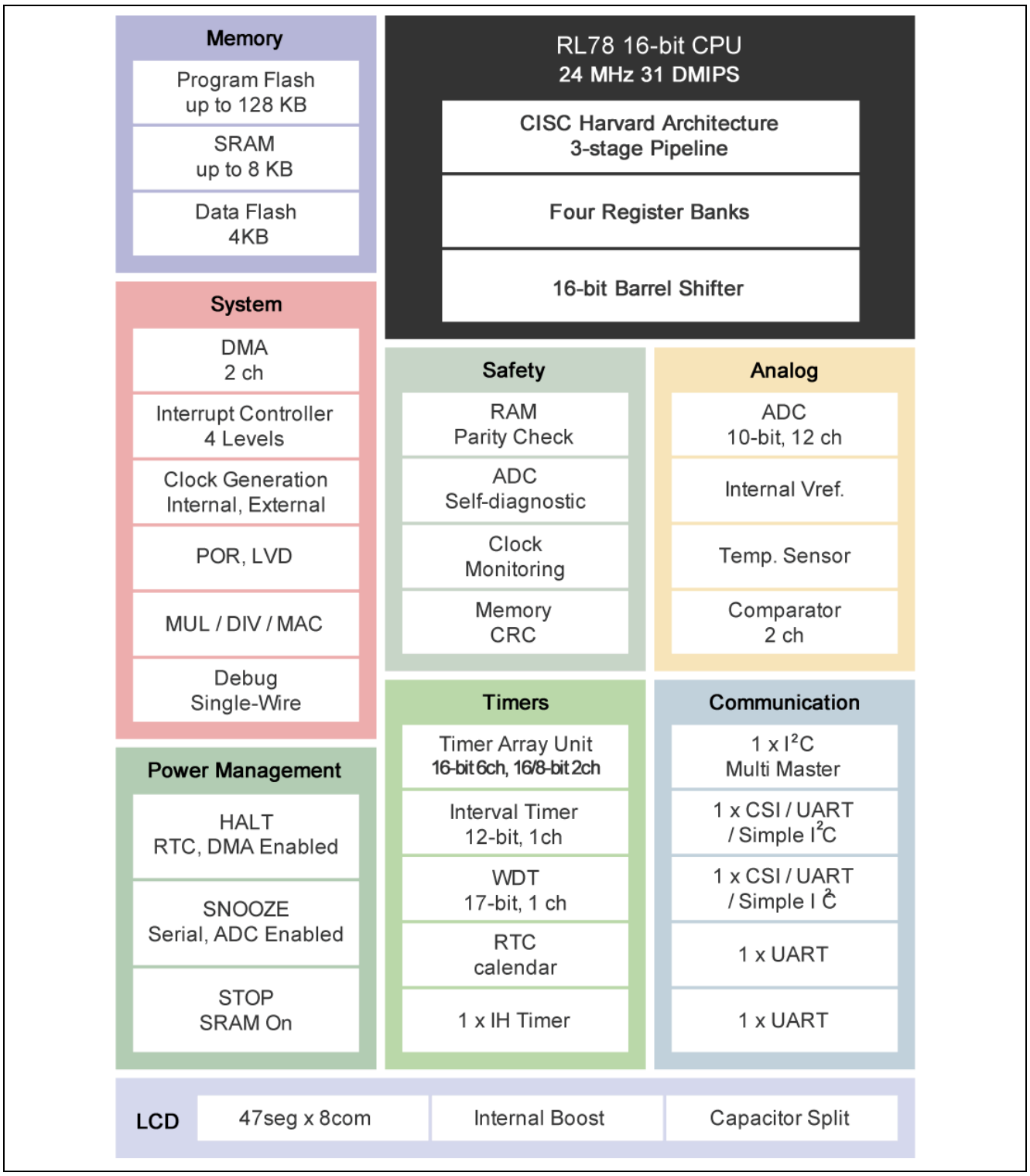

Figure 2.1 RL78/L13 (80-pin products) Block Diagram

2.2 Key Features

- Minimum instruction execution time: Can be changed from high speed (0.04167 μs @ 24 MHz operation with high-speed on-chip oscillator) to ultra-low speed (30.5 μs @ 32.768 kHz operation with subsystem clock)
- General-purpose registers: (8-bit register × 8) × 4 banks
- ROM: 128 KB, RAM: 8 KB
- Selectable high-speed on-chip oscillator clock: 48/24/16/12/8/6/4/3/2/1 MHz (TYP.)
- On-chip single power supply flash memory
- On-chip debug function
- On-chip power-on-reset (POR) circuit
- On-chip watchdog timer (operable with the dedicated low-speed on-chip oscillator)
- On-chip key interrupt function
- On-chip clock output/buzzer output controller
- On-chip BCD (binary-coded decimal) correction circuit
- I/O port: 65 (N-ch open drain I/O [withstand voltage of 6 V]: 2, N-ch open drain I/O [V_{DD} withstand voltage]: 18)
- Timer
  16-bit timer: 8 channels (with remote control output function)
  16-bit timer KB20 (IH): 1 channel (IH-only PWM output function)
  12-bit interval timer: 1 channel
  Real-time clock 2: 1 channel (calendar for 99 years, alarm function, and clock correction function)
- Serial interface
  CSI: 2 channels
  UART/UART (LIN-bus supported): 4 channels/1 channel
  Simplified I^2C communication: 2 channels
  I^2C communication: 1 channel
- 8/10-bit resolution A/D converter: 12 channels
- Comparator: 2 channels
- LCD controller/driver: 51 segment signal output pins, 8 common signal output pins
- DMA (Direct Memory Access) controller: 4 channels
- Standby function: HALT mode, STOP mode, SNOOZE mode
- Power supply voltage: V_{DD} = 1.6 to 5.5 V
- Operating ambient temperature: T_A = -40 to +85 °C

With low power consumption, the standard LCD microcontroller RL78/L13 is suitable for LCD display of home appliances or measurement devices.

2.3 Pin Configuration

Figure 2.2 shows the pin configuration of RL78/L13 (80-pin products).

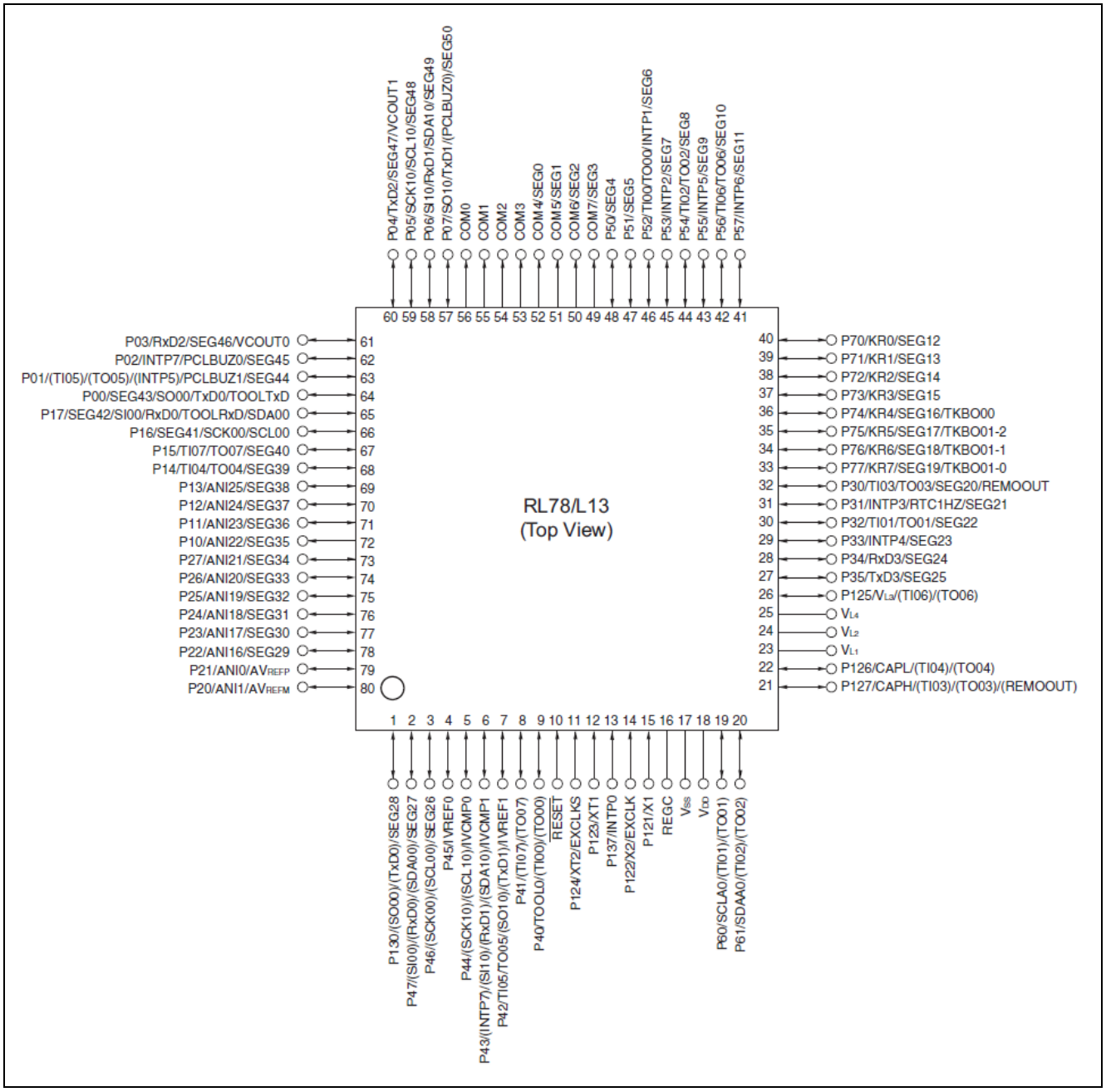

Figure 2.2 RL78/L13 (80-pin products) Pin Configuration

3. System Outline

3.1 Principle Introduction

RL78/L13 microcontroller communicates with the energy metering IC by SPI. After initialization, RL78/L13 sends configuration commands to the energy metering IC to start monitoring the load state. If there is a load, RL78/L13 MCU receives the metering voltage value, current value, frequency value, active power value and power factor every 500ms from the metering IC. As well as the number of energy pulses per 15s. Keys will change which value is shown on the LCD. Every time the [+] key is pressed, the LCD will rotate between the voltage, current, total elapsed time, frequency, carbon dioxide emission, total electric energy consumption, and active power in order. If [-] key is pressed, LCD will show those various measurement parameters in reverse order. The total elapsed time, the amount of carbon dioxide emission, and the amount of energy consumption are calculated by MCU. And RL78/L13 stores the value of the time and the energy in data flash. If there is no load the LCD has no display value. The system carries out key scan, LCD refresh and temperature detection every 100ms. The buzzer alarm will go off when the ambient temperature detected is more than 60 °C.

Figure 3.1 shows the system block diagram.

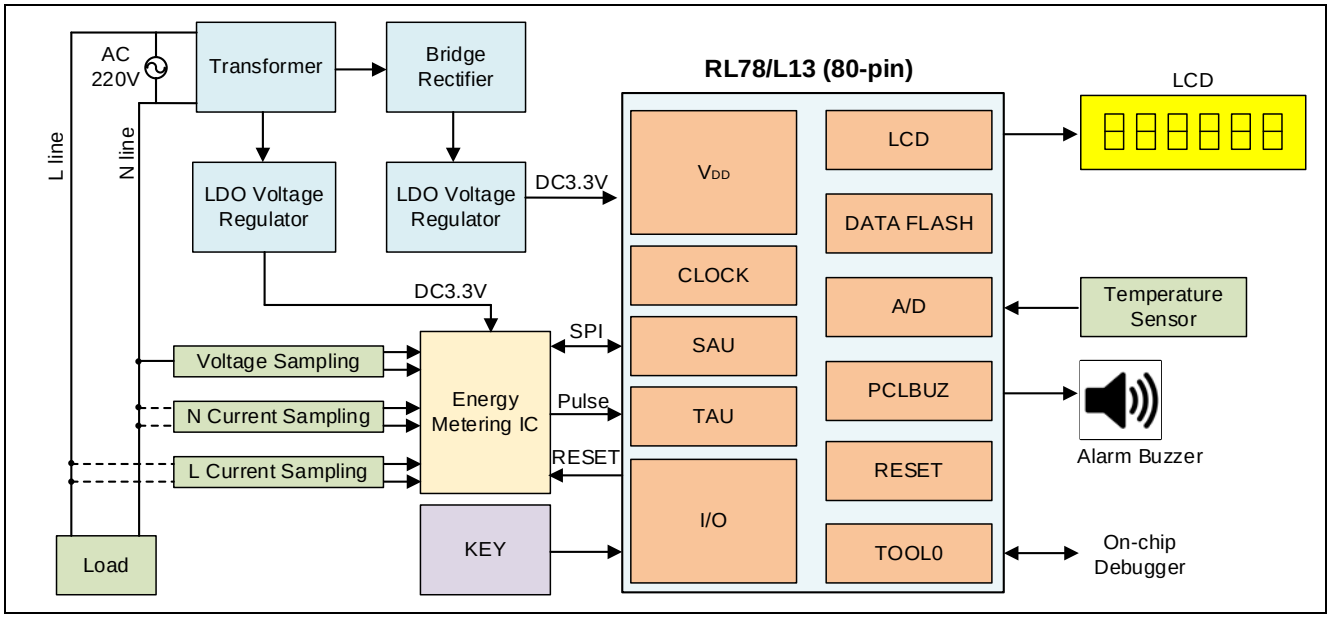

Figure 3.1 System Block Diagram

3.2 Peripheral Functions to be Used

Table 3.1 lists the peripheral functions to be used and their usage.

Table 3.1 Peripheral Functions to be Used

Peripheral Function	Usage
CSI00 of SAU0	Communicate with energy metering IC, including sending configuration command, and receiving the data of active power, power factor, current, voltage, frequency and the number of energy pulses.
LCD	Control the LCD display. The display content includes the value of voltage, current, time, frequency, carbon dioxide emission, energy consumption, active power.
DATA FLASH	Store the values of the total elapsed time and total energy consumption.
A/D converter	Detect the temperature sensor and get the operating temperature.
PCLBUZ0	Control the buzzer. When the temperature is more than 60 °C, the buzzer will go off.
Channel0 of TAU0	1 ms interval timer.
Channel1 of TAU0	Operated as a real-time clock to get the total elapsed time of metering.

3.3 Pins to be Used

Table 3.2 lists the pins to be used and their function.

Table 3.2 Pins to be Used

Pin Name	Description
P44	[+] key input port
P43	[-] key input port
P40/TOOL0	On-chip debug
RESET	Hardware reset
P124/XT2/EXCLKS P123/XT1	32.768 kHz crystal resonator connection
REGC	Connect this pin to V_{SS} via a capacitor (0.47 to 1 µF) with good characteristics to stabilize internal voltage.
V_{SS}	Ground
V_{DD}	Power supply voltage
P127/CAPH P126/CAPL VL1 VL2 VL4 P125/VL3	Connect with a capacitor to drive the LCD respectively
P35/TxD3	UART transfer (reserved)
P34/RxD3	UART receive (reserved)
P33	[SET] key input port
P31	[ENTER] key input port
P77	Control a LED for carbon dioxide emission mode
P76	Control a LED for frequency mode
P75	Control a LED for total elapsed time mode
P74	Control a LED for current mode
P73	Control a LED for voltage mode
P72	Control a LED for active power mode
P71	Control a LED for total electric energy consumption mode
COM0, COM1, COM2, COM3, COM4/SEG0, COM5/SEG1, COM6/SEG2, COM7/SEG3, P50/SEG4, P51/SEG5, P52/SEG6, P53/SEG7, P54/SEG8, P55/SEG9, P56/SEG10, P57/SEG11	Control LCD
P02/PCLBUZ0	Control a buzzer
P00/SO00 P17/SI00 P16/SCK00	Communicate with energy metering IC by CSI interface
P15	Control the RESET pin of energy metering IC
P20/ANI1	Sample the voltage of temperature sensor output

3.4 Operating Instructions

(1) Plug the mini power monitor into an electric socket and then plug the electric appliance into the socket of the unit.

(2) When the mini power monitor is powered on, it will enter the initial task. In initial task, the buzzer will sound 800ms and LCD will be ON. After that, the power monitor will detect whether there is a load connected. If there is no load, the power monitor will enter wait mode and LCD will be OFF. If there is a load detected, the power monitor will enter the measurement task.

(3) In measurement task, LCD will display the metering contents. The LED which is ON will indicate what mode it is. Every time [+] key is pressed, LCD will show the voltage, current, total elapsed time, frequency, carbon dioxide emission, total electric energy consumption, active power in order. If [-] key is pressed, LCD will show those various measurement parameters in reverse order.

The examples of LCD display:

<1> Voltage mode: 230.00, unit: V. (Range: 0.01 ~ 655.35V)

<2> Current mode: 326, unit: mA. (Range: 1 ~ 65535 mA)

<3> Time mode: 16, unit: min. (Range: 0 ~ 99999 min)

<4> Frequency mode: 50, unit: Hz. (Range: 45 ~ 65 Hz)

<5> Carbon dioxide mode: 0.01, unit: kg. (Range: 0.00 ~ 7849.99 kg)

<6> Energy mode: 0.02, unit: kWh. (Range: 0.00 ~ 9999.99 kWh)

<7> Power mode: 75, unit: W. (Range: 1 ~ 32768 W)

(4) In total elapsed time display mode, long press the [SET] key for 2 seconds to enter clearing mode. In this mode, the number on the LCD will flash. If the [ENTER] key is pressed, the value of the total elapsed time will be clear to "0" and the monitor will return to the total elapsed time display mode.

(5) In total electric energy consumption display mode, long press the [SET] key for 2 seconds to enter clearing mode. In this mode, the number on the LCD will flash. If the [ENTER] key is pressed, the value of the total electric energy consumption and the carbon dioxide emission will be clear to "0" and the monitor will return to the total electric energy consumption display mode.

(6) If the mini power monitor detects the ambient temperature exceeding 60 °C, it will start to alarm. Please power off the monitor immediately.

4. Hardware

The power supply circuit has two channels of DC 3.3V through a transformer and a LDO regulator from 220VAC[Note]. One is for the microcontroller and peripheral, the other is for the energy metering chip. A shunt resistor is used in the phase line current sampling circuit and a current transformer is used in the neutral line current sampling circuit. When an appliance is detected, the energy metering chip will send the voltage value, the current value and so on to the MCU. The LCD display function pins of RL78/L13 can drive the LCD directly. P71~P77 are used to drive the LEDs to indicate the display mode. P31, P33, P43 and P44 are used as key input ports. The ambient temperature is calculated based on the voltage which is sensed by ANI1. The buzzer is driven by square wave generated by the buzzer output function. Due to the large operating current of the buzzer, a triode is used to improve the current drive capability of the PCLBUZ0 port.

Note: The voltage of civil standard electric supply is different in each region, for an example, 220V in China. But the actual voltage has a range from 200V to 240V. Please select the appropriate transformer based on the local electric supply.

Figure 4.1 shows the board picture.

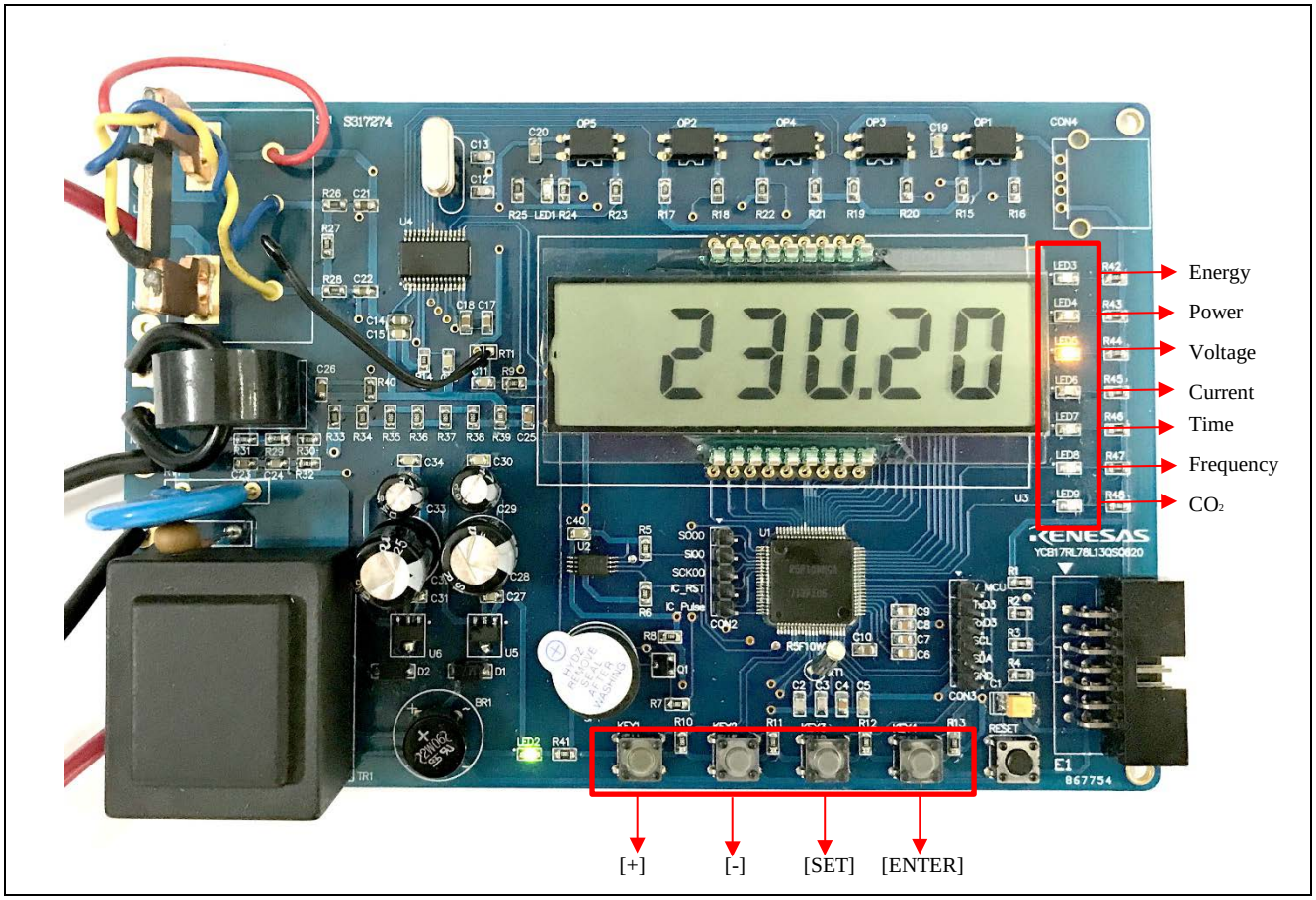

Figure 4.1 Board Picture

4.1 Power Supply Circuit

Figure 4.2 shows the schematics of the power supply circuit.

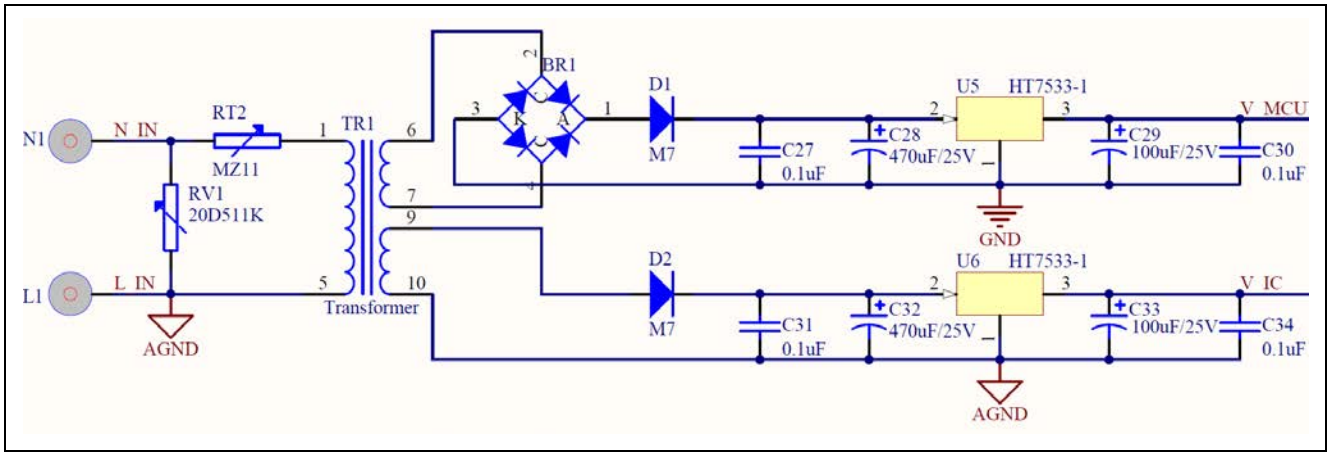

Figure 4.2 Power Supply Circuit

Power supply circuit is composed of the varistor, thermistor, transformer, full-bridge rectifier and LDO voltage regulator. The varistor and thermistor provide short circuit protection for the power supply circuit and the transformer[Note] is used to generate 9V from the alternating 220V. The transformer generates two channels of 9V AC output, one is through a full-bridge rectifier BR1, Schottky diodes D1 and LDO regulator HT7533 generates DC 3.3V which is used as power supply for the microcontroller and peripheral circuitry; the other is through the Schottky diode D2 and LDO and outputs DC 3.3V for the energy metering chip.

Note: Please select the appropriate transformer based on the local electric supply.

4.2 Energy Metering IC Control Circuit

Figure 4.3 shows the schematics of the energy metering IC control circuit.

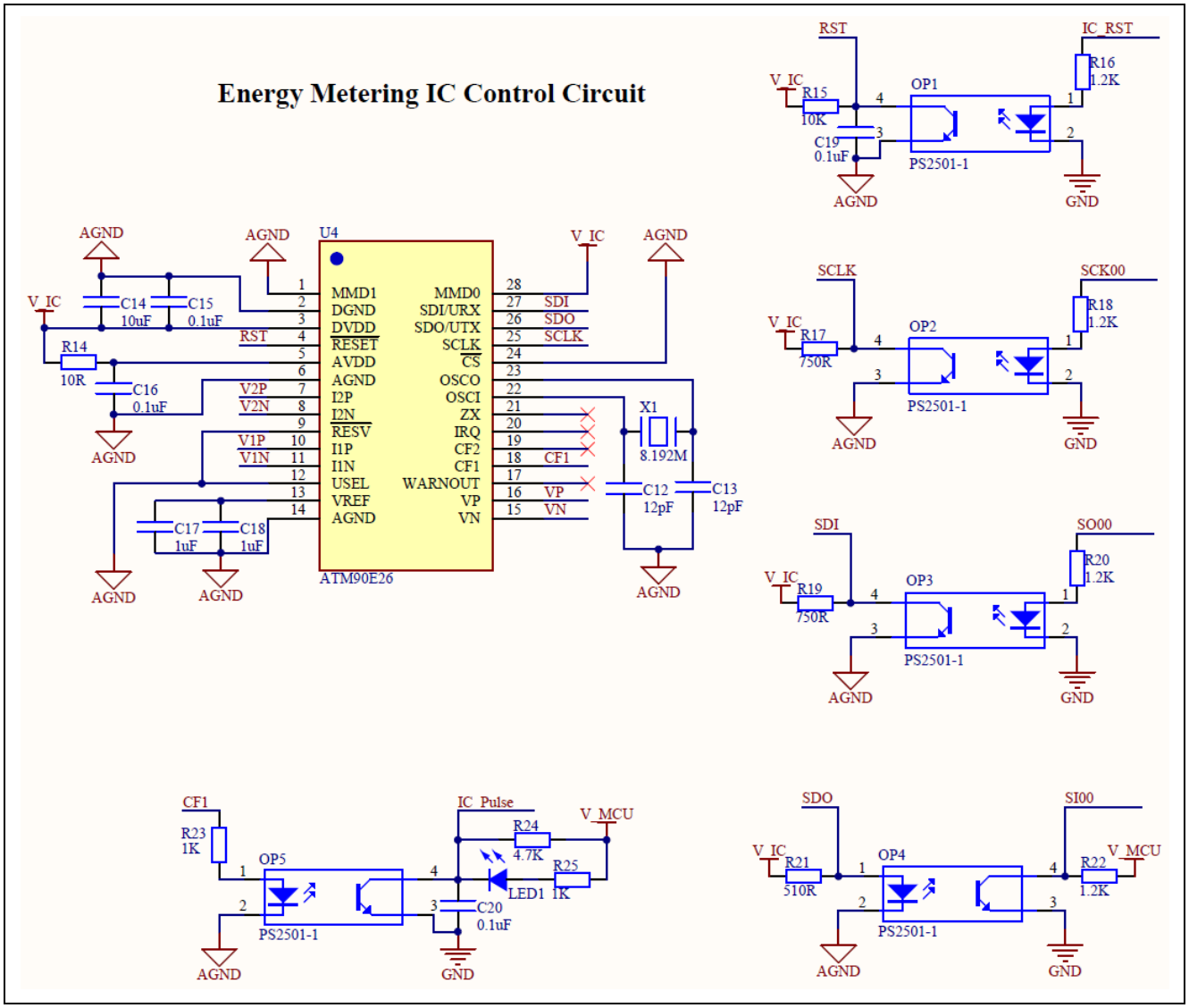

Figure 4.3 Energy Metering IC Control Circuit

The M90E26 is a high-precision single-phase energy metering IC. RL78/L13 communicates with the M90E26 by SPI communication interface. Because the M90E26 is connected with the AC 220V, in order to protect the MCU, the MCU is isolated from the energy metering IC by optical isolators (PS2501). P15 pin of RL78/L13 is connected to the optical isolator and used to control the reset pin of M90E26. Energy pulse output port of M90E26 is connected to the TI04 pin of RL78/L13 through the optical isolator.

4.3 Current Sampling Circuit

Figure 4.4 shows the schematics of the L current sampling circuit. Figure 4.5 shows the schematics of the N current sampling circuit.

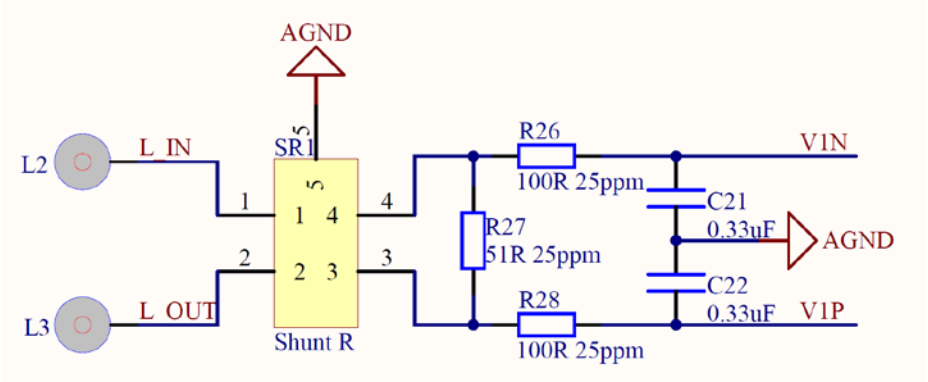

Figure 4.4 L Current Sampling Circuit

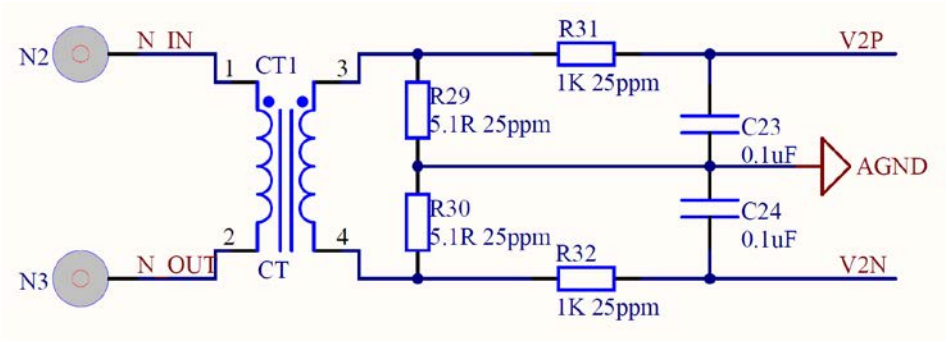

Figure 4.5 N Current Sampling Circuit

The current sampling circuit is divided into two parts: one is the phase line (L line) sampling circuit and the other is the neutral line (N line) sampling circuit. The phase line (L line) connects in series with a shunt resistor SR1 used for L line current sampling; the neutral line (N line) is connected with a current transformer CT1 used for N line current sampling.

4.4 Voltage Sampling Circuit

Figure 4.6 shows the schematics of the voltage sampling circuit.

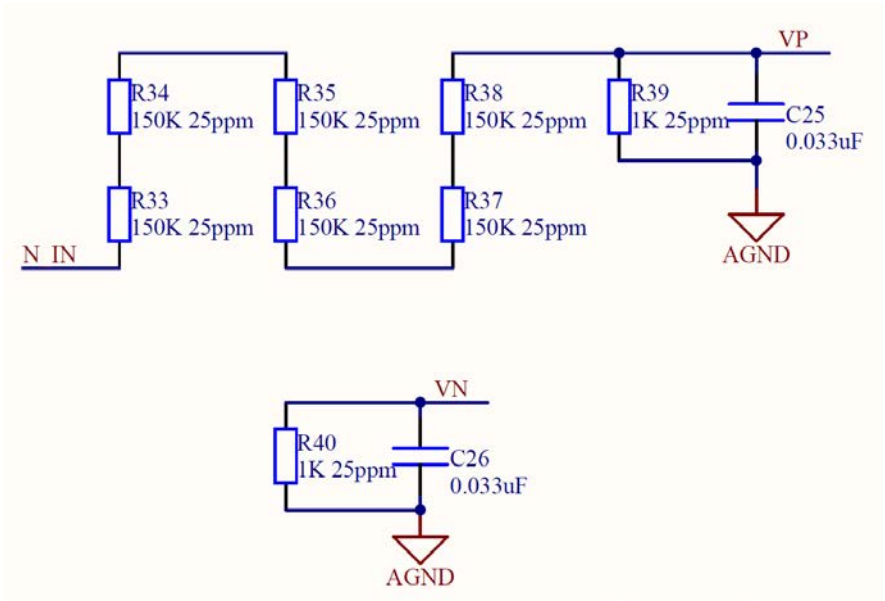

Figure 4.6 Voltage Sampling Circuit

In this document, the phase line (L line) is connected to the analog ground (AGND). The neutral line (N line) connected in series with a set of precision resistors forms a resistor divider network which can be used for voltage sampling.

4.5 LCD Circuit

Figure 4.7 shows the schematics of the LCD circuit.

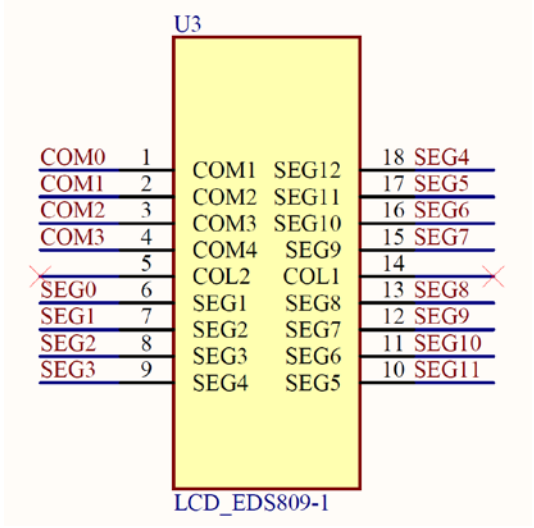

Figure 4.7 LCD Circuit

EDS809-1 which is a LCD with 4 COM and 11 SEG is used for display. RL78/L13 has 4(8)[Note] COM pins and 51(47)[Note] SEG pins, it can independently implement the LCD drive control.

Note: The values in parentheses are the number of signal outputs when 8 com is used.

4.6 Temperature Detector Circuit

Figure 4.8 shows the schematics of the temperature detector circuit.

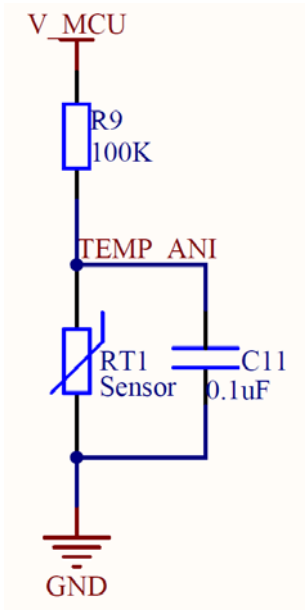

Figure 4.8 Temperature Detector Circuit

RL78/L13's ANI1 pin is used as input port of temperature sensor (10K negative temperature coefficient thermistor) to real-time detect the ambient temperature. If the temperature exceeds 60 °C, the buzzer will begin to alarm.

5. Software

5.1 Integrated Development Environment

The sample code described in this chapter has been checked under the conditions listed in the table below.

Table 5.1 Operation Check Conditions

Item	Description
Microcontroller used	RL78/L13 (R5F10WMG)
Operating frequency	High-speed on-chip oscillator (HOCO) clock: 48 MHz CPU/peripheral hardware clock: 24 MHz Subsystem clock oscillator clock: 32.768 kHz
Operating voltage	3.3V (can run on a voltage range of 2.7 V to 5.5 V) LVD: OFF
Integrated development environment (CS+)	CS+ V6.00.00 from Renesas Electronics Corp.
C compiler (CS+)	CC-RL V1.05.00 from Renesas Electronics Corp.
Integrated development environment (e2 studio)	e2 studio V6.0.0 from Renesas Electronics Corp.
C compiler (e2 studio)	CC-RL V1.05.00 from Renesas Electronics Corp.

5.2 Option Byte

Table 5.2 summarizes the settings of the option bytes.

Table 5.2 Option Byte Settings

Address	Value	Description
000C0H/010C0H	11101111B	Watchdog timer counter operation disabled (counting stopped after reset)
000C1H/010C1H	01011111B	LVD reset mode which uses 2.45V (2.40V to 2.50V)
000C2H/010C2H	11110000B	HS mode, fHOCO: 48 MHz CPU clock fCLK: 24 MHz
000C3H/010C3H	10000100B	Enables on-chip debugging

5.3 Operation Outline

The tasks of the whole system are listed as below: initial task, wait mode, measurement task, and alarm mode.

Figure 5.1 shows the block diagram for the tasks transition.

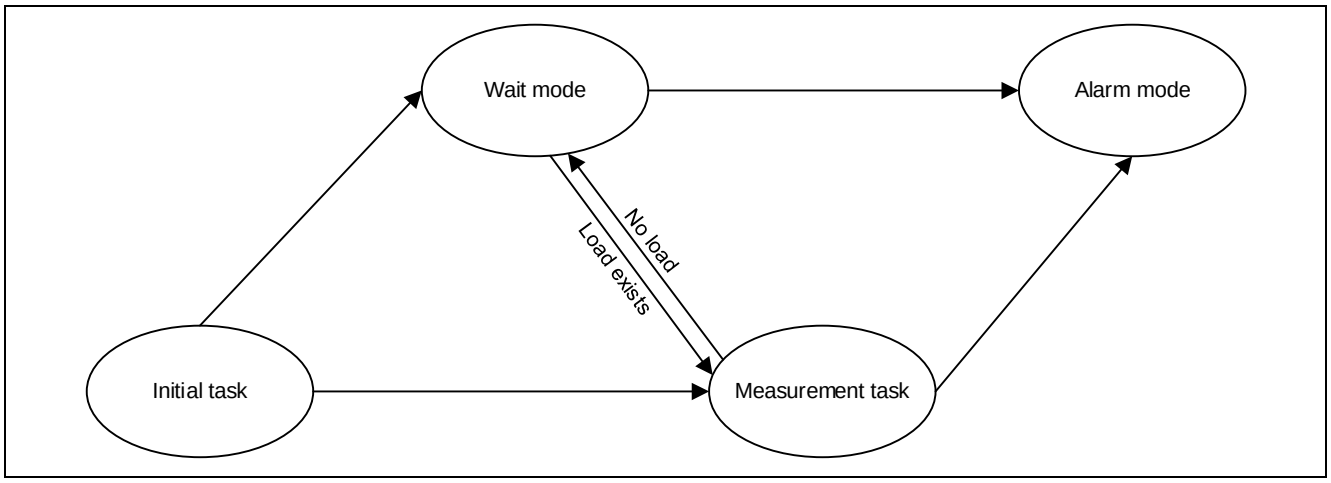

Figure 5.1 Tasks Transition Block Diagram

(1) Initial task

After power-on, the system executes initial task. In this task, the buzzer will sound 800 ms. The LCD and all LEDs are ON. Then, the mini power monitor will detect whether there is a load connected. If there is no load, the system will enter wait mode. If there is a load detected, the system will enter measurement task.

(2) Wait mode

The LCD and all LEDs are OFF.

(3) Measurement task

The system receives the data of active power, power factor, current, voltage, frequency and the number of energy pulses from energy metering IC, and obtains the values for display through calculating these received data. The LCD will display the metering contents. The LEDs indicate which display mode it is. Every time [+] key is pressed, LCD will show the voltage, current, total elapsed time, frequency, carbon dioxide emission, total electric energy consumption, active power in order. If [-] key is pressed, LCD will show those various measurement parameters in reverse order.

(4) Alarm mode

If the mini power monitor detects the ambient temperature exceeding 60 °C, the system enters the alarm mode. The buzzer starts sounding. Please power off the monitor immediately.

5.4 Flow Chart

5.4.1 Main Processing

Figure 5.2 shows the flowchart for main processing routine.

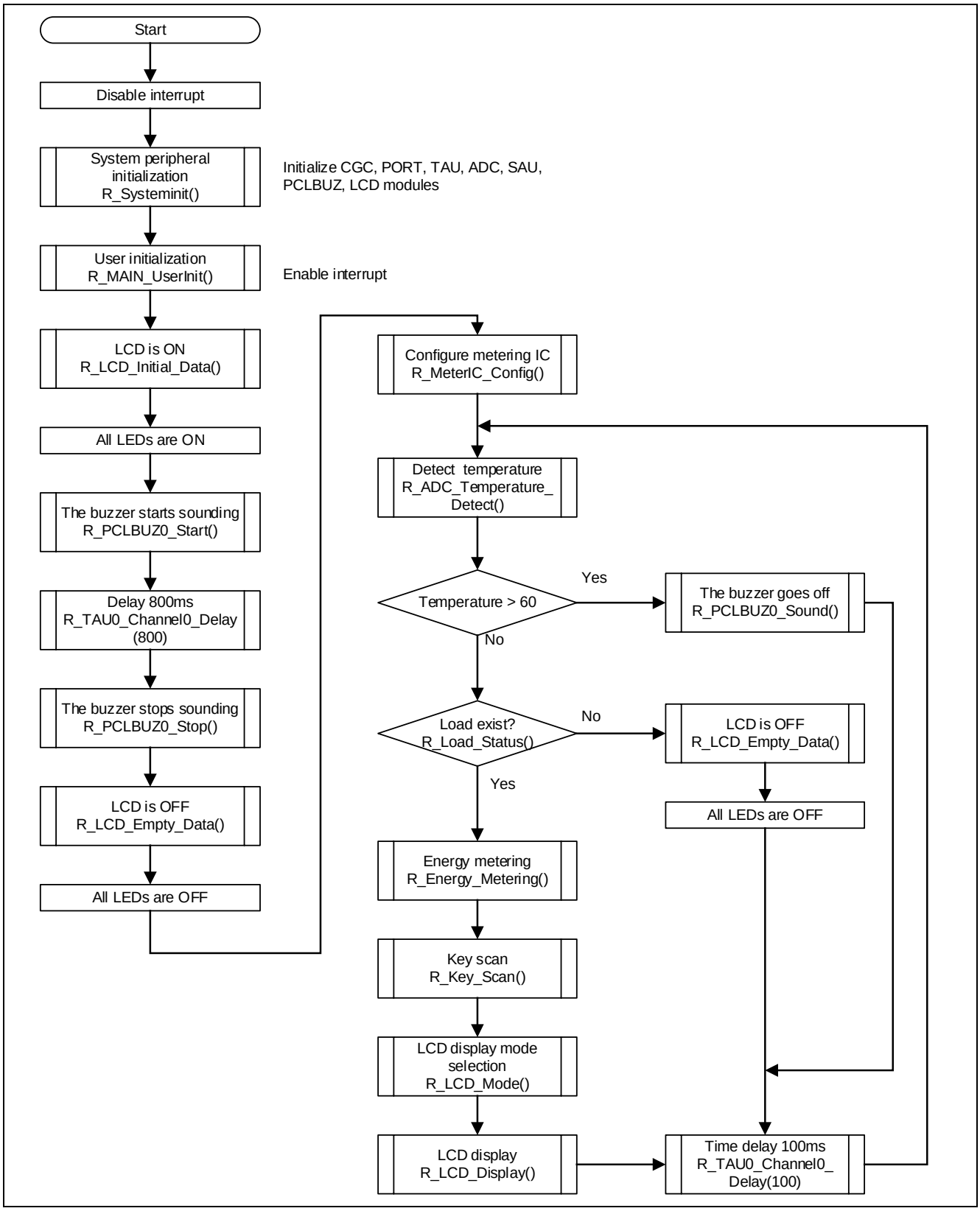

Figure 5.2 Main Processing

5.4.2 Temperature Detect

Figure 5.3 shows the flowchart for temperature detect routine.

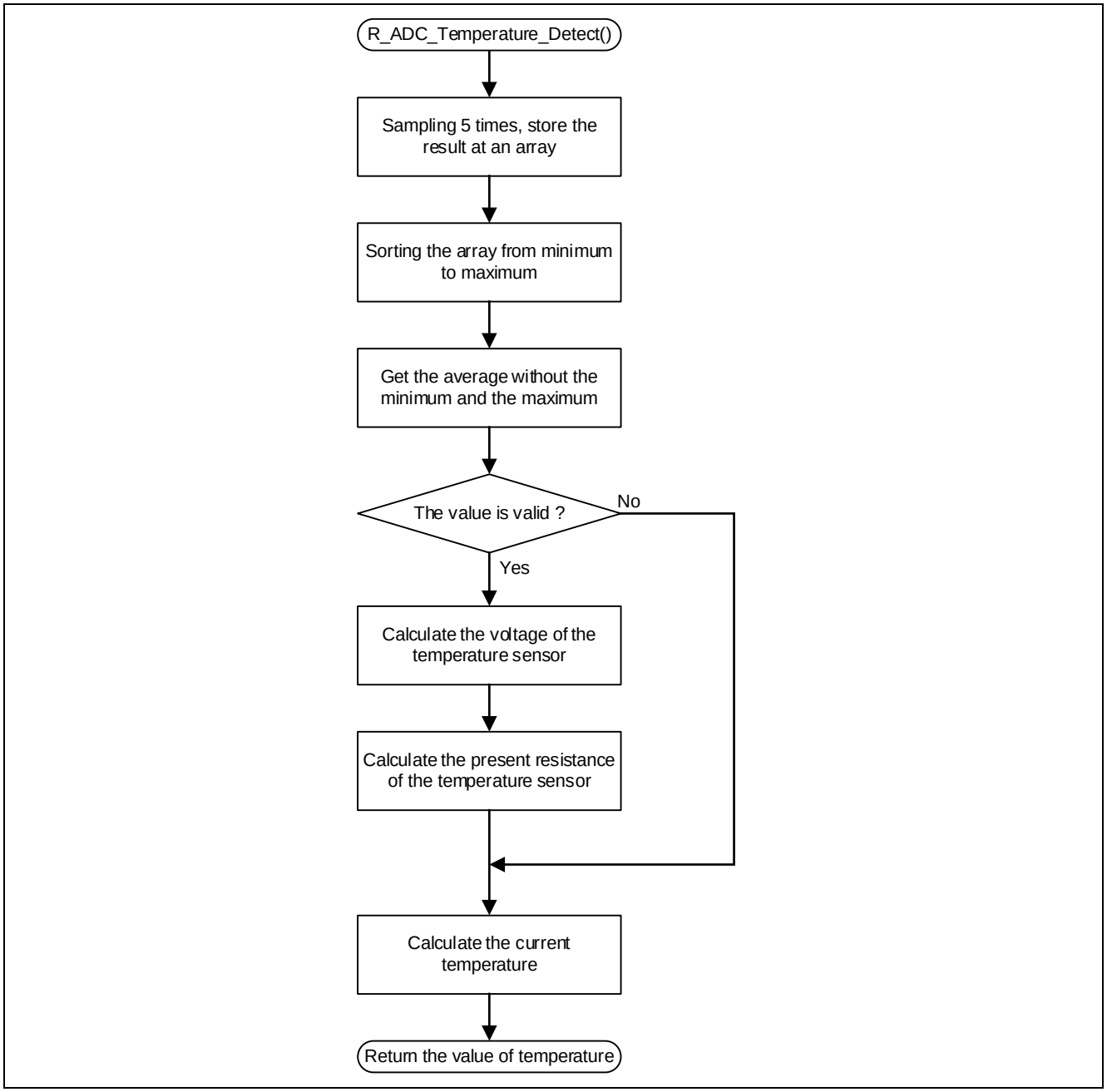

Figure 5.3 Temperature Detect

5.4.3 Load Status Check

Figure 5.4 shows the flowchart for load status check routine.

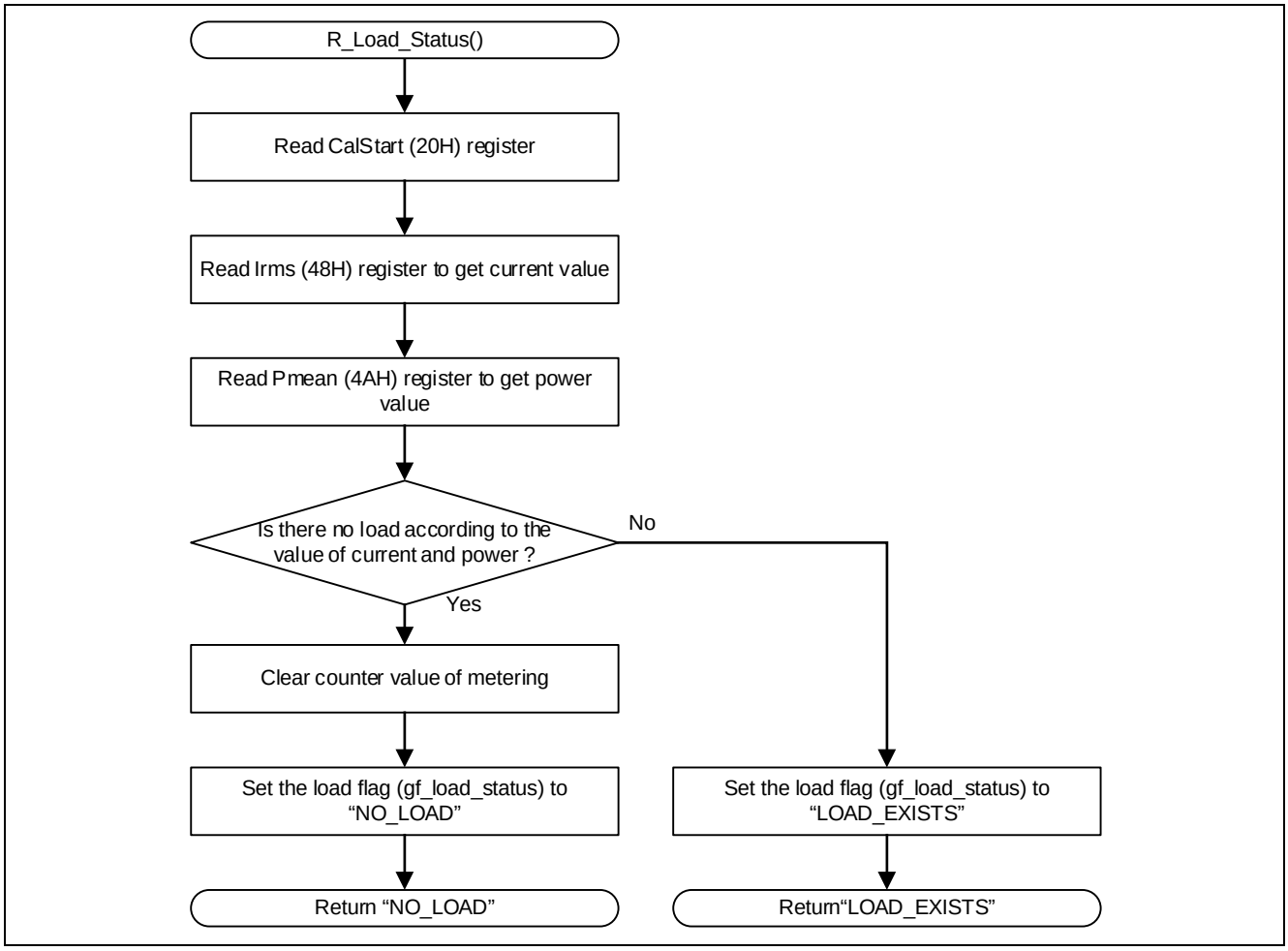

Figure 5.4 Load Status Check

6. Sample Code

The sample code is available on the Renesas Electronics Website.

7. Reference Documents

RL78/L13 User's Manual: Hardware (R01UH0382)

RL78 Family User's Manual: Software (R01US0015)

(The latest versions of the documents are available on the Renesas Electronics Website.)

Technical Updates/Technical News

(The latest information can be downloaded from the Renesas Electronics Website.)

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Revision History

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	Dec. 31, 2017	—	First edition issued

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Handling of Unused Pins

   Handle unused pins in accordance with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of Microprocessing unit or Microcontroller unit products in the same group but having a different part number may differ in terms of the internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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