RE01 1500KB Group

How to reduce power consumption by using the external DC/DC converter

Introduction

The RE01 1500KB Group can be supplied with power from a highly efficient external DC/DC converter instead of the regulator (LDO) built into the device to help reduce the devices power consumption.

This application note describes the software control procedure and the hardware configuration for supplying power from the external DC/DC converter to the internal circuit of the device.

Target Device

RE01 1500KB Group

Caution

If you apply this application note to another device, it is necessary to modify the software according to the specification of the MCU you use and evaluate it adequately.

Contents

1. Overview of low power consumption using the external DC/DC

The RE01 1500KB group (hereinafter, this device) supplies the voltage generated by the internal regulator (LDO) to the device core logic for the operation of the internal circuits.

The current consumption can be reduced by using the external DC/DC that can generate the voltage more efficiently.

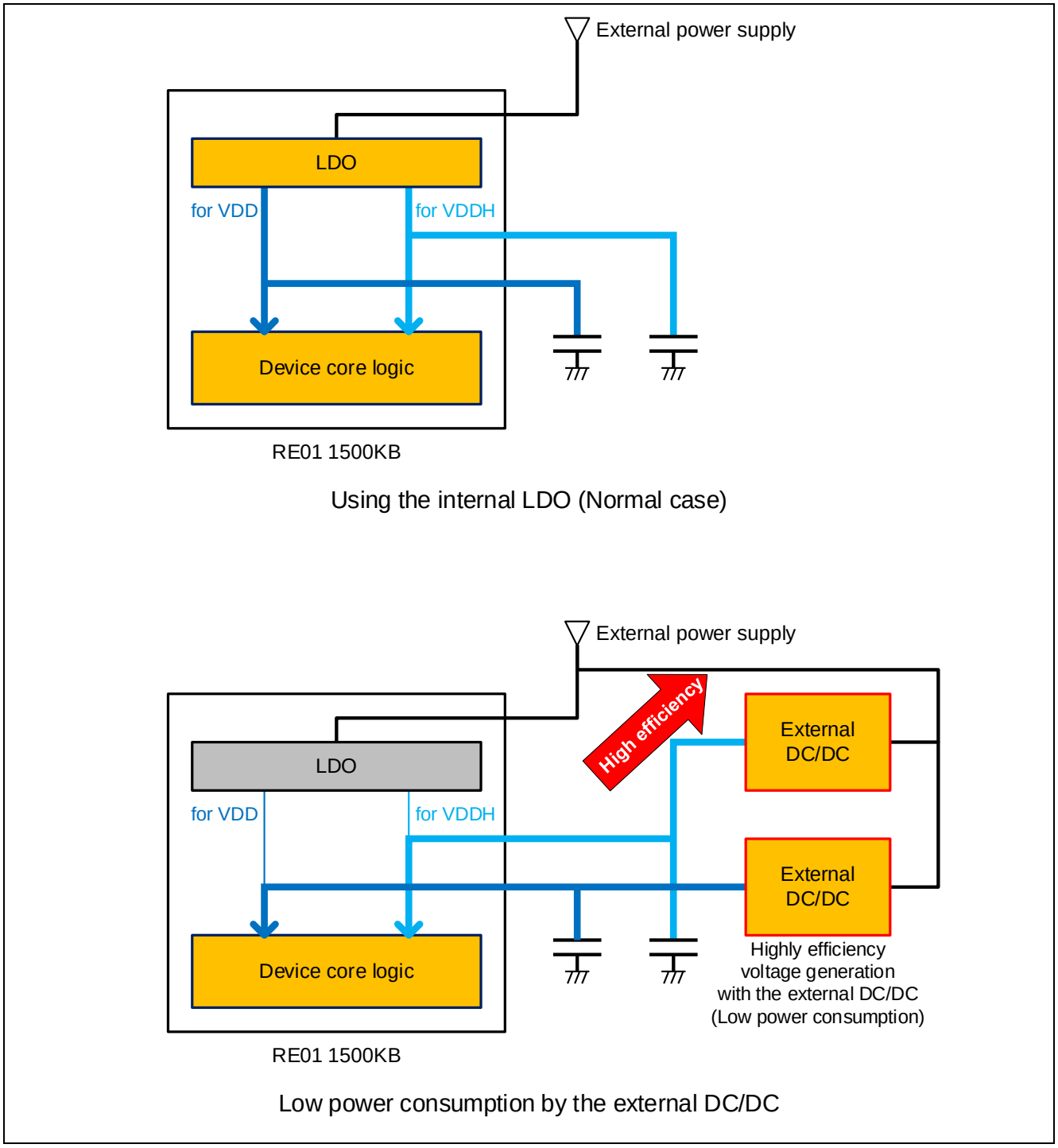


Figure 1-1 Image of low power consumption by the external DC/DC

2. Voltage and supply of internal circuits

This device requires two power supply voltages, VDD and VDDH, for the operation of the internal circuits. There are two ways to supply voltage to VDD and VDDH.

2.1 Supplied from the internal regulator (LDO)

Immediately after turning on the power to the device, the internal LDO operates to supply the VDD and VDDH voltages.

When the device transits to boost mode, the voltage of VDD changes. VDDH is constant regardless of the mode. Table 2-1 shows the electrical characteristics of VDD and VDDH when the internal LDO operates.

Table 2-1 Electrical characteristics of VDD and VDDH (when the internal LDO operates)

Item		**Voltage**
VDD	Other than boost mode	0.79V
	Boost mode	1.0V
VDDH		1.25V

2.2 Supplied from the external DC/DC

This device can stop the internal LDO and supply voltage to the internal circuits from the external DC/DC. In this case, supply the voltage from the VCL pin to VDD and the voltage from the VCLH pin to VDDH.

It is recommended to use the regulator ISL9123 made by Renesas for the external DC/DC. If you use other devices, please evaluate them thoroughly.

The voltage supplied from the ISL9123 to the VCL and VCLH pins should be as shown in Table 2-2.

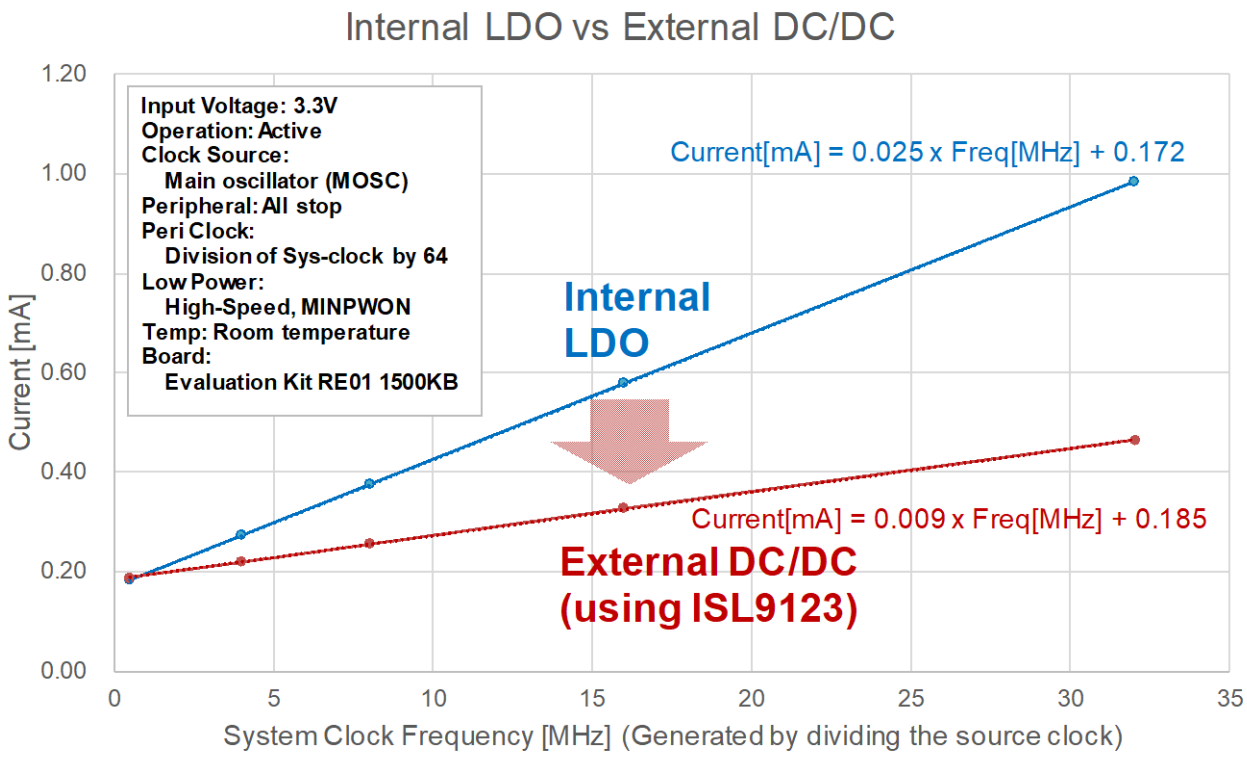
Table 2-2 Voltage supplied from ISL9123 to VCL and VCLH pins

Item		**Min**	**Typ**	**Max**	**Unit**
Voltage supplied to VCL pin	Other than boost mode	0.819	0.85	0.881	V
	Boost mode	0.988	1.025	1.062	V
Voltage supplied to VCLH pin		1.205	1.25	1.295	V

3. Advantage, disadvantage, and restriction of using the external DC/DC

3.1 Advantage: reduced power consumption

The current consumption can be reduced by changing the voltage supply to the internal circuits from the internal LDO to the external DC/DC. Figure 3-1 shows the difference in current consumption between the internal LDO and the external DC/DC.



Note: The values in the figure are reference values.

Figure 3-1 Difference in current consumption between the internal LDO and the external DC/DC

3.2 Disadvantage: increased number of parts

The number of components increases because the external DC/DC and components around them are required.

3.3 Restriction: restriction when transitioning to boost mode

When transitioning to boost mode, the voltage of VDD changes. When the voltage is supplied from the internal LDO, the VDD voltage changes at the same time as the mode transition. When using the external DC/DC in both boost mode and other modes, the voltage output of the external DC/DC must be changed dynamically.

When changing to the boost mode or changing from the boost mode to another mode, the mode must be changed while the voltage is being supplied from the internal LDO.

4. Circuit configuration example

Figure 4-1 shows a circuit configuration example when using external DC/DC. Use two ISL9123s to supply voltage to VCL and VCLH pins. The level input to the EN pin of ISL9123 is selected by the output of the general-purpose port.

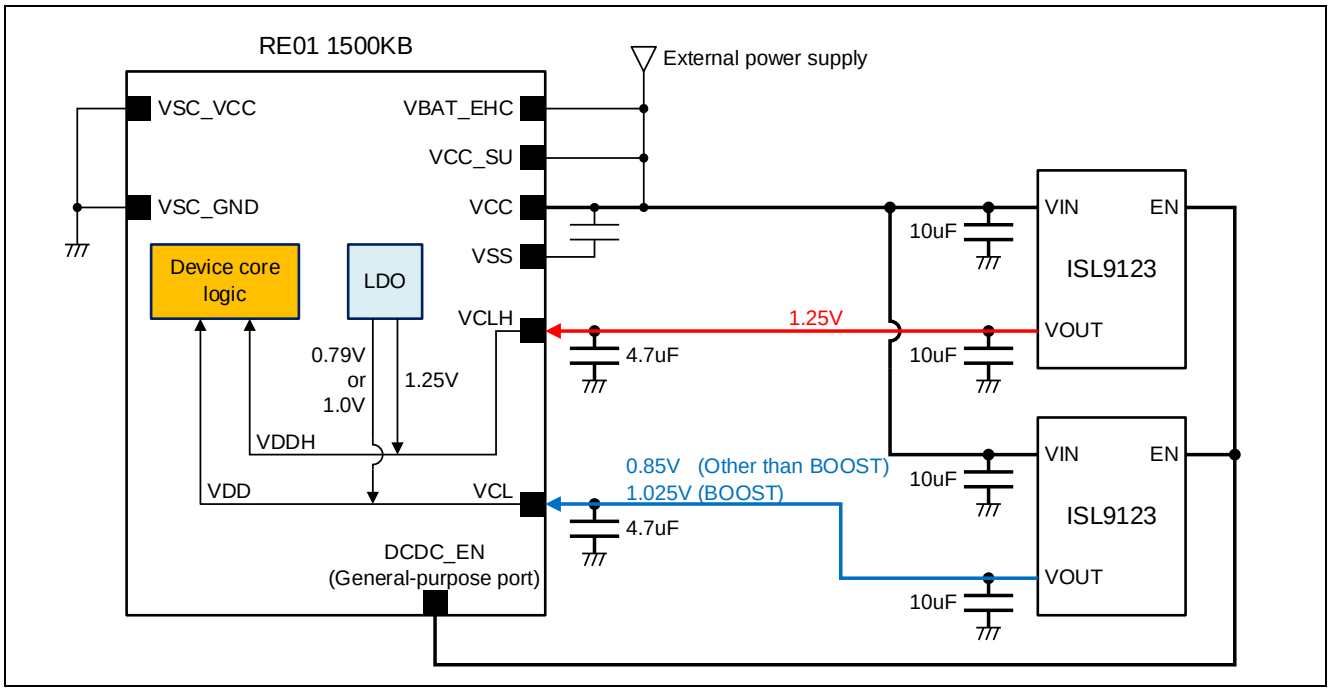


Figure 4-1 Circuit configuration example when using the external DC/DC

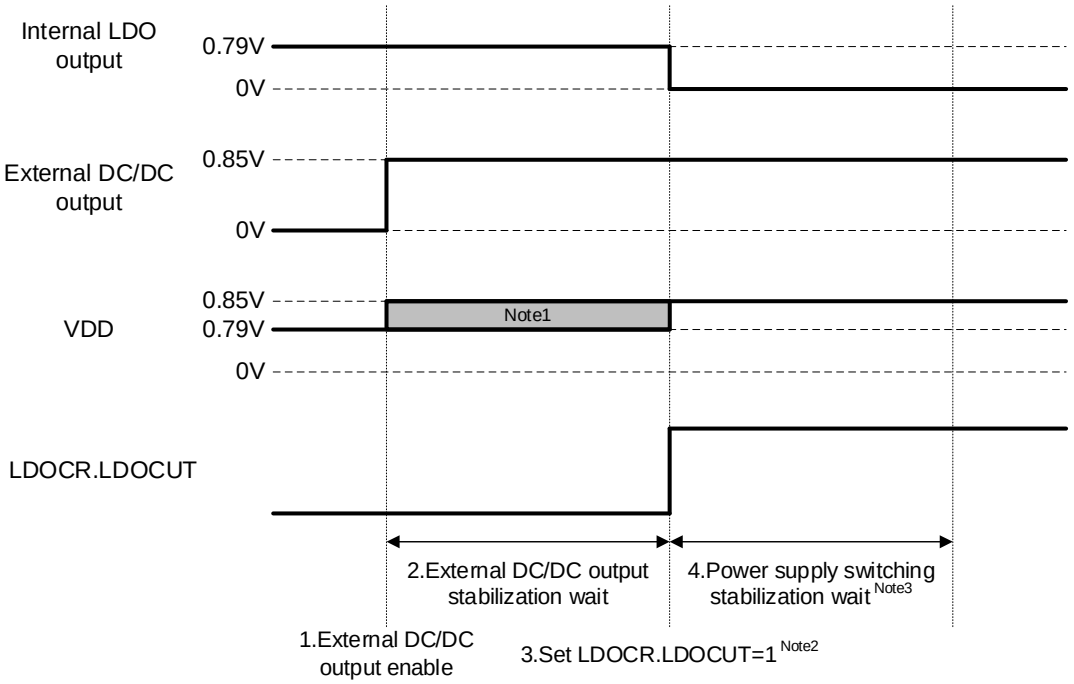
5. Procedure for using the external DC/DC

The following shows the procedure for supplying power from the external DC/DC to the internal circuits. When switching to boost mode, it is necessary to transition to boost mode before supplying power from the external DC/DC.

5.1 When not transitioning to boost mode

1. Enables the external DC/DC voltage output.
2. Wait until the external DC/DC voltage output stabilizes. Note1
3. Set LDOCR.LDOCUT = 1 (LDO stops). Note2
4. Wait for the power supply switching to stabilize. Note3

Note: 1. VDD and VDDH voltages may become unstable due to the internal LDO and external DC/DC voltage output competition.
2. If necessary, reduce device power consumption before setting LDOCR.LDOCUT = 1. For details, see "5.3 Precautions when stopping the internal LDO".
3. Adjust the waiting time according to the system. For details, see "5.3 Precautions when stopping the internal LDO".



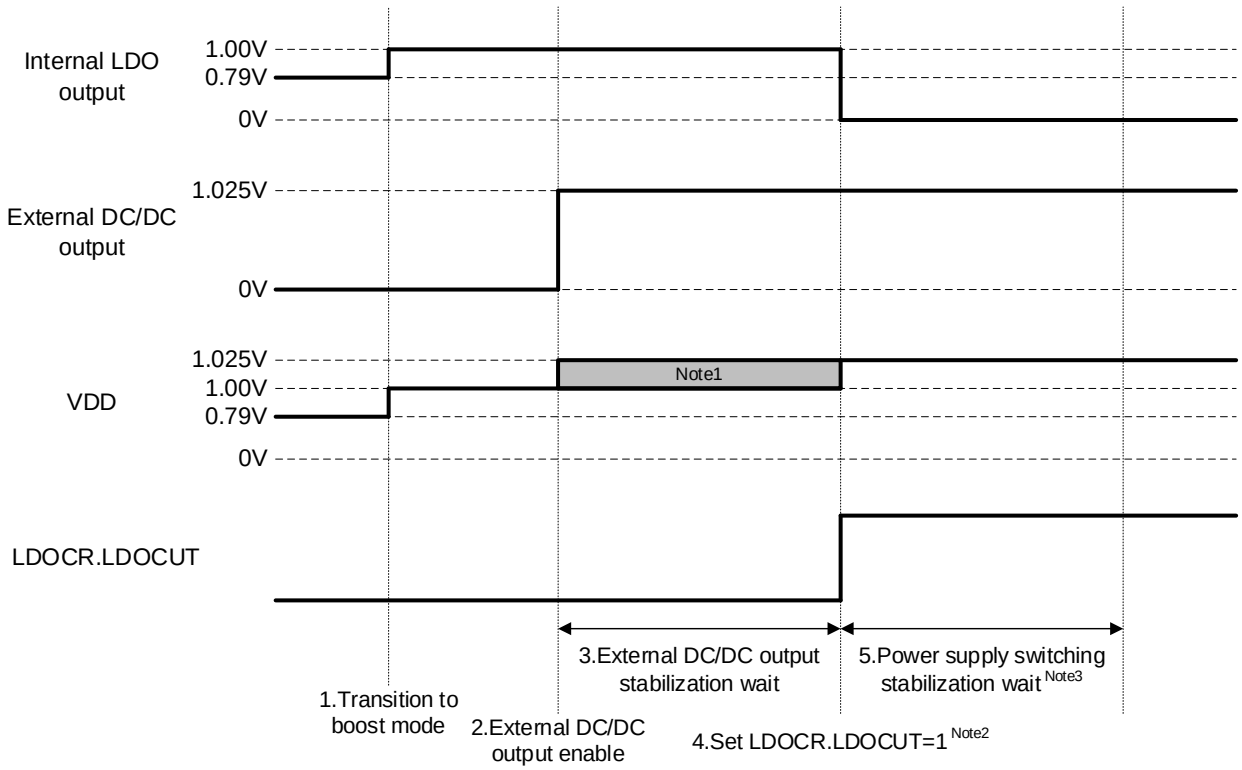
Note: 1. VDD and VDDH voltages may become unstable due to the internal LDO and external DC/DC voltage output competition.
2. If necessary, reduce device power consumption before setting LDOCR.LDOCUT = 1. For details, see "5.3 Precautions when stopping the internal LDO".
3. Adjust the waiting time according to the system. For details, see "5.3 Precautions when stopping the internal LDO".

Figure 5-1 Timing chart for enabling the external DC/DC (when not transitioning to boost mode)

5.2 When transitioning to boost mode

0. Set the external DC/DC output voltage to 1.025V. (Voltage output remains disabled)
1. Transition to boost mode with LDOCR.LDOCUT = 0 (LDO works).
2. Enables the external DC/DC voltage output.
3. Wait until the external DC/DC voltage output stabilizes. Note1
4. Set LDOCR.LDOCUT = 1 (LDO stops). Note2
5. Wait for the power supply switching to stabilize. Note3

Note: 1. VDD and VDDH voltages may become unstable due to the internal LDO and external DC/DC voltage output competition.
2. If necessary, reduce device power consumption before setting LDOCR.LDOCUT = 1. For details, see "5.3 Precautions when stopping the internal LDO".
3. Adjust the waiting time according to the system. For details, see "5.3 Precautions when stopping the internal LDO".



Note: 1. VDD and VDDH voltages may become unstable due to the internal LDO and external DC/DC voltage output competition.
2. If necessary, reduce device power consumption before setting LDOCR.LDOCUT = 1. For details, see "5.3 Precautions when stopping the internal LDO".
3. Adjust the waiting time according to the system. For details, see "5.3 Precautions when stopping the internal LDO".

Figure 5-2 Timing chart for enabling the external DC/DC (when transitioning to boost mode)

5.3 Precautions when stopping the internal LDO

When setting LDOCR.LDOCUT = 1 (LDO is stopped), the power supply from the internal LDO to the internal circuit stops, and the load on the external DC/DC increases. If the external DC/DC cannot withstand the load, the VDD and VDDH voltages will drop.

After setting LDOCR.LDOCUT = 1, wait by software until the VDD and VDDH voltages stabilize. Adjust the waiting time according to the system.

The voltage drop associated with switching from the internal LDO to the external DC/DC can be reduced by reducing the power consumption of the device. If necessary, reduce device power consumption before setting LDOCR.LDOCUT = 1. The followings are examples of how to reduce the power consumption of the device.

- Decrease the operating frequency.
- Change the power control mode or the power supply mode to a mode with lower power consumption.
- Stop unnecessary peripheral functions. (Set the module stop)

6. Precautions when using the external DC/DC

6.1 Reset

When the internal LDO is stopped, make sure that resets other than the RES# pin reset and power-on reset do not occur.

The LDOCR register is not initialized by resets other than RES# pin reset and power-on reset. Therefore, if a reset other than RES# pin reset and power-on reset occurs while the internal LDO is stopped, the internal LDO will not start after the reset.

If the EN signal of the external DC/DC is controlled by the general-purpose port of this device, the port output will be initialized at reset, and the power supply from the external DC / DC will be stopped. If the voltage supply from both the internal LDO and the external DC/DC stops, the device operation stops.

6.2 Precautions when using boost mode

The voltage supplied to the VCL pin differs between boost mode and other modes.

The power control mode after device reset is normal mode.

If the device is reset while using the boost mode, it will transition to normal mode. When supplying the voltage from the external DC/DC again after reset, supply the voltage according to the device mode to the VCL pin.

6.3 Current consumption when transitioning to boost mode

When transitioning to boost mode, the current consumption increases instantaneously because the capacitor connected to the VCL pin is charged by increasing the voltage of VDD.

6.4 Wait time when switching from the internal LDO to the external DC/DC

Switch from the internal LDO to the external DC/DC while the external DC/DC voltage output is stable. For the waiting time from the activation of the external DC/DC voltage output to the switching of the voltage supply source, wait in software according to the electrical characteristics of the external DC/DC.

6.5 Input voltage range from the external DC/DC

The voltage supplied from the external DC/DC to the VCL and VCLH pins should be as shown in Table 2-2. The correct operation is not guaranteed if the voltage value cannot be observed.

In particular, note that the voltage supplied to the VCL pin differs between boost mode and other modes.

6.6 VCC voltage and external DC/DC input voltage range

If the lower limit of the external DC/DC input voltage is higher than the lower limit of the VCC voltage of this device (1.62V), make sure that the VCC voltage does not become lower than the lower limit of the external DC/DC input voltage.

Also, if the upper limit of the external DC/DC input voltage is lower than the upper limit of the VCC voltage of this device (3.3V), make sure that the VCC voltage does not become higher than the upper limit of the external DC/DC input voltage.

If the VCC voltage is outside the range of the input voltage of the external DC/DC, the external DC/DC becomes inoperable and the voltage supply to the VCL and VCLH pins stops, and the device stops operating.

Example) When ISL9123 is used for the external DC/DC

VCC voltage of this device: 1.62V to 3.3V

Input power supply voltage of ISL9123: 1.8V to 5.5V

In this case, make VCC = 1.8V to 3.3V.

6.7 Power supply to the internal circuit

To prevent interruption of the voltage supply to VDD and VDDH, be sure to operate either the internal LDO or the external DC/DC. If both stops at the same time and the supply of voltage to VDD or VDDH stops, device operation stops.

7. Sample code

7.1 Overview

This application note includes a sample code project to switch between the internal LDO and the external DC/DC.

The sample code project is a project whose operation has been confirmed on Evaluation Kit RE01 1500KB (RTK70E015DSxxxxxBE). The settings of this project are consistent with R7F0E015D2CFB implemented in Evaluation Kit RE01 1500KB. The settings of this project are consistent with R7F0E015D2CFB implemented in Evaluation Kit RE01 1500KB.

Note that the Evaluation Kit RE01 1500KB cannot use the external DC/DC in boost mode because the output voltage of the external DC/DC (ISL9123) mounted cannot be changed.

7.2 Specification

7.2.1 List of used ports

Table 7-1 shows the used ports in the sample code

Table 7-1 Used ports in the sample code

Used ports	Functions
P009	LED0: Flashes after reset release, flashes before switching between the internal LDO and the external DC/DC
P410	SW3: IRQ2 interrupt
P405	DCDC_EN2: Controls the level input to the EN pin of the external DC/DC (ISL9123)

7.2.2 Target board settings

Evaluation Kit RE01 1500KB requires jumper settings to use the external DC/DC.

Table 7-2 shows the jumper settings of Evaluation Kit RE01 1500KB.

Figure 7-1 shows the parts layout of Evaluation Kit RE01 1500KB.

Table 7-2 Jumper settings of Evaluation Kit RE01 1500KB

Jumper	Settings	Content
J4	1-2 shorted	Connect the VCL pin to the VOUT pin of the external DC/DC (ISL9123)
J14	1-2 shorted	Connect the VCLH pin to the VOUT pin of the external DC/DC (ISL9123)

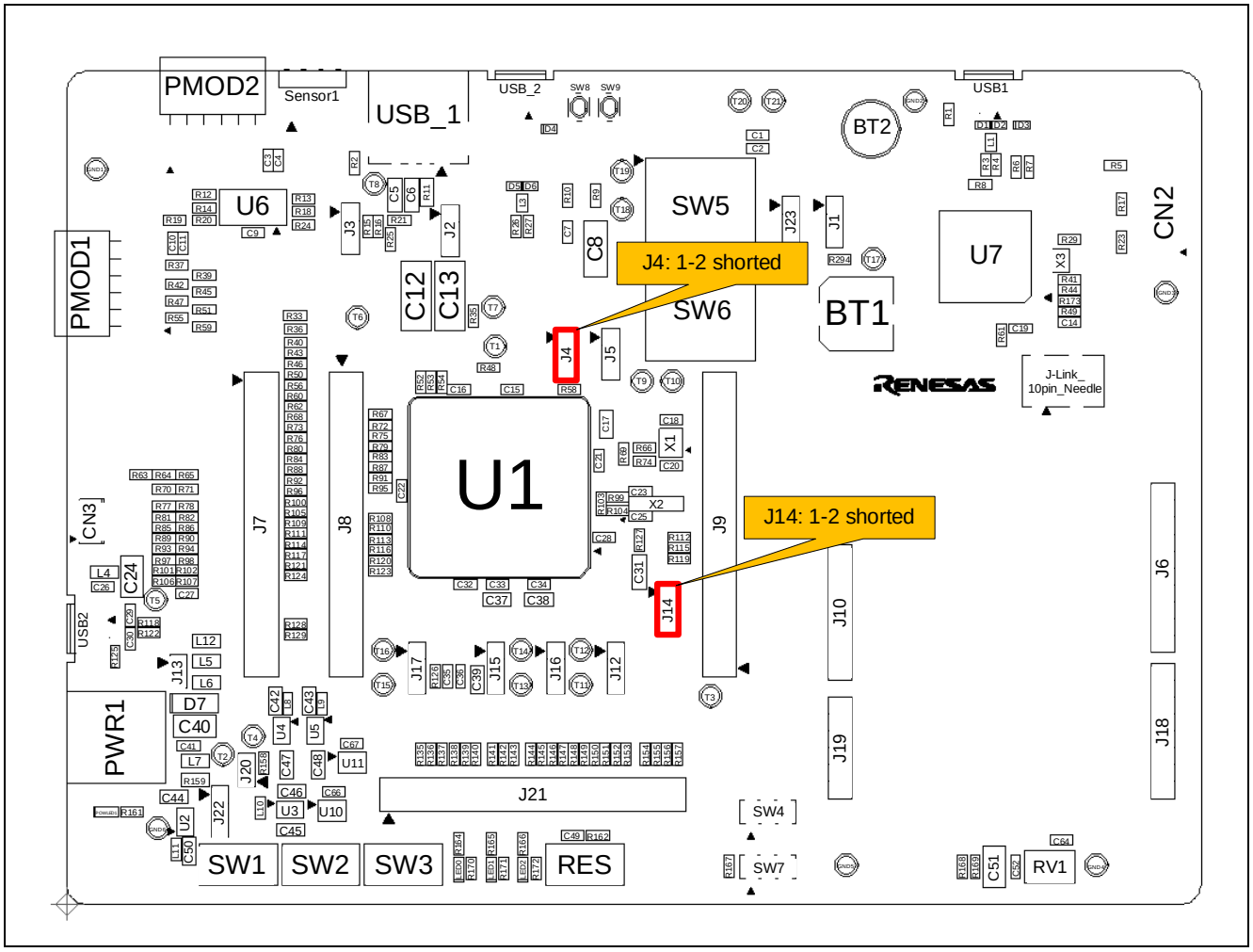


Figure 7-1 Parts layout of Evaluation Kit RE01 1500KB

7.2.3 File Configuration

The sample code uses RE01 1500KB group CMSIS Driver Package.

Table 7-3 shows the files added or changed in the sample code.

Table 7-3 Files added or changed in the sample code

Name	Outline	Remarks
main.c	Main processing	-
main_cfg.h	Constants used in sample code	Added file
nop.c	NOP processing	Added file
nop.h	Definition of NOP processing function	Added file
pin.c	The ports used in the sample code are set in this file	Select P410 for IRQ2 pin
r_system_cfg.h[Note]	The IRQ event link numbers used in the sample code are set in this file	Set IRQ event channel of IRQ2 to 2

Note For interrupt settings in r_system_cfg.h, see the section “Interrupt (NVIC) Settings” in RE01 1500KB CMSIS Package Startup Guide.

7.2.4 Option-setting Memory

Table 7-4 shows Option-setting memory settings of the sample code. Set the optimal value for the system as necessary.

Table 7-4 Option-setting memory settings of the sample code

Symbol	Address	Setting value	Content
AWS	0100A164h~0100A167h	FFFF FFFFh	No access window setting
OSIS	0100A150h~0100A15Fh	FFFF FFFFh	No protection of ID code (all bytes are FFh)
SECMPUxxx	00000408h~0000043Bh	FFFF FFFFh	Security MPU disabled
OFS1	00000404h~00000407h	FFFF FFFFh	LVD0 reset invalid after reset release HOCO oscillation stop after reset release
OFS0	00000400h~00000403h	FFFF FFFFh	IWDT stop WDT stop after reset release

7.3 Conditions for Confirming Operation

The Sample code has been confirmed to operate under the conditions shown in Table 7-5.

Table 7-5 Confirmed operating conditions

Item		**Conditions**
MCU		R7F0E015D2CFB 144pin
Operating frequency	After reset release (Initial value)	• Middle-speed on-chip oscillator (MOCO) : 2MHz • System clock (ICLK) : 2MHz (MOCO * 1/1) • Peripheral module clock A (PCLKA) : 2MHz (MOCO * 1/1) • Peripheral module clock B (PCLKB) : 2MHz (MOCO * 1/1)
Operating voltage		3.3V
Target board		Evaluation Kit RE01 1500KB (RTK70E015DSxxxxxBE)
Integrated Development Environment	GCC	Renesas e^2 studio Version 7
	IAR	IAR Embedded Workbench for Arm® Version 8.40
C compiler	GCC	GCC Arm® Embedded Version 6.3.1.20170620 GNU 6-2017-q2-update
	IAR	IAR C/C++ Compiler for Arm® Version 8.40
Debugger		Segger J-Link OB
I/O header version		Rev1.10
CMSIS Driver Package version		Rev1.10

Note The current consumption can be measured by modifying the target board as follows.
R158 : Open, J22 : Connect to ammeter.
For details, refer to the Evaluation Kit RE01 1500KB user's manual.

7.4 Software Description

The sample code operates as follows by using the R_SYSTEM driver functions.

1. After reset release, the sample code flashes the LED Note three times.
2. The sample code then turns off the LED Note and wait for an IRQ2 interrupt.
3. When an IRQ2 interrupt occurs, the sample code flashes the LED Note four times quickly. Then, it enables the voltage output of the external DC/DC and changes the voltage supply to the internal circuit to the external DC/DC.
4. When IRQ2 interrupt occurs again, the sample code flashed LED Note twice at low speed. Then, it changes the voltage supply to the internal circuit to the internal LDO and stops the external DC/DC voltage output.
5. Repeat these changes by pressing SW3.

Note By changing the main_cfg.h file settings, the control of the LED can be disabled and so removes the current flowing to LED.

7.4.1 List of Functions

The specifications for functions added in this sample code are shown below.

Main	
Outline	Main processing
Header	None
Declaration	int main(void)
Description	Repeat changing between the internal LDO and the external DC/DC, triggered by pressing SW3.
Argument	None
Return value	0

ext_dcdc_enable	
Outline	Validation of voltage supply from the external DC/DC
Header	None
Declaration	static void ext_dcdc_enable(void)
Description	This function flashes the LED four times quickly. Then, it enables the voltage output of the external DC/DC and changes the voltage supply to the internal circuit to the external DC/DC.
Argument	None
Return value	None

ext_dcdc_disable	
Outline	Disabling voltage supply from the external DC/DC
Header	None
Declaration	static void ext_dcdc_disable(void)
Description	This function flashes the LED twice at low speed. Then, it changes the voltage supply to the internal circuit to the internal LDO and stops the external DC/DC voltage output.
Argument	None
Return value	None

irq2_wait	
Outline	Wait for IRQ2
Header	None
Declaration	static void irq2_wait(void)
Description	Execute endless loop until IRQ2 interrupt occurs.
Argument	None
Return value	None

led_port_init	
Outline	Initial setting for LED0 port
Header	None
Declaration	static void led_port_init(void)
Description	Set the initial setting for port using as LED0, and flash LED0 three times.
Argument	None
Return value	None

led0_set	
Outline	Controlling LED0
Header	None
Declaration	static void led0_set(uint8_t flag)
Description	Turn on or turn off the LED0
Argument	flag 0: Tern on 1: Tern off
Return value	None

irq2_setup	
Outline	Setting for IRQ2 interrupt
Header	None
Declaration	static void irq2_setup(void)
Description	Set the IRQ2 interrupt
Argument	None
Return value	None

irq2_int	
Outline	Interrupt handling of IRQ2
Header	None
Declaration	static void irq2_int(void)
Description	Execute the interrupt handler by IRQ2 interrupt
Argument	None
Return value	None

BoardInit	
Outline	Terminal settings on the using board
Header	None
Declaration	void BoardInit(void)
Description	This function is called by SystemInit() function after reset release
Argument	None
Return value	None

7.4.2 List of Constants

The modifiable constant is shown in Table 7-6.

Table 7-6 Confirmed operating conditions

Contents	Initial value	Setting	File
MAIN_CFG_LED_ENABLE	1	0: Disable LED0 control Note 1: Enable LED0 control	main_cfg.h

Note This setting can reduce the current flowing to LED.

7.4.3 Flowcharts

The main process of changing the voltage supply to the internal circuit is shown in Figure 7-2.

The validation of voltage supply from the external DC/DC is shown in Figure 7-3.

The disabling voltage supply from the external DC/DC is shown in Figure 7-4.

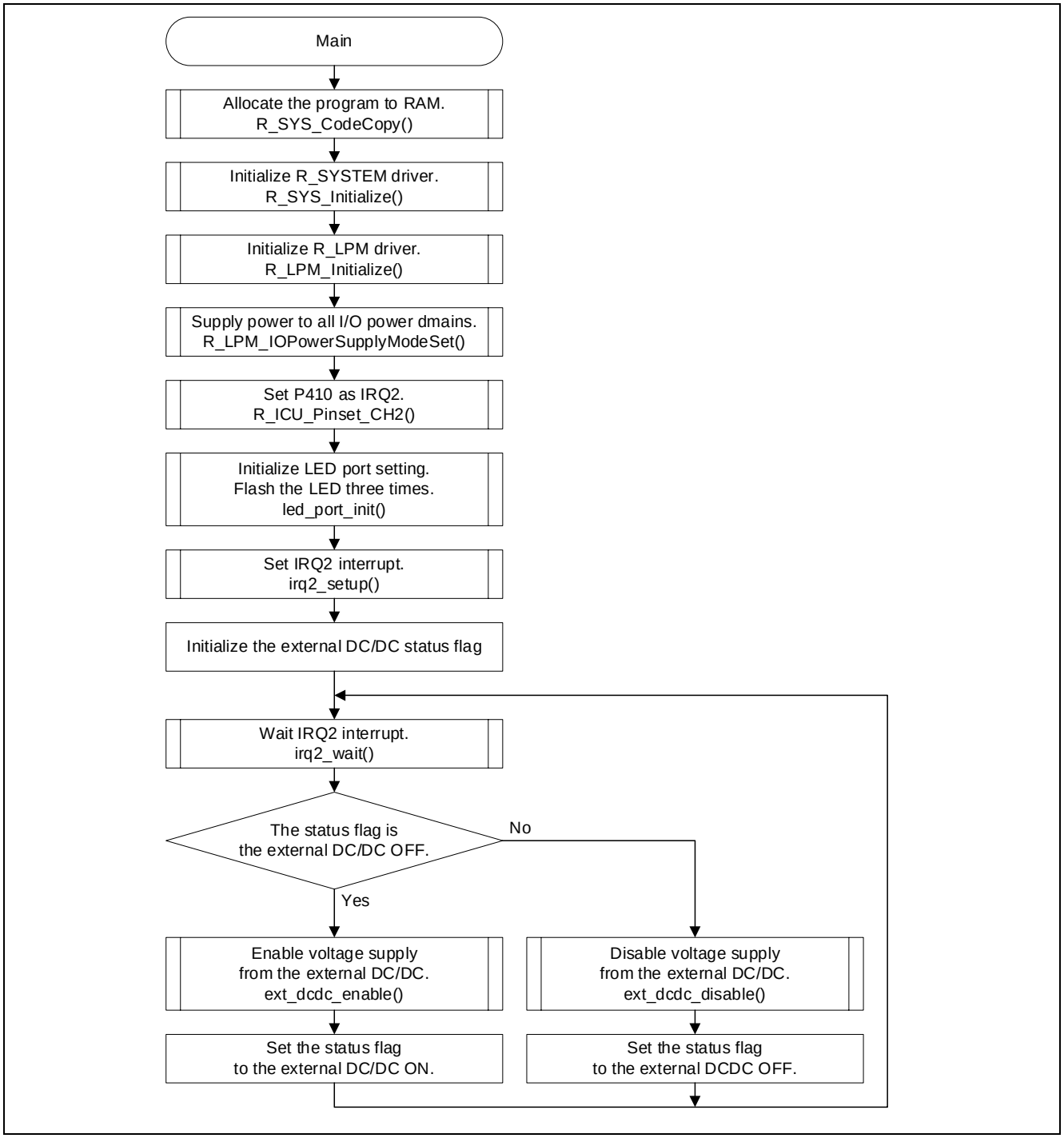


Figure 7-2 Main process of changing the voltage supply to the internal circuit

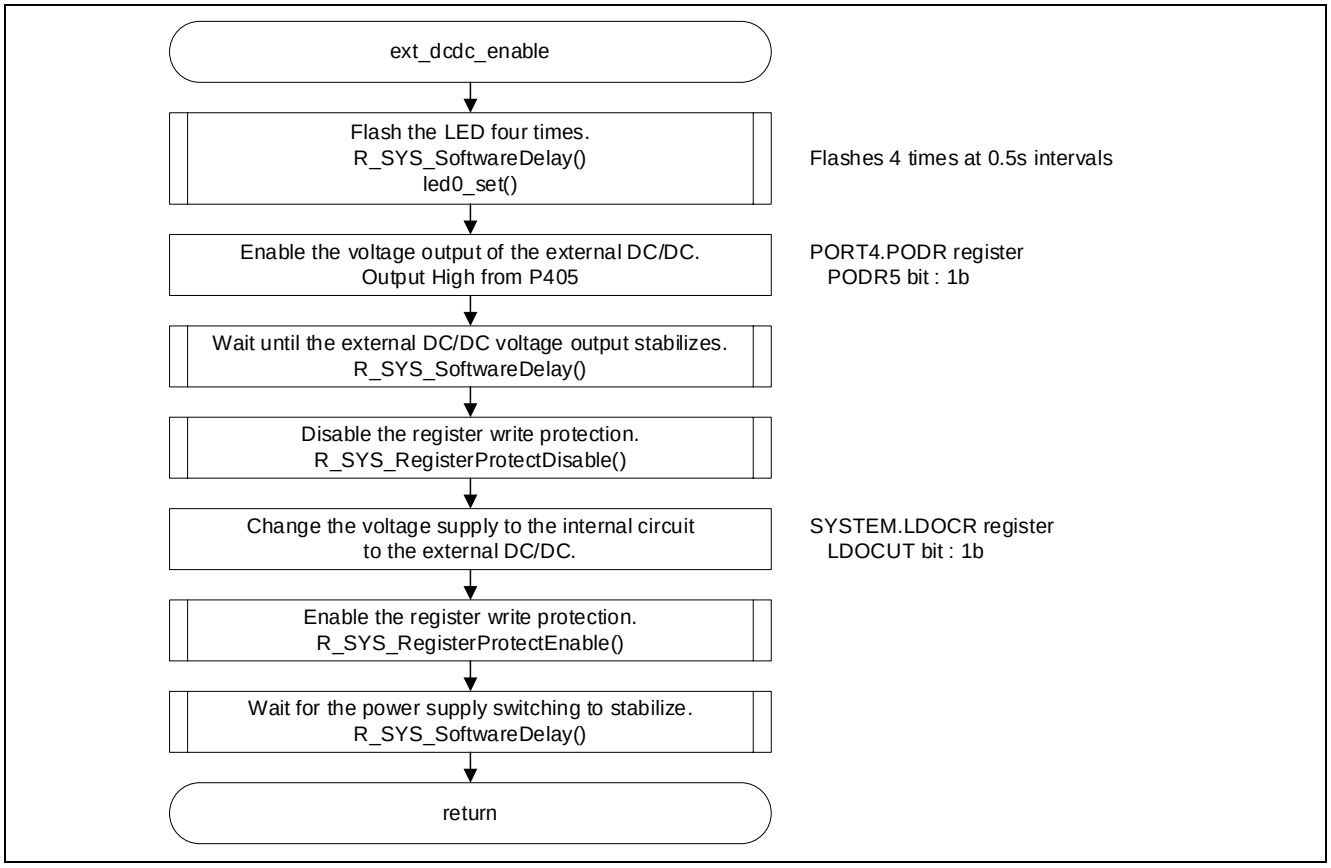


Figure 7-3 Validation of voltage supply from the external DC/DC

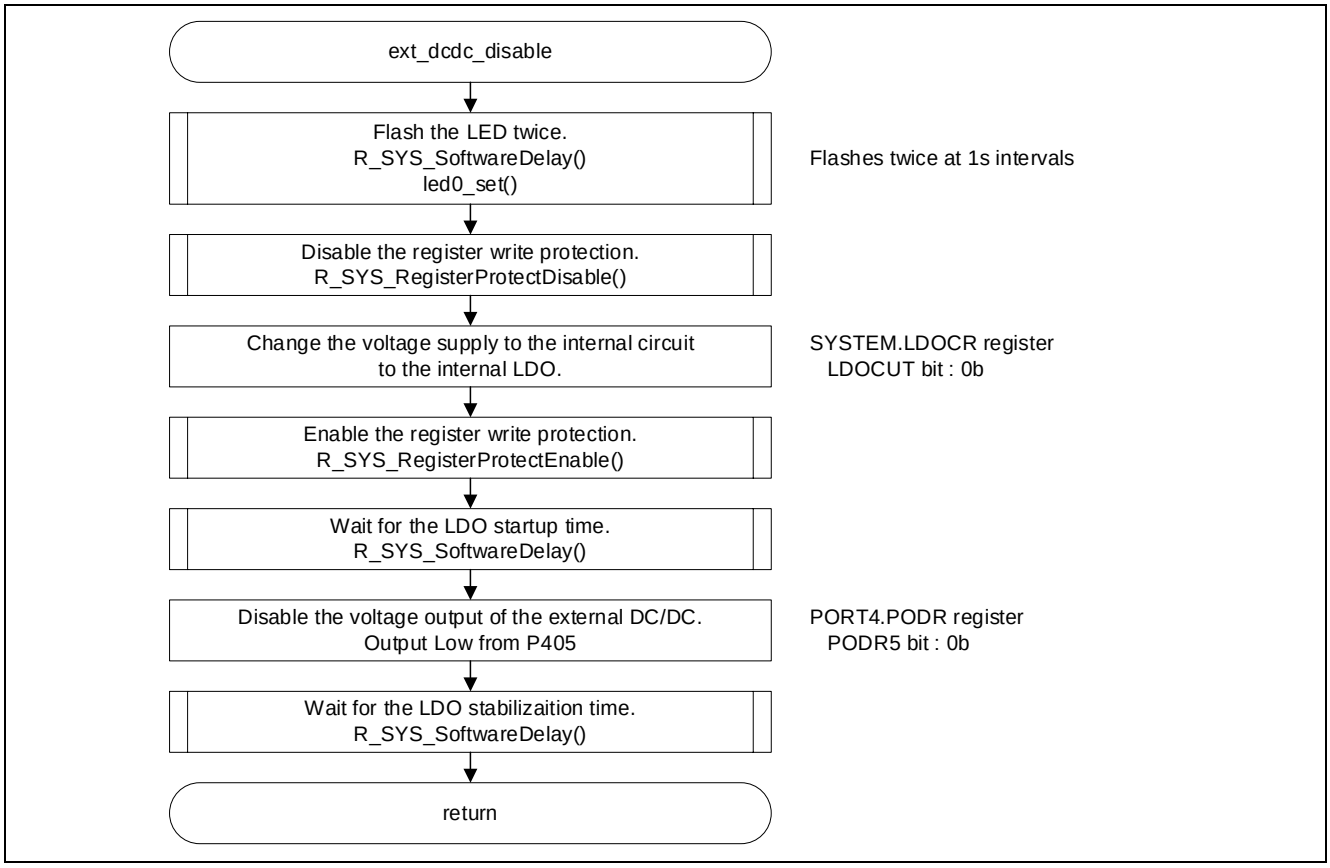


Figure 7-4 Disabling voltage supply from the external DC/DC

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	May.15.2020	-	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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