RL78/G11 + HIP2106A + ISL28006

Wireless Charger

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Introduction

This document describes a Renesas microcontroller RL78/G11 application for wireless charger.

Target Device

RL78/G11

When applying the sample program covered in this application note 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

Wireless charging uses an electromagnetic field to transfer energy between two objects through electromagnetic induction. This is usually done with a charging station. Energy is sent through an inductive coupling to an electrical device, which can then use that energy to charge batteries or run the device.

The principle of wireless charging is simply an open cored transformer consisting of a transmitter and receiver coils. When receiver coils are positioned on the transmitter coil, magnetic coupling occurs once the transmitter coil is driven. The magnetic flux is coupled into the secondary coil which induces a voltage and current flows.

The function block diagram of wireless charging is shown in Figure 1.1.

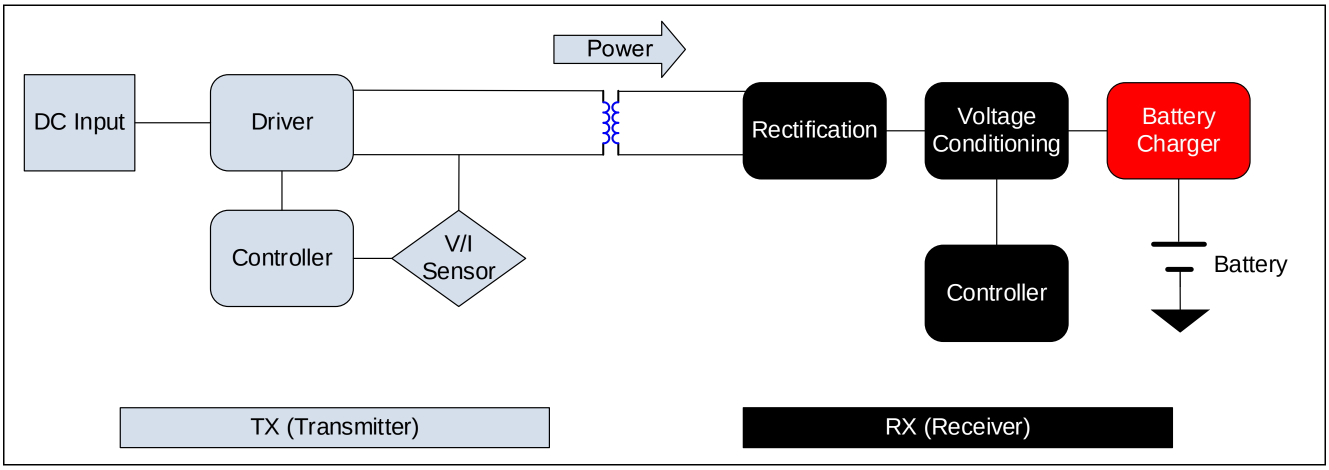

Figure 1.1 Function Block Diagram of Wireless Charging

Many smart phone manufacturers add this technology into their products. Most of these phones have adopted the Qi wireless charging standard. Major manufacturers, such as Apple and Samsung, produce many models of their phones in high volume with Qi capabilities.

This document provides a wireless charger solution based on Renesas low cost microcontroller RL78/G11.

1.2 Specifications and Main Technical Parameters

Technical Parameters

- Power supply: 5 V (DC power supply)
- Wireless charging standard Qi
- Input range 5V/1A
- Powerful charge current 800mA (Max.)
- Output power 4W (Max.)

Specifications

- Wireless charging standard Qi is an open interface standard. The system uses a charging pad and
- a compatible device, which is placed on top of the pad, charging via
- resonant inductive coupling.
- Visual indication function: If a receiver is detected, the green led will be turned on.
  If no receiver is detected, the green led will be turned off.
  If any one of over current, over temperature or abnormal voltage is detected, the red LED will blink.

- System protection If over voltage is detected after RESET / Initialization, the red LED will blink.
  If over current or over temperature is detected during Power Transfer Handle, power transmission is broken off and the red LED will blink.
- Operating temperature: -10°C ~ 45°C
- Operating humidity: 5 ~ 99% RH (No condensate water)

2. RL78/G11 Microcontroller

2.1 RL78/G11 Block Diagram

Figure 2.1 shows the block diagram of RL78/G11 (20-pin products).

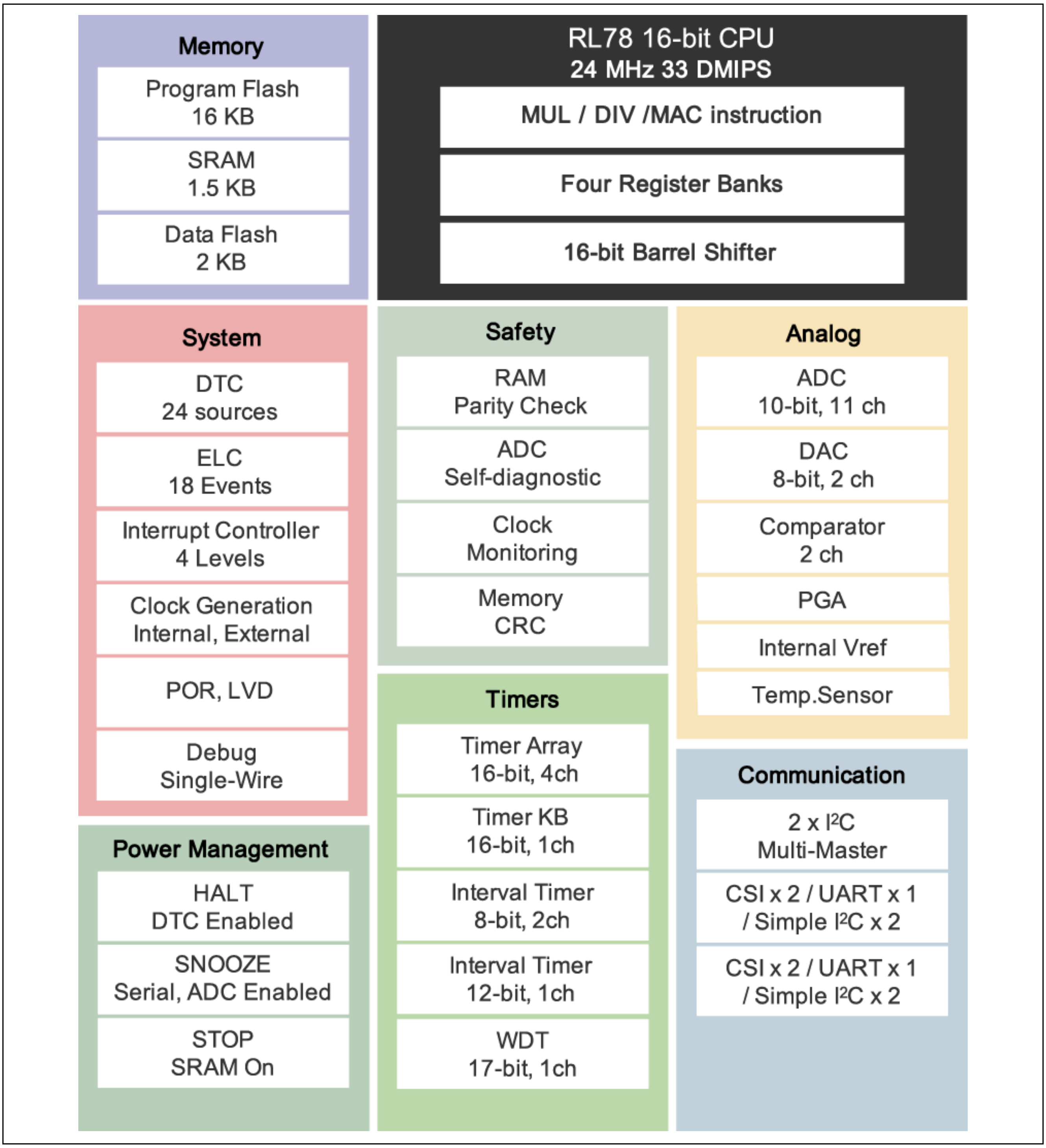

Figure 2.1 RL78/G11 (20-pin products) Block Diagram

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 (66.6 μs: @ 15 kHz operation with low-speed on-chip oscillator clock)
- General-purpose registers: (8-bit register × 8) × 4 banks
- ROM: 16 KB, RAM: 1.5 KB, data flash: 2 KB
- Selectable high-speed on-chip oscillator clock: 48/24/16/12/8/6/4/3/2/1 MHz (TYP.)
- Selectable middle-speed on-chip oscillator clock: 4/2/1 MHz (TYP.)
- On-chip debug function
- On-chip selectable power-on-reset (POR) circuit
- On-chip voltage detector (LVD)
- On-chip watchdog timer (operable with the dedicated low-speed on-chip oscillator)
- On-chip key interrupt function: 8 key interrupt input pins
- On-chip clock output/buzzer output controller
- On-chip BCD (binary-coded decimal) correction circuit
- I/O port: 17 to 21
- Timer
  16-bit timer (TAU): 4 channels
  TKB: 1 channel
  12-bit interval timer: 1 channel
  8-bit interval timer: 2 channels
- Serial interfaces
  CSI: 4 channels
  UART: 2 channels
  I²C/Simplified I²C communication: 4 channels
  Multi-master I²C: 2 channels
- 8/10-bit resolution A/D converter: 10 to 11 channels
- 8/10-bit resolution D/A converter: 2 channels
- Comparator: 2 channels
  Operating modes: Comparator high-speed mode, comparator low-speed mode, window mode
- PGA: 1 channel
- Data transfer controller (DTC)
- Event link controller (ELC)
- Standby function: HALT or STOP mode
- Power supply voltage: VDD = 1.6 to 5.5 V
- Operating ambient temperature: TA = -40 to +85°C

RL78/G11 is widely used in common technologies for industry, office, home appliance, healthcare, security, city and detectors application.

2.3 Pin Configuration

Figure 2.2 shows the pin configuration of RL78/G11 (20-pin products).

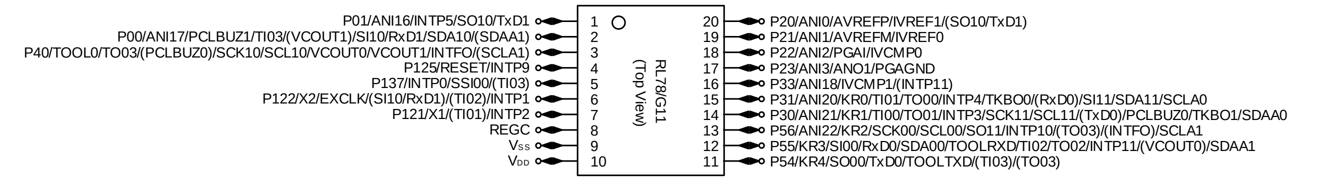

Figure 2.2 RL78/G11 (20-pin products) Pin Configuration

3. System Outline

3.1 Principle Introduction

After system initialization is completed, HALT mode is entered for low power consumption. Every second the MCU is woken up from HALT mode for phone detection. If a receiver (the smartphone that supports Qi standard) is detected, power transmission is started, and the green led is turned on.

Figure 3.1 shows the system block diagram for this document.

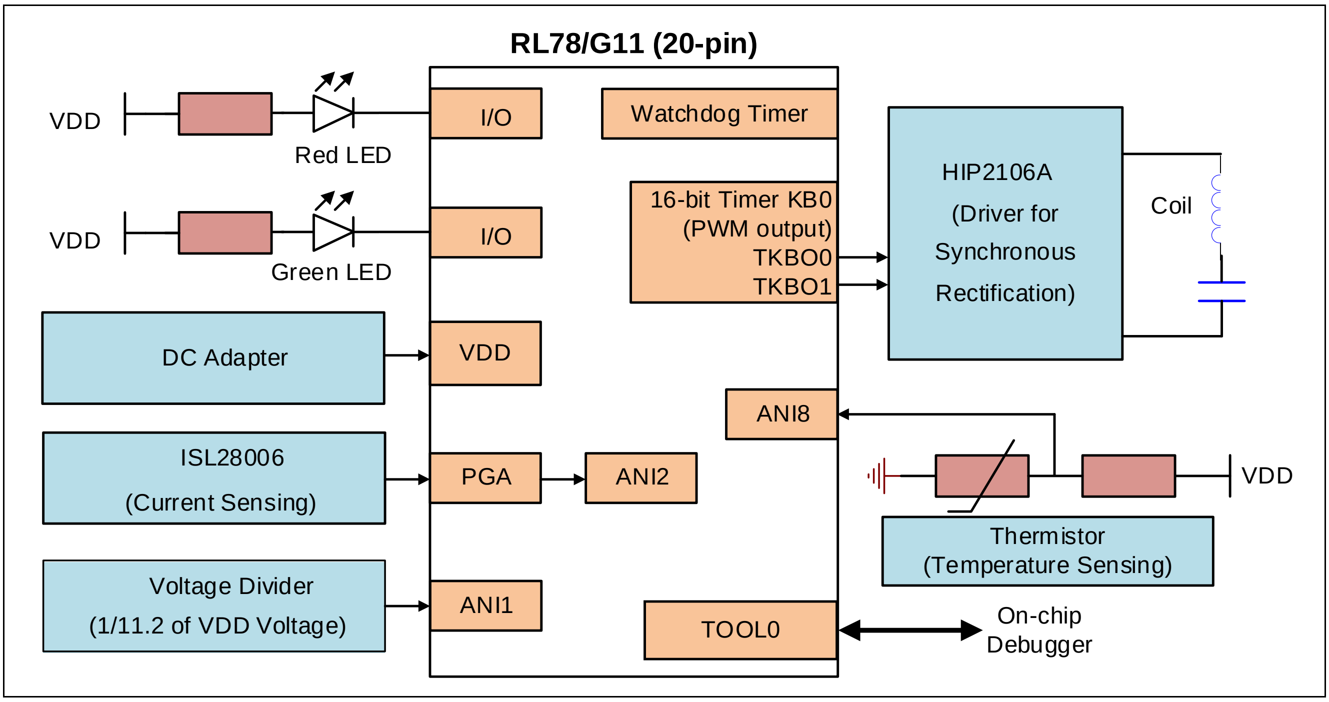

Figure 3.1 System Block Diagram

3.2 Peripheral Functions to be Used

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

Table 3.1 Peripheral Functions to be Used

Peripheral Function	Usage
A/D Converter	Monitor the current. Monitor the temperature. Monitor the voltage.
Programmable Gain Amplifier (PGA)	The current sensing analog voltage input from the PGAI pin is amplified (x8) within the microcontroller.
16-bit Timer KB0	Output PWM to control the coil.
Timer Array Unit Channel 3	Generate 1 second interval to wake up MCU from HALT mode.
I/O port	Control the status LEDs.

3.3 Pins to be Used

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

Table 3.2 Pins to be Used

Pin Name	Description
P40/TOOL0	On-chip debug
P125/RESET	Hardware reset
V_{SS}	Ground
V_{DD}	Power supply voltage
P31/TKBO0	One PWM output to control the coil
P30/TKBO1	The other PWM output to control the coil
P21/ANI1	Monitor the voltage of power supply
P22/PGAI	Monitor the charging current
P33/ANI8	Monitor the temperature
P20	Drive the red LED to indicate error
P01	Drive the green LED to indicate charging

3.4 Operating Instructions

(1) Connect the wireless charging transmitter to a DC 5V power. As no phone is placed on the coil, both the green LED and the red LED are turned off.

Caution: because the consumption current of wireless charging transmitter is fairly high, the wireless charging transmitter cannot be powered by an emulator, such as E1, or PC USB interface.

(2) Put the smartphone that supports Qi standard on wireless charging transmitter coil, and the green led will be turned on. At the same time, the smartphone sends charging notice sound and a charging icon will be shown on the mobile's screen.

(3) When the smartphone is removed from wireless charging transmitter coil, the green led will be turned off.

(4) If any one of over current, over temperature, or abnormal voltage is detected, the red led will blink.

4. Hardware

The wireless charging transmitter consists of a DC 5V power input, a current sense amplifier, voltage detection circuit, temperature monitor circuit, main MCU, LED indication circuit, PWM driver circuit and a coil.

If a receiver (the smartphone that supports Qi standard) is detected, power transmission is started, and the green LED is on.

Figure 4.1 shows the board picture.

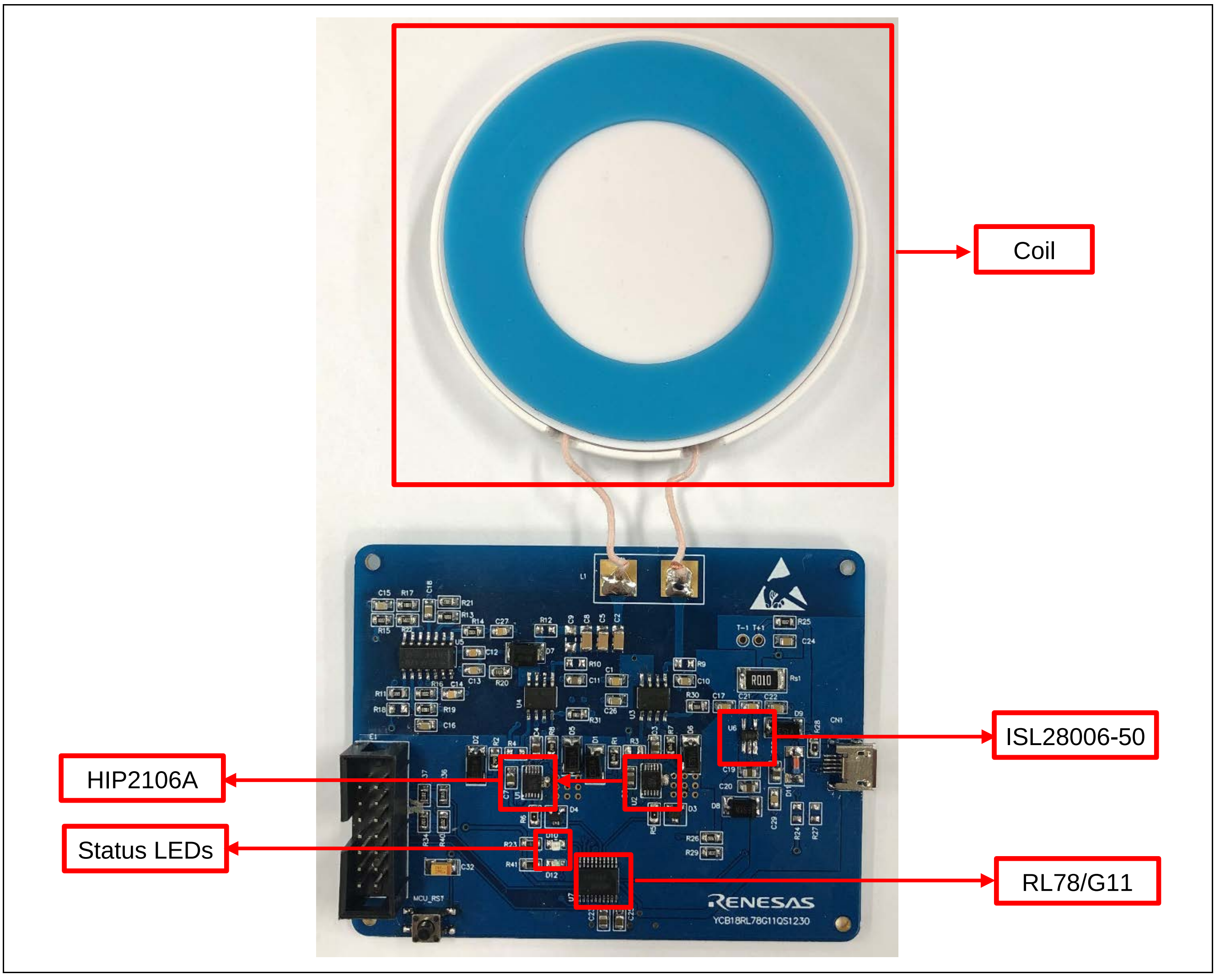

Figure 4.1 Board Picture

4.1 Current Monitor Circuit

RL78/G11's PGA and ANI2 acts as the current monitor signal input pin in wireless charging transmitter. If the consumption current of the wireless charging transmitter is greater than safety threshold (900mA), it will stop power transmission for 5 seconds. At the same time, the red LED will blink for 5 seconds. And then, the wireless charging transmitter will return to standby mode.

For proper scaling of the current monitor signal, a current sense resistor of 10mΩ and a current shunt amplifier are adopted in the current detection circuit. The current shunt amplifier is ISL28006 that is a micropower, uni-directional high-side and low-side current sense amplifier featuring a proprietary rail-to-rail input current sensing amplifier. The ISL28006 is ideal for high-side current sense applications where the sense voltage is usually much higher than the amplifier supply voltage. The ISL28006 is available in fixed (100V/V, 50V/V, 20V/V and Adjustable) gains.

The ISL28006 features a common-mode input voltage range from 0V to 28V. The proprietary architecture extends the input voltage sensing range down to 0V, making it an excellent choice for low-side ground sensing applications. The benefit of this architecture is that a high degree of total output accuracy is maintained over the entire 0V to 28V common mode input voltage range.

The current monitor circuit is shown in Figure 4.2.

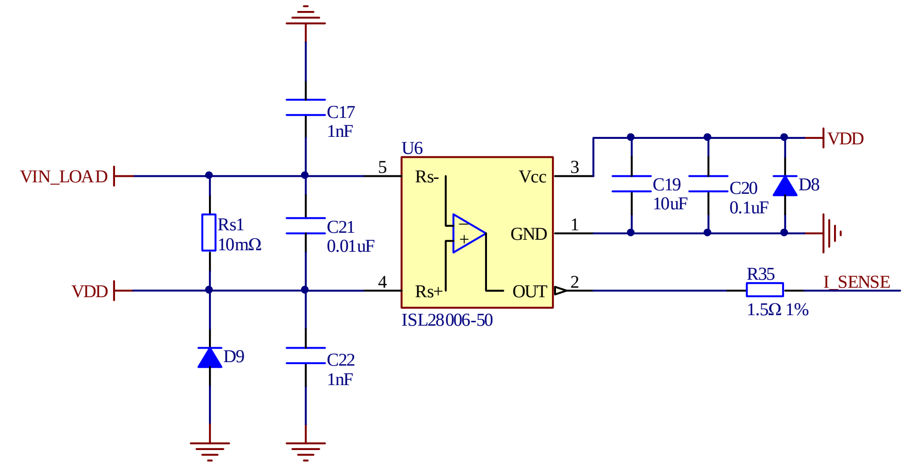

Figure 4.2 Current Monitor Circuit

Besides, the current monitor circuit plays another important role that detects whether an RX (receiver) is put on the wireless charging transmitter coil.

If the smartphone is put on the wireless charging transmitter coil, and the transmitter is then driven, magnetic coupling occurs. The magnetic flux is coupled into the receiver coil of the smartphone. And then, a voltage and a current flow will occur in the receiver coil. As the smartphone is put on the transmitter coil, the current consumption of the wireless charging transmitter will increase, and the AD convention result of current monitor signal is greater. Otherwise, if the smartphone is removed from transmitter coil, the current monitor value will decrease.

So, if the current monitor value is greater than high detection threshold, it can be thought that an RX (receiver) is put on the transmitter coil. If current monitor value is less than low detection threshold, it can be thought that the RX (receiver) has left the transmitter coil. If current monitor value is greater than safety threshold (900mA), metal may be put on the transmitter coil which causes eddy current.

4.2 Power Transmission Circuit

The power transmission circuit consists of one HIP2106A and four N-Channel MOSFET drivers. The transmitter coil and charging capacitors form electromagnetic generating circuit. The PWM wave's frequency is 100~115 KHz (auto adjustment) and its duty cycle is 50%.

The power transmission circuit is shown in Figure 4.3.

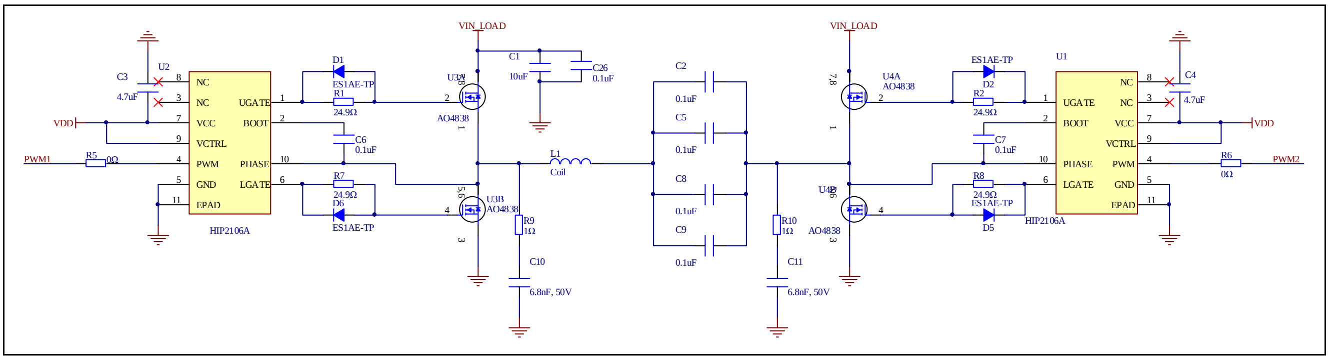

Figure 4.3 Power Transmission Circuit

A single-stage full bridge resonant inverter is used in the wireless charger transmit circuit as shown in Figure 4.3, to convert DC power to AC square wave power. MCU changes the PWM frequency based on the LC tank resonant frequency to match inductor and resonant capacitor to generate AC sinusoidal wave current on primary coil. If a receiver – a smartphone, is just on the transmitter coil, the receiver will get power and can be charged.

In order to contain magnetic fields and avoid coupling to other adjacent system components, a shielding is added as the backing board of transmitter coil.

4.3 LED Indication

The P01 pin of RL78/G11 in wireless charging transmitter controls the green LED to indicate the charging status.

- If a receiver is put on the transmitter coil, the green LED will be turned on.
- If the receiver is removed from the transmitter coil, the green LED will be turned off.

The P20 pin of RL78/G11 in wireless charging transmitter controls the red LED to indicate alarming.

- If an abnormal value of power supply (out of the range 4.5~5.5V) is detected, the red LED will keep blinking for 5 seconds.
- If over current or over temperature is detected, the red LED will keep blinking for 5 seconds.

4.4 Voltage Detection Circuit

The ANI1 pin of RL78/G11 in wireless charging transmitter detects VIN_LOAD's variation. The voltage of VIN_LOAD will be first detected after the MCU resets. If the power supply voltage is out of range (4.5~5.5V), power transmission will not be started, and the red LED will keep blinking.

The voltage detection circuit is shown in Figure 4.4.

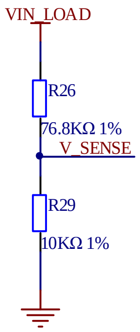

Figure 4.4 Voltage Detection Circuit

R26 and R29 form resistive voltage dividing circuit. V_SENSE which is detected by ANI1 directly reflects the variation of VIN_LOAD. In normal case, VIN_LOAD should be a little bit lower than VDD. If VIN_LOAD is out of range, some serious problems may happen. If this happens, power transmission will not be started, and the red LED will keep blinking.

4.5 Temperature Monitor Circuit

The ANI18 pin of RL78/G11 in wireless charging transmitter detects temperature variation. If the temperature of transmitter coil is higher than safety threshold (60°C), power transmission will stop for 5 seconds and the red LED will keep blinking for 5 seconds.

An NTC thermistor of which resistance decreases as temperature rises is adopted in temperature monitor circuit (between T+ and T- in Figure 4.5). The NTC forms the low leg of a temperature dependent voltage divider. The resistance of NTC is 10K at 25°C and 3K at 60°C.

The temperature monitor circuit is shown in Figure 4.5.

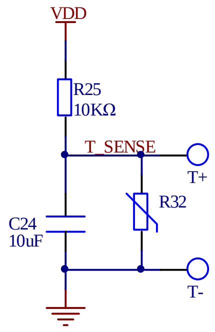

Figure 4.5 Temperature Monitor Circuit

If the temperature of NTC rises, the NTC's resistance value will decrease. At the same time, the voltage difference of NTC will decrease and A/D conversion value of ANI18 will decrease.

4.6 External DC 5V Power

Because the consumption current of wireless charging transmitter is fairly high, the wireless charging transmitter cannot be powered by an emulator, such as E1, or PC USB interface. So, an external DC 5V power adapter is needed. The adapter adopted in wireless charging transmitter is shown in Figure 4.6.

The adapter's specification is:

Input: 100~240V (50/60Hz);

Output: 5V (1A).

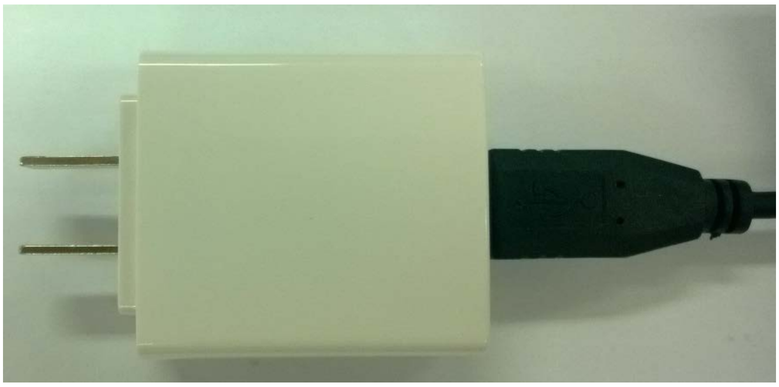

Figure 4.6 Power Adapter

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/G11 (R5F1056AA)
Operating frequency	High-speed on-chip oscillator clock: HOCO 48MHz CPU/peripheral hardware clock: 24 MHz
Operating voltage	5 V (can run on a voltage range of 4.0 V to 5.5 V.) Low voltage detector operation setting: Reset mode (internal reset generation level: 3.98 V) When power supply falls: TYP. 3.98V (3.90 V to 4.06 V) When power supply rises: TYP. 4.06V (3.98 V to 4.14 V)
Integrated development environment (CS+)	CS+ V7.00.00 from Renesas Electronics Corp.
C compiler (CS+)	CC-RL V1.07.00 from Renesas Electronics Corp.
Integrated development environment (e^2 studio)	e^2 studio V7.1.0 from Renesas Electronics Corp.
C compiler (e^2 studio)	CC-RL V1.07.00 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	11111110B	Watchdog timer operation is enabled. (Count is started after reset) Watchdog timer overflow interval: 4369.07ms Watchdog timer operation is stopped in HALT/STOP.
000C1H/010C1H	11100011B	LVD detection voltage: rising edge 4.06V(typ.), falling edge 3.98V(typ.)
000C2H/010C2H	11110000B	f_{HOCO}: 48MHz, f_{IH}: 24MHz HS (high-speed main) mode Operation voltage range: 4.0V~5.5V
000C3H/010C3H	10000101B	On-chip debugging is enabled.

5.3 Operation Outline

The tasks of the entire system are listed as below: Reset/Initialization, Over Voltage Handle, Servo Handle, Over Temperature Handle, Over Current Handle and Power Transfer Handle.

Figure 5.1 shows the block diagram for the tasks transition.

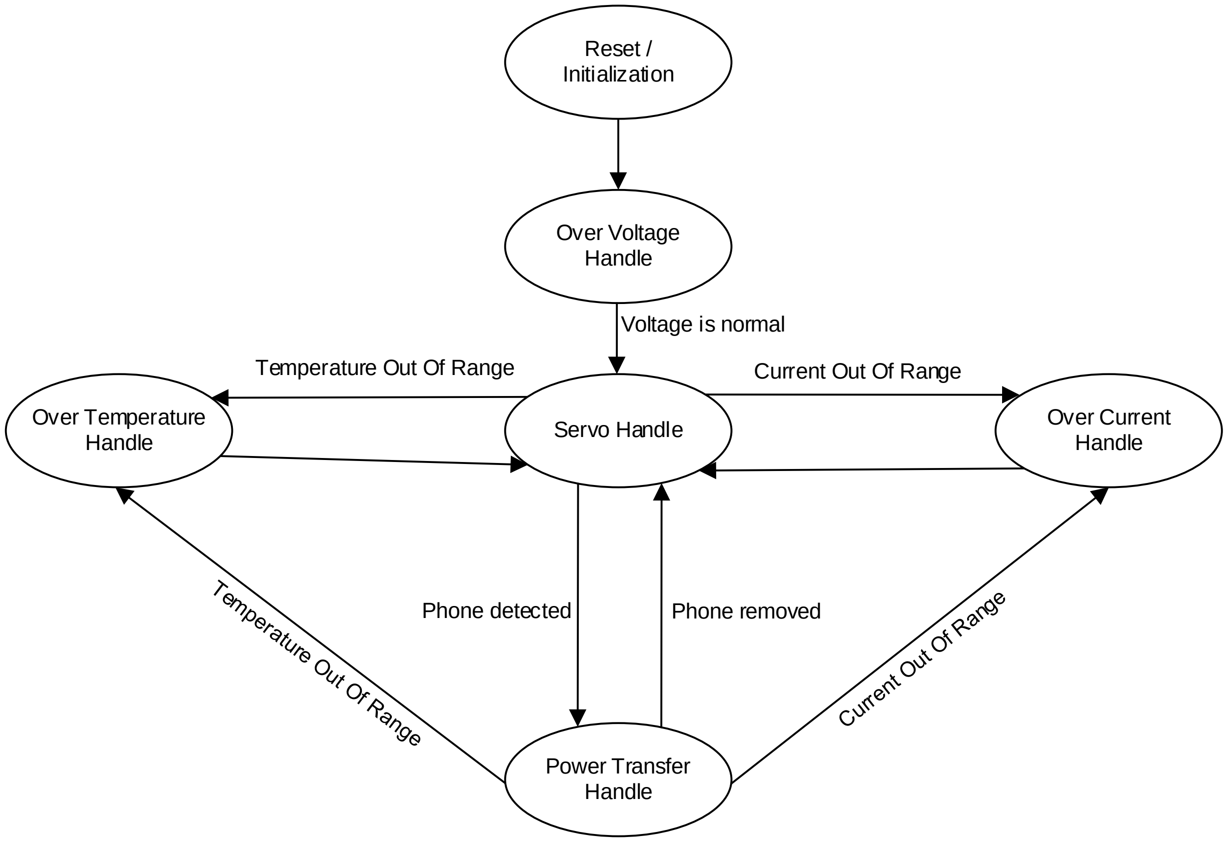

Figure 5.1 Tasks Transition Block Diagram

(1) Reset / Initialization

After a DC power is input, the system is powered on and initialization routine of each module is executed.

(2) Over Voltage Handle

After initialization, the system will check whether the power supply voltage is in the range (4.5~5.5V) or not.

(3) Servo Handle

PWM is output to drive the coil at 1 second interval. Charging current is checked to confirm if there is any over current condition. And if there is one, the system will start Over Current Handle. If there is a smartphone on the wireless charging transmitter coil, the system will transfer to Power Transfer Handle. Or else the MCU enters HALT mode for low power consumption.

(4) Power Transfer Handle

The green LED is turned on to indicate charging status. The transmitter coil starts to charge the smartphone based on the optimal PWM frequency.

(5) Over Temperature Handle

If any over temperature is detected, the red led will blink for 5 seconds.

(6) Over Current Handle

If over current is detected, the red led will blink for 5 seconds.

5.4 Flow Chart

5.4.1 Main Processing

Figure 5.2 shows the flowchart for main processing routine.

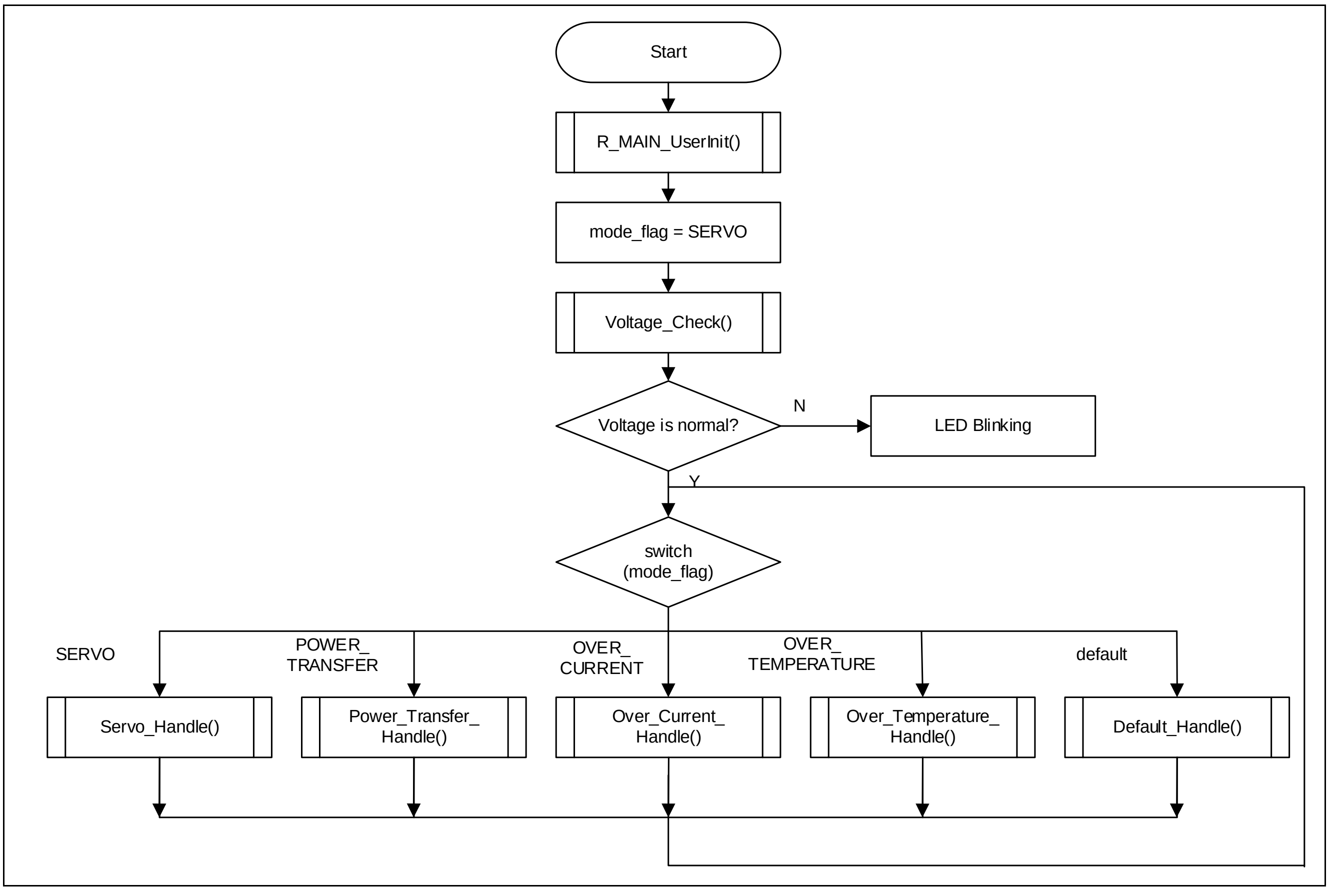

Figure 5.2 Main Processing

5.4.2 Flow Chart of Servo Handling

Figure 5.3 shows the flowchart for servo handling.

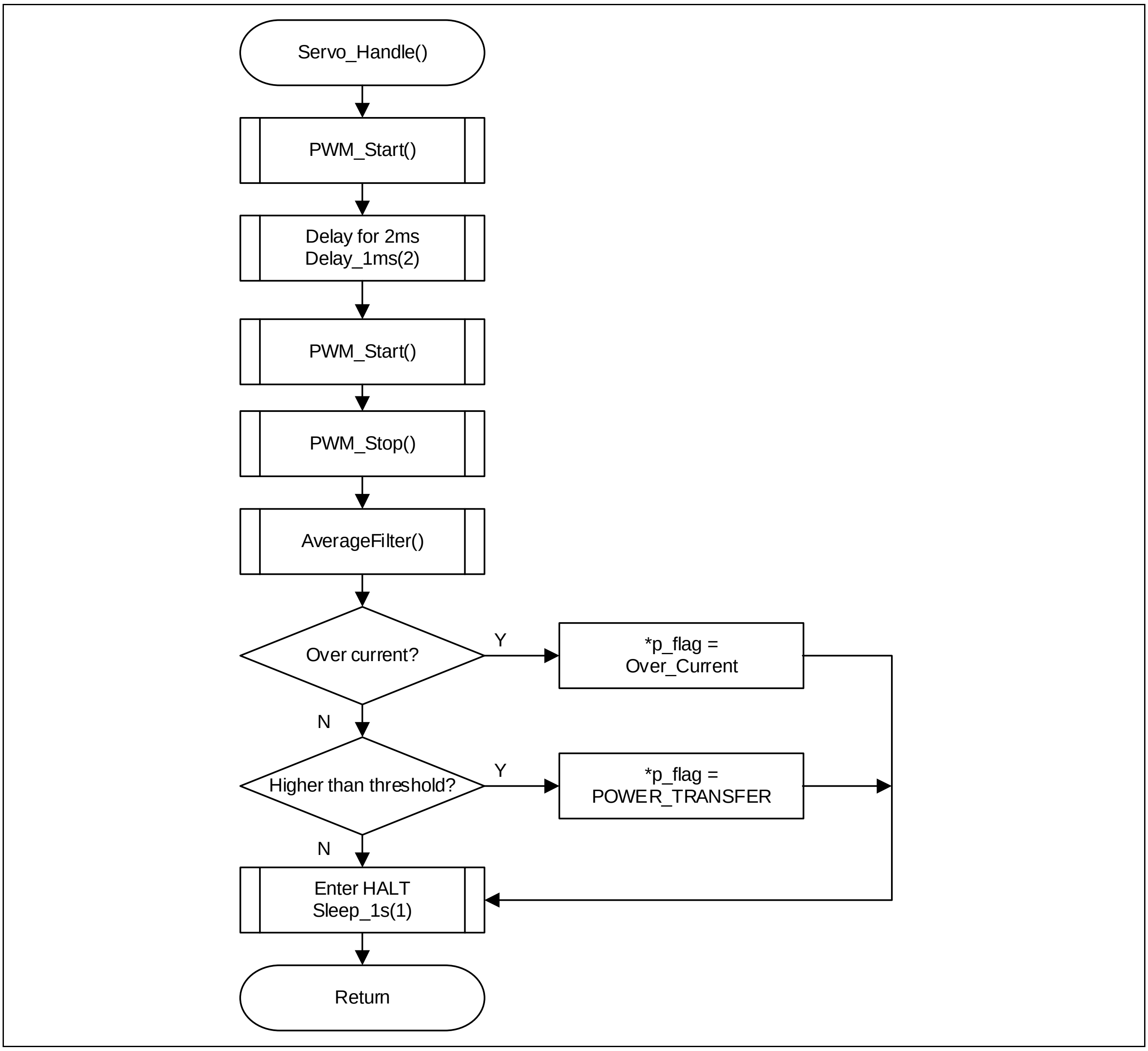

Figure 5.3 Flow Chart of Servo Handling

5.4.3 Flow Chart of Power Transfer Handling

Figure 5.4 shows the flowchart for power transfer handling.

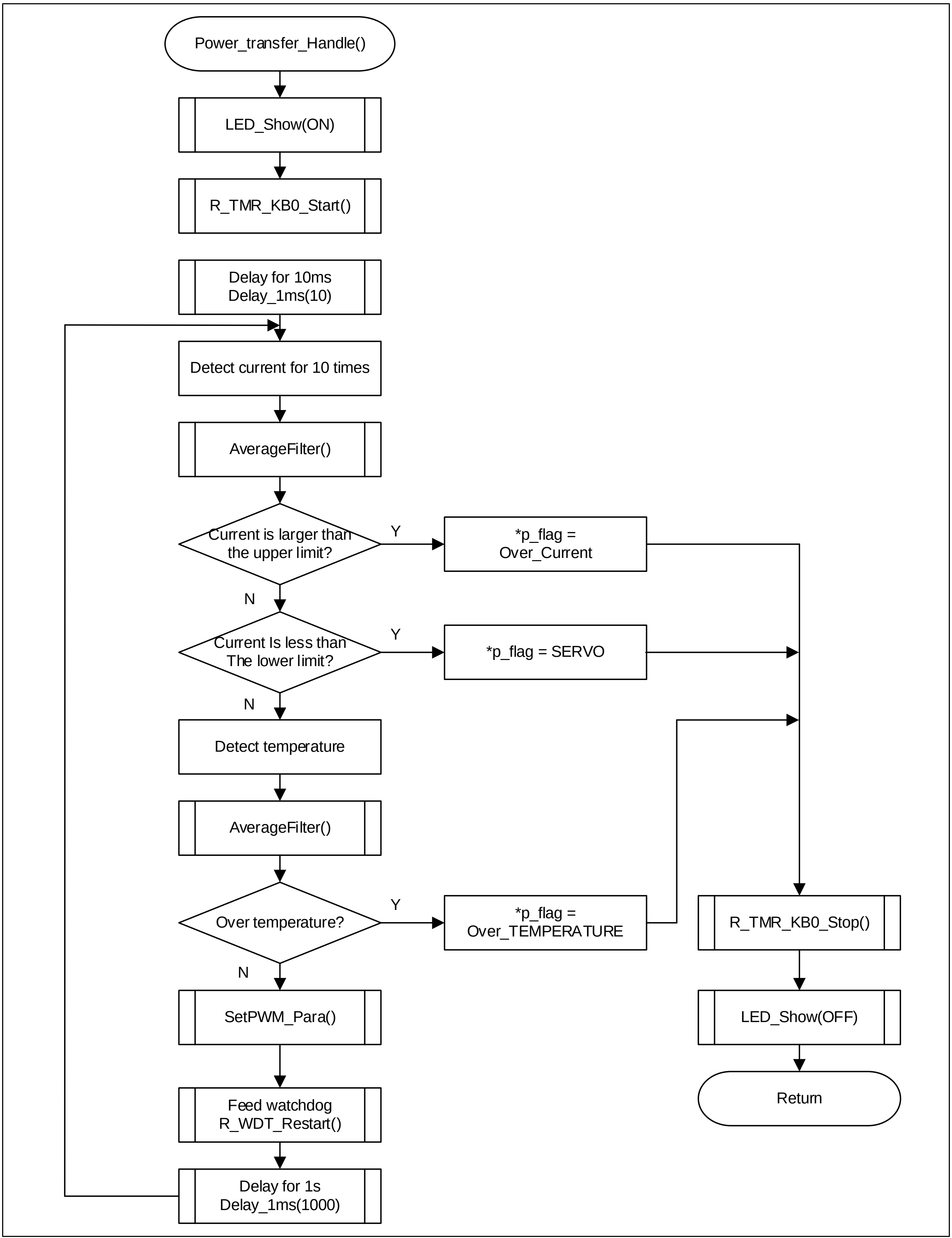

Figure 5.4 Flow Chart of Power Transfer Handling

5.4.4 Flow Chart of Over Current Handling

Figure 5.5 shows the flowchart for over current handling.

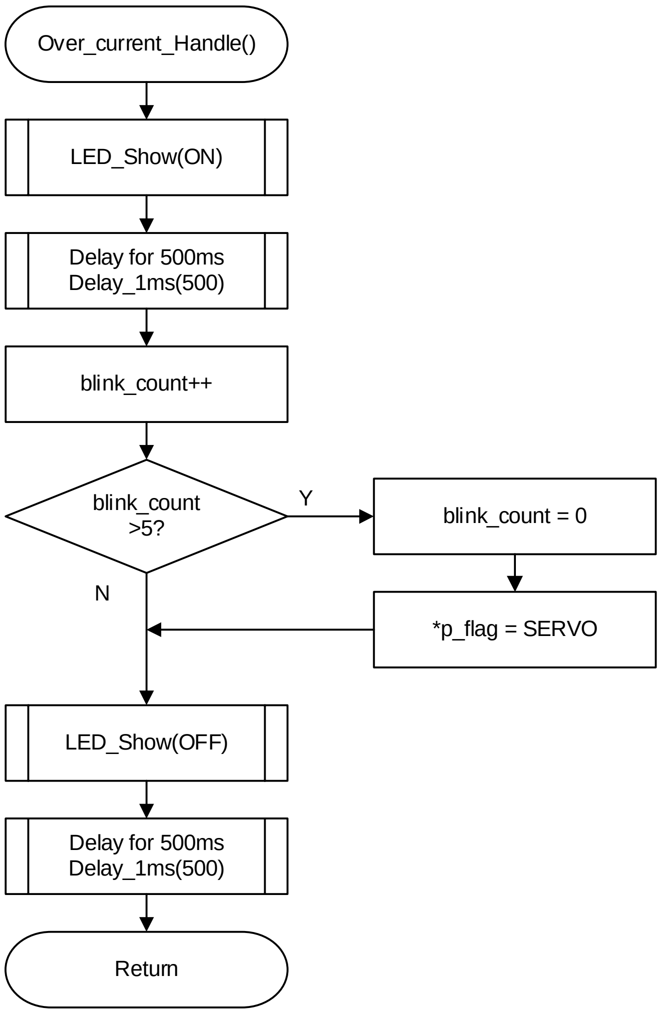

Figure 5.5 Flow Chart of Over Current Handling

5.4.5 Flow Chart of Over Temperature Handling

Figure 5.6 shows the flowchart for over temperature handling.

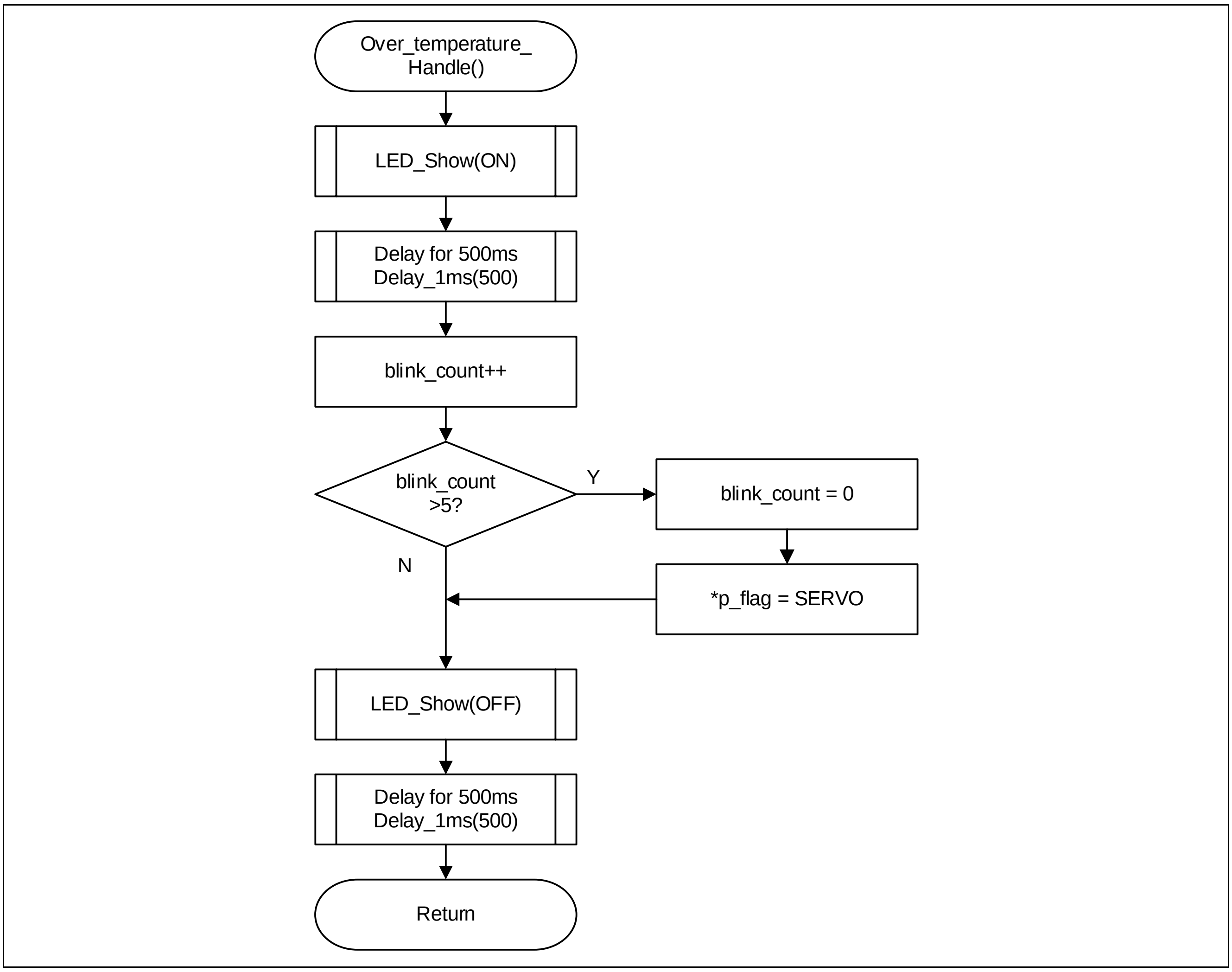

Figure 5.6 Flow Chart of Over Temperature Handling

5.4.6 Flow Chart of Default Handling

Figure 5.7 shows the flowchart for default handling.

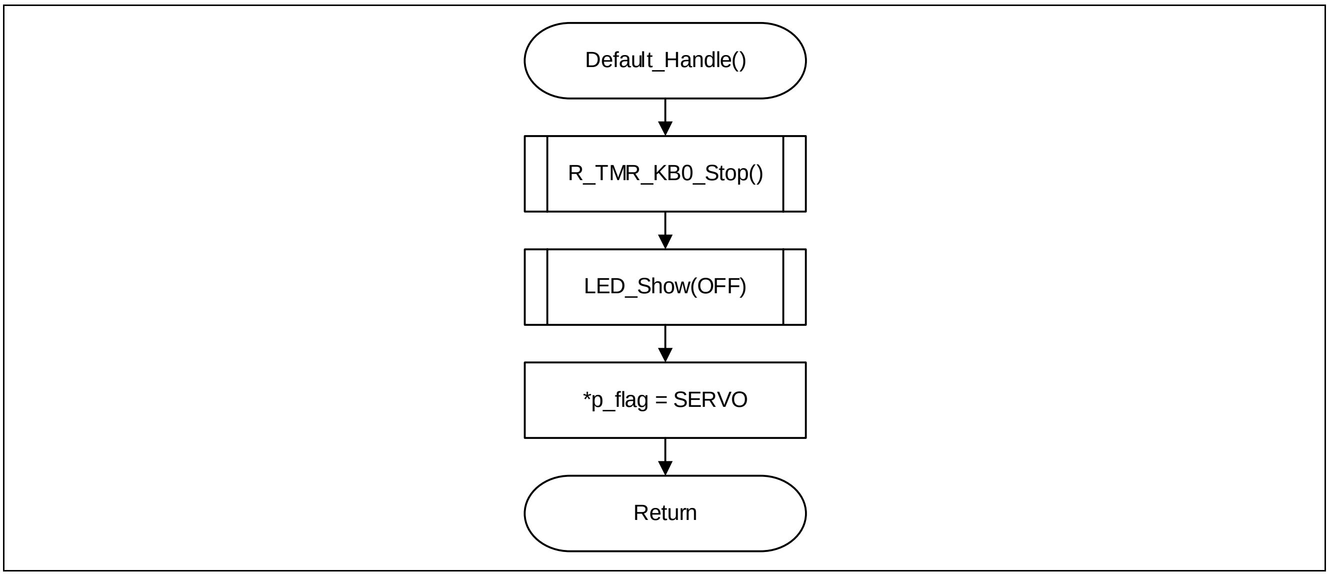

Figure 5.7 Flow Chart of Default Handling

6. Sample Code

The sample code is available on the Renesas Electronics Website.

7. Reference Documents

RL78/G11 User's Manual: Hardware (R01UH0637)

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.)

Website and Support

Renesas Electronics Website
  http://www.renesas.com/

Inquiries
  http://www.renesas.com/contact/

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Mar. 31. 2019	—	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. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

   The state of the product is undefined at the time 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 time 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 time 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 time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. 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 the 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.

5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is 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. Additionally, 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.

6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).

7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of 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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Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit: www.renesas.com/contact/.